ANNUAL REPORT

OF

THE UNITED STATES

GEOLOGICAL AND GEOGRAPHICAL SURVEY

OF

THE TERRITORIES,

EMBRACING COLORADO,

BEING A REPORT OF PROGRESS OF

THE EXPLORATION FOR THE YEAR 1873,

BY

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CONDUCTED UNDER THE AUTHORITY OF THE SECRETARY OF THE INTERIOR.

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LETTER TO THE SECRETARY.

WASHINGTON, *July* 1, 1874.

SIR: In accordance with your instructions, I have the honor to present for your approval the Seventh Annual Report of Progress of the United States Geological Survey of the Territories for the fiscal year commencing July 1, 1873, and ending June 30, 1874. In my letter to the Secretary of the Interior, dated January 27, 1873, (Ex. Doc. No. 166,) inviting his attention to some views in behalf of an appropriation for continuing the survey of the Territories, and his recommendation of the same, the plan of operations for the ensuing season was marked out in general terms as follows:

For the last two years the survey has operated about the sources of the Missouri and Yellowstone Rivers; but the expenses of transportation, subsistence, and labor are so great that it seems desirable to delay the further prosecution of the work in the Northwest until railroad-communication shall be established. The Indians, also, are in a state of hostility over the greater portion of the country which remains to be explored. It seems desirable, therefore, to transfer the field of labor, for the coming season, to the eastern portion of the Rocky Mountain range, in Colorado and New Mexico. I propose to commence with the southern limit of the belt of the survey of the fortieth parallel, so successfully completed under the direction of Mr. Clarence King. The northern limit of the area marked out is latitude 40° 30′; the western limit, the east bank of the Green and Colorado Rivers; the eastern limit, the one hundred and third meridian west of Greenwich, extending the belt southward to the south line of the United States.

There is probably no portion of our continent, at the present time, which promises to yield more useful results, both of a practical and scientific character. This region seems to be unoccupied, at this time, as far as I am aware, by any other survey under the Government, and the prospect of its rapid development within the next five years, by some of the most important railroads in the West, renders it very desirable that its resources be made known to the world at as early a date as possible.

In accordance with the recommendation of the Secretary of the Interior, an appropriation of $75,000 was made for the systematic survey of Colorado, and, at as early a date as the season would permit, the party reached Denver. This place formed our starting-point for the various portions of the territory which had previously been marked out for the season's work. Early in the winter, the area to be surveyed in Colorado was divided into three districts, and a preliminary map was constructed, based on the land-surveys of those portions concerning which there was any definite knowledge. We found that none of the existing maps were of any great service in the more elevated portions of Colorado. The area to be surveyed comprised the eastern portion of the mountainous part of Colorado, and it was separated into three districts: North, Middle, and South districts.

As soon as suitable preparations could be made at Denver, three well-equipped parties were assigned to these areas. Each party consisted of a topographer, an assistant topographer, a geologist, two packers, and a cook. There were usually two or three others attached to each party as general assistants or collectors in natural history.

There were also three other parties, with very important duties to perform: First, a party under Mr. James T. Gardner, to carry the primary triangulation over the entire area to be explored, thus connecting and harmonizing the work of the first three parties; secondly, the photographic party, under Mr. Jackson, which also passes over the entire field, gathering such information and procuring such views as will be useful to all the other parties and to the public generally; to this party are also attached one or two naturalists or collectors; thirdly, the quartermaster's party, which furnishes supplies to all the others. It is very important that the working parties in the respective fields shall lose no time from their proper duties, and, with this systematic arrangement, they may work through an entire season without the loss of even a day. During the present season (1874) there will probably be a party, consisting of a topographer and the necessary assistants, under the immediate direction of the chief geologist, which will make special studies of some of the more complicated areas already examined during the last year. This will render the final work more complete.

It will be seen, therefore, that the organization is complete and compact, and prepared for the systematic work for which it is intended. It may be enlarged at any time to meet the needs of the Government. The addition of one or more parties at any time does not affect the integrity of the organization. Each one of the parties is complete in itself, and may be sent to any portion of the public domain as the needs of the Department may require.

The divisions operating in the districts assigned during the season of 1873 were denominated for convenience the First or Middle Park division, Second or South Park division, and the Third or San Luis division. The Middle Park division was directed by A. R. Marvine, assistant geologist, with G. R. Bechler, topographer, and S. B. Ladd, assistant topographer. E. T. Luce and S. H. Nealy were attached to this division for a portion of the season as general assistants.

The following interesting abstract has been prepared by Mr. Marvine of the work of his division, which will apply, for the most part, to the others.

The area surveyed by the Middle Park division of the United States Geological and Geographical Survey of the Territories during the season of 1873 comprised an area of about fifty-six hundred square miles, approximately in the form of a rectangular belt, its eastern end resting on the plains near Denver City and stretching westward across the main chain of the Rocky Mountains, including the Middle Park.

The methods of survey were precisely the same as in the other divisions of the party; the main portion of the work being done from topographical stations situated upon the most commanding points within the region, together making a system of secondary triangles within the primary system. From these commanding points, of which seventy, averaging about eight miles apart, were occupied during the season, both drainage-sketches expressed in contours, and perspective profile-sketches, were made by the topographers, and angles, both horizontal and vertical, taken to all the intersections of streams, their principal crooks and bends, all points, spurs, saddles, and sudden changes of slopes; which, with similar angles taken from adjacent stations upon the same points, served to fix their positions and elevations; and with the thousands of points thus fixed during the season with an exceedingly close approximation to absolute truth, the map is filled in from sketches made by the topographer.

The geologist, meanwhile, has made his own detailed and special studies and sections along the route traveled, or on special trips for this purpose; and this detail he generalizes from the higher stations made by the topographer, obtaining extensive views from them, from which he can trace his formations across the country; and with the locations and directions furnished by the topographer more accurately and readily than he can obtain them himself, he can secure data by which he can readily color a general geological map upon his return. Indeed, next to entering the field with a finished topographical map of the region to be examined, a thing as yet impossible in our West, the union of topography and geology in one and the same party best furnishes the data for a realization of the full value of the otherwise more or less disconnected observations of the geologist; and equal benefits accrue to the topographer, for mannerism and inexpressive effects are inevitable results when a topographer sees but the surface of a country and understands not its anatomy. Association of topographer and geologist thus leads to benefits to each, and is certainly a great advantage to the system of field-working now followed by the survey.

The first chapter of his report deals with the main drainage-systems and principal topographical features of the whole district, which material is greatly supplemented by the report Mr. Ladd has prepared upon the means of communication, elevations, distribution of timber, grass-lands, and population.

The Sedimentary rocks underlying the great plains are all thrown up along the mountain-base, with their edges exposed. The formations thus exposed form the subject of Chapter II, where they are treated in order from the lowest, the Triassic, resting directly on the Archæan rocks, through the Jurassic, Cretaceous, and Lignitic (Upper Cretaceous or Eocene,) with a few facts about the more recent gravels and lavas.

The detail-characters of the lower beds are exhibited (Plate I) in detail-sections made at six points along the front of the mountains, while their structural features—the more simple fold of the south, the more complex echelon-folds of the north, and the changes between—are shown (Plate II) by cross-sections at seventeen points along the mountain-front. A map to show the distribution of the Lignitic coal-openings, with railroads, &c., is also given, and attention paid to what is at present known concerning the usefulness of these coals.

The mountains are composed of a great series of metamorphic schists, gneisses, and granites of pre-Silurian age, (with minor masses of eruptive rocks,) all thrown into a complex system of folds, which are very difficult to trace on account of the absence of permanent features in any one horizon; metamorphism so frequently obscuring what distinctive features certain strata may possess for a little distance. A single, indeed many, season's work, would be insufficient to unravel the problems in structure, but more especially in metamorphism, here presented. Even such material as is here presented cannot be made fully available until carefully plotted on the final map. In the mean while, however, Mr. Marvine has prepared a provisional geological map of the eastern slope of the front range, where these rocks were best studied, which shows their general structure, accompanying it with a brief chapter on the more general phenomena here observed.

The Sedimentary rocks of the Middle Park form the subject of Chapter IV, their distribution being shown on the accompanying map, and their structure by the five cross-sections on Plate III, together with minor sections and figures. The relations between the geology and the topography is particularly referred to. The more interesting geological features here observed are: that the Cretaceous rocks seem to be the oldest Sedimentaries, resting directly on the Archæan, a decided unconformability of deposition between the Cretaceous and Lignitic formations, proving that a small east and west anticlinal fold, which occurs along the Lower Grand River in the Park, was formed at the close of the Cretaceous, and before the more extended Rocky Mountain uplift; the inclination of probably post-Tertiary lake-beds, pointing to a comparatively recent slight continuation of this uplift; and interesting glacial phenomena.

The energy and devotion to the work displayed by Mr. Marvine merit the highest commendation, and the results so admirably brought out in his report, as shown by the above short résumé, are but the promise of the future. The map of the first district, prepared by Mr. Bechler, with the assistance of Mr. Ladd, will be engraved the present summer, and will more than sustain the high reputation which he gained by his labor in the Snake River district during the season of 1872.

During the field-season of 1873, Henry Gannett was topographer in charge of the Middle or South Park division. This party consisted, during the greater part of the season, of eight men, Dr. A. C. Peale, division geologist; W. Rush Taggart, assistant division geologist; Henry W. Stuckle, assistant topographer; J. H. Batty, naturalist; two packers; and a cook.

The area assigned to this party is limited on the north by the parallel of latitude of 39° 15′; on the south by the parallel of 38° 30′; on the east by the eighth guide-meridian of the land-survey, and on the west by the one hundred and seventh meridian.

The party left Denver on May 29, and commenced field-work on June 1, and ended October 21. The secondary triangulation and the topographical work of the district were completed, with the exception of a part of the country in the immediate neighborhood of the North Fork of the South Platte, and a small area on Ten-Mile Creek, which will be completed early this season.

In the prosecution of the topographical work, ninety-six stations of sufficient importance to be numbered were made, besides a large number, twenty-five or thirty, of minor importance, for obtaining local details, &c.; nine peaks exceeding 14,000 feet in elevation, and a very large number of peaks exceeding 13,000 feet, were measured as accurately as possible by barometer or theodolite. All the important passes in the mountain-ranges within this district were examined.

During the winter and spring, in the office, Mr. Gannett has made a map on a scale of two miles to one inch, in 200-foot contours of the area worked, and has also reduced the hypsometric work of the season. He has prepared for the press a new edition of the "Lists of Elevations West of the Mississippi River," (which will contain about 75 octavo-pages,) and has prepared a short geographical report, and a short memoir on the results of the trigonometric leveling carried on during the past season.

Doctor Peale, the geologist of the South Park division, was assisted by Mr. W. R. Taggart, and their plan of work was as follows: One performed the detailed work at or near camp, such as making measured sections, collecting fossils, &c., while the other accompanied the topographer to the station selected for the day's observations, which was generally the highest point in the immediate region. At the latter place, the boundaries of the geological formations were defined in colors on a drainage-sketch; this was, of course, based on previous detailed work. In this manner, the geologist was able to make much more perfect results than he could otherwise have done. The amount of labor thus performed by this party was very great, and reflects great honor on the survey.

The labors of Mr. J. T. Gardner during the season of 1873 have shown the importance of careful instrumental observation in raising the standard of the topographical work of the survey. His methods will be explained more fully by himself in a subsequent portion of this report.

The primary triangulation during the season of 1873 covers about 17,000 square miles. Over two-thirds of this area the triangles are completed, and the third angles of the remaining triangles will be observed this season.

Sixteen stations were visited and the angles at them repeatedly observed. Thirty-two more points were located from the primary stations by cuts.

Forty-seven closed triangles were used in the adjustment of the system. Their mean error of closure, after reduction for spherical excess, is 10″.3.

Two of the principal stations were accurately located in latitude and longitude by the United States Coast Survey.

Azimuths were observed at five of the stations.

The system of triangles rests upon a base about six miles long near Denver. This was twice measured with a steel tape under twenty pounds strain and the temperature taken every five minutes. A check-base will be measured this year. A secondary triangulation, resting upon this primary, was carried by the topographers over the same area. The primary triangles range from thirty to sixty miles in the length of their sides, while the secondary average eight miles.

Mr. A. D. Wilson, a topographer of large experience, directed the San Luis division. His method of work was, on arriving at his field of labor, to select a peak from which, in his judgment, he could see the surrounding country to the best advantage, and from this also to choose other points in advance. These points or stations were carefully located by a system of secondary triangles, connecting directly with the primary-triangulation points, several of which were visited. From each station were taken angles, both vertical and horizontal, to all peaks, passes, ends of spurs, streams, junctions of roads, and all recognizable features of the country. The drainage-sketches and instrumental observations were made by Mr. Wilson, while the assistant topographer, Mr. Chittenden, was employed in making profile-sketches and observing the barometer. Barometric observations were made at all stations, camps, passes, valleys, and places of note. The district thus surveyed embraced an area between longitude 104° 30′ and 107° and latitude 37° 50′ and 38° 45′, of about eight thousand four hundred square miles. Within this district ninety-nine regular stations were made by Mr. Wilson, besides ten or twelve by the assistant, which give an average distance from station to station of seven or eight miles.

According to instructions received, Doctor Endlich, geologist for the San Luis division, visited, on May 17, 1873, the mining-regions of Gilpin, Bowlder, and Clear Creek Counties in Colorado, remaining there until July 1. During that time all the important mines in operation were personally inspected, with a view of determining their geological and mineralogical relations among themselves as well as with reference to the geognostic formations surrounding them. On July 3, the San Luis division, to which he was attached as geologist, took the field, and remained in active field-service until October 5. Eight thousand four hundred square miles were surveyed topographically and geologically, and particular attention paid to the agricultural and mineralogical resources of the country traversed.

Geological work and topographical observations were carried on in harmony with each other, so that the geologist was able to prepare a map showing, with a considerable degree of accuracy, the horizontal distribution of formations throughout the district assigned.

The topographical stations were almost invariably accepted by the geologist as suitable for his examination, and a co-operation was thus secured that must render better results than can be obtained by any other method which may claim to cover an equally large area.

During the winter of 1873–'74, the report upon the sections examined was worked up from the notes taken in the field. A large map, showing the distribution of formations, was prepared, and a report submitted. This report is divided into four chapters and an appendix; the first chapter treating of the mining-regions explored; the three next of the geology of the San Luis district, which was divided into three sections in order to facilitate descriptions and the comprehension of localities. In the appendix are contained "Mineralogical notes," describing two new species of mineral, and the occurrence of native tellurium—being the second locality in the world where it occurs—and a "Catalogue of minerals found in Colorado Territory," enumerating over one hundred and fifty species, by far more in number and locality than had ever before been reported from that Territory.

Experience in the field has shown most clearly the necessity of combining topographical observations with geological research. Of all maps that are of importance and great use to the geologist, contour-maps must be preferred. He may note by his observations, and express by means of vertical sections, the arrangement of strata throughout a certain mountain, ridge, or range, and the contour given on the map will then greatly facilitate his work by enabling him to define more correctly than in any other way the limits of the successive strata.

From the stations selected, the geologist can indicate the points important for his work; the topographer can locate these points and reproduce them on the maps which are plotted during the winter following the field-work, thus giving to the former data that must be invaluable to any one who appreciates precise work, even when done on so large a scale.

Mr. W. H. Jackson performed his duties in the field with his usual success. His triumphs in the mountain regions of Colorado are already well known all over the country. The panoramic views of the mountain-peaks have been of great value to the topographer as well as the geologist, and have proved of much interest to the public generally.

Mr. W. H. Holmes also made numerous panoramic sketches from the high peaks used as primary stations. The value of the present report is greatly increased by the beautiful and accurate sketches and sections from the results of his skill in the field and in the office. His knowledge of structural geology is such that he merits the position of assistant geologist.

Mr. James Stevenson acted as quartermaster and executive officer of the survey, and performed the labors incident to his department with judgment and fidelity.

Mr. Robert Adams, jr., of Philadelphia, acted as assistant quartermaster, with entire satisfaction.

By the kind permission of General Sherman and General Ord, Lieut. W. L. Carpenter, U. S. A., accompanied the survey as naturalist, and the result of his zeal in the work is well shown in subsequent portions of this report.

Prof. W. D. Whitney, of Yale College, rendered most valuable assistance to Mr. Gardner in his geographical work, for the months of July and August, without compensation from the Government.

Mr. Leo Lesquereux is permanently attached to the survey as paleontologist. He has just completed a memoir on the fossil flora of the Dakota group, with thirty plates, and is now preparing a second memoir on the flora of the Lignitic group, which will contain over sixty plates. This work will be ready for publication in about six months.

Mr. F. B. Meek, the eminent paleontologist, is also a member of the survey, and has nearly completed his most valuable, but long delayed, memoir on the invertebrate fossils of the West, which will go to press the present summer. It will contain forty-five beautifully-engraved plates, all of which are now finished.

Prof. C. Thomas will remain in charge of the office, superintending the printing of the reports while the main party is in the field.

The survey is under obligations for most valuable papers from Dr. A. S. Packard, S. I. Smith, A. E. Verrill, H. A. Hagen, and Baron R. Ostensacken.

I have only words of commendation for all the members of the survey for their devotion to the work.

To the officers of the various railroads in the West, to the citizens of Colorado, and to the press all over the country, the survey is under many obligations.

HISTORY OF THE SURVEY.

A brief history of the survey may not be out of place in this connection and at the present stage of its progress. In the spring of 1867, when the Territory of Nebraska was admitted into the Union as a State, Congress passed a bill setting apart the unexpended balance of the appropriation for the legislative expenses of the Territory for the purpose of procuring a geological survey of the State. The amount proved to be about $5,000, and the summer of 1867 was occupied in making an examination of the eastern portion of the State. A preliminary report was published in the annual report of the Commissioner of the Land-Office for that year. Some four years after, a final report, in octavo, was printed by Congress.

In the spring of 1868, $5,000 more was appropriated, and the survey was extended into the Territory of Wyoming, along the line of the Union Pacific Railroad. A second annual report was made as the result of this brief preliminary examination. But it was not until the spring of 1869 that the survey received its present form. At the close of the session a clause was added to the sundry civil bill, in the following words, "For the continuation of the geological survey of the Territories of the United States, by Prof. F. V. Hayden, ten thousand dollars, to be expended under the direction of the Secretary of the Interior." By direction of the Secretary of the Interior a geological reconnaissance was extended along the eastern portion of the Rocky Mountain range, from Cheyenne to Santa Fé, N. Mex., and in the winter of 1869–'70 an annual report was published containing the preliminary results. In 1870 the appropriation was increased to $25,000, and the season was occupied in exploring portions of Wyoming Territory. In 1871 $40,000 was appropriated for the continuation of the survey, and by direction of the Secretary of the Interior the work transferred to the interesting region about the head-waters of the Yellowstone and Missouri Rivers. To this expedition one topographer was attached.

In 1872 the work was continued in that region, with an increased appropriation of $75,000, with two large parties and a full corps of topographers and geologists. The result was a still more detailed exploration of previously little-known portions of Montana and Idaho, especially about the sources of the Yellowstone, Missouri, and Snake Rivers. A preliminary account of the results of the survey was given in the annual report for 1872.

During the season of 1873 the geographical, as well as the geological, corps was more complete and better prepared for its duties than at any previous period. The Territory of Colorado was assigned to it as the field of its labors; and the report of progress, which contains many of the important results, is now ready for publication.

THE PUBLICATIONS OF THE SURVEY.

The plan of publication of the results of the survey has been matured gradually, and it is believed that it meets the requirements of the scientific men of the country, as well as the people at large. The publications are divided into three principal classes.

The first class consists of the annual reports, or reports of progress. These will be issued every year, and will give early information of the progress of each season's labors. They will contain much new and important matter.

The second class comprises a series of "miscellaneous publications" on different subjects connected with the West, which are important contributions, but are to some extent compilations, and usually issued in smaller editions. They consist of elevations, meteorological observations, accounts of the botany, ornithology, entomology, catalogues, &c.; all based on the labors of the survey.

The third class will embrace the more technical and matured results, and will be issued in quarto form, and are designed more especially for libraries and men of science. These volumes will be elaborately illustrated.

To meet the wishes of some of the collaborators of the survey, who desired the early publication of important results, a bulletin was published during the past winter and two numbers issued. This will be continued from time to time as circumstances may require.

The following is a list of the publications of the survey up to the present time:

1. First, Second, and Third Annual Reports of Progress for 1867–'68–'69, 261 pages, 8vo.

2. Fourth Annual Report of Progress for 1870, (Wyoming, &c.,) 511 pages, 8vo., with twenty-two wood-cut illustrations.

3. Fifth Annual Report of Progress for 1871, (Montana, &c.,) 538 pages, 8vo., with sixty-four wood-cuts, two plates and five maps.

4. Sixth Annual Report of Progress for 1872, (Idaho, &c.,) 844 pages, 8vo., with sixty-eight wood-cuts, twelve plates and five maps.

5. Seventh Annual Report of Progress for 1873, in process of publication.

6. Final Report of the Geological Survey of Nebraska during the year 1867, 264 pages, 8vo., with a colored geological map and eleven plates of Carboniferous fossils.

7. Supplement to the Fifth Annual Report on the Fossil Flora of the West, by Leo Lesquereux, 22 pages, 8vo.

8. Synopsis of New Vertebrata from the Tertiary of Colorado, obtained during the summer of 1873, by Prof. E. D. Cope, 19 pages, 8vo.

Miscellaneous publications.

9. No. 1.—Lists of elevations in that portion of the United States west of the Mississippi. Collated and arranged by Henry Gannett, assistant, pp. 47, 8vo. Second edition. A third edition of this important paper will be issued shortly, very much enlarged and improved.

10. No. 2.—Meteorological Observations during the year 1872; Utah, Idaho, and Montana; prepared for publication by Henry Gannett, assistant, 120 pages, 8vo.

11. No. 3.—Hand-book of the Ornithology of the Territories of the Northwest, by Dr. Elliott Coues, U. S. A., (in press.)

12. No. 4.—Synopsis of the Flora of Colorado, by Prof. T. C. Porter and John M. Coulter, 180 pages, 8vo.

13. No. 5.—Catalogue of Photographic Negatives belonging to the survey, by William H. Jackson, 83 pages, 8vo.

14. No. 6.—Meteorological Observations, taken by the survey during 1873, 70 pages, 8vo.

Bulletins.

15. Bulletin No. 1.—Pliocene Vertebrate Paleontology of Northern Colorado, Cope, 28 pages, 8vo.

16. Bulletin No. 2.—Vertebrate Paleontology, Cope; Cretaceous Flora, Lesquereux, Acrididæ, Thomas; Geography, Elevations, &c., Gardner; 27 pages, 8vo.

Quarto publications.

17. Vol. I. Contributions to the Extinct Vertebrata of the Western Formations, by Prof. Joseph Leidy, 358 pages, with thirty-seven plates.

18. Vol. II. The Vertebrata of the Cretaceous Formations of the West, by Prof. E. D. Cope.

19. Vol. III. The Vertebrata of the Eocene Formations of the West, by Prof. E. D. Cope; 40 plates.

20. Vol. IV. The Vertebrata of the Miocene and Pliocene Formations of the West, by Prof. E. D. Cope; 40 plates.

21. Vol. V. Synopsis of the Acrididæ of North America, by Prof. Cyrus Thomas; 258 pages, 4to, one plate.

22. Vol. VI. Contributions to the Fossil Flora of the Cretaceous and Tertiary Formations of the West, by Prof. J. S. Newberry; 60 plates.

23. Vol. VII. The Fossil Flora of the Cretaceous Formations of the Western Territories, by Prof. Leo Lesquereux; 30 plates.

24. Vol. VIII. The Fossil Flora of the Tertiary Formations of the Western Territories, by Prof. Leo Lesquereux; 60 plates.

25. The Fossil Invertebrata of the Western Territories, by F. B. Meek; 45 plates.

26. Sections, profiles, and other illustrations of the Geology of the Western Territories explored by the survey, with descriptive text by F. V. Hayden, in three parts. Part 1 contains about 75 plates of sections, &c. Part 2, 52 plates of scenery, prepared by the Albertype process from the photographs of the survey. Part 3, 37 plates of the Hot Springs, Geysers, &c., of Montana. A small edition of the profiles, sections, &c., one hundred copies have been issued without the text.

Maps.

1871. 1. Yellowstone Lake.
2. Lower Geyser Basin of Firehole River.
3. Upper Geyser Basin of Firehole River.
4. Yellowstone National Park.
Notes by A. Schonborn.
5. Parts of Idaho, Montana, and Wyoming Territories. (Preliminary map for field use.)

1872. 6. Lower Geyser Basin of Firehole River. (Scale, six inches to the mile.)
7. Upper Geyser Basin of Firehole River. (Scale as above.)
8. Henry's Lake, Idaho.

9. Shoshone Geyser Basin, and Lake.
10. Parts of Idaho and Wyoming about the heads of the Snake River. (Scale, five miles to one inch.)
    (Prepared by G. R. Bechler.)
11. Parts of Montana and Wyoming about the heads of the Yellowstone, Gallatin, and Madison Rivers. (Scale, four miles to one inch.) Drawn by Henry Gannett from field-notes by A. Burck.
12. Part of Colorado, based on the United States land-survey. 1873. Compiled for field use.

No. 11, containing the complete list of the Ornithology of the Northwest, is passing rapidly through the press. Nos. 14, 18, 19, 20, 22, 23, 24, 25, and 26 are either ready for the press or in an advanced state of preparation, and will be issued within a year.

The map of a portion of Montana and Wyoming Territories, embracing most of the country about the sources of the Madison, Gallatin, and Yellowstone Rivers, in contour lines of 100 feet, and on a scale of four miles to one inch, can hardly be said to be published yet, only a few copies having been issued. The data for this map were collected in the field by Mr. Adolph Burck, assisted by Mr. Henry Gannett. In the office it was completed by Mr. Gannett. The following explanation in regard to the method and purpose of the map will certainly be sufficient for all fair-minded men.

The topographical work was carried on mainly from a meandered line, (meandered with compass and odometer.) Points along the line were located by angles, using the meandered line as a base-line. Much topography, also, was done from mountain-peaks, with gradienter and compass. In addition to this, short bases were measured in several localities with steel-tape, and connected with the topographical work, to serve as checks, and the whole was checked at the camps by sextant observations for latitude and time, the longitude being determined by chronometer, the rate of which was repeatedly checked.

The location of the contours was contrôlled by barometric observations, vertical angles with the gradienter, and slope angles with the clinometer. While not pretending to be an accurate contour map, which it would be useless to attempt to make in a hasty reconnaissance, it does assume to express, with considerable accuracy, the form of the country, in its vertical as well as in its horizontal features.

The system of plotting maps with elevation curves is of the greatest importance for practical geological studies of any locality or country that has been surveyed in that way. It is evident that wherever sedimentary formations occur the curve system greatly facilitates the work of the geologist. Geological maps, if carefully made, will always represent more or less scalloped curved lines, denoting the boundaries of the different geological formations, and it is therefore apparent that whenever the stratigraphical conditions have been observed, and are known, a map showing the elevation curves will enable the geologist to recognize, with great accuracy and certainty, details of geological distribution that otherwise would require considerable time and labor to work out.

In working out sections the curves are of importance, giving the geologist a means by which to give a correct diagram of the line of country through which he has made his section, and furthermore furnishes him valuable data facilitating the measurement of strata.

The map of the sources of Snake River and its tributaries, on a scale of five miles to one inch, is a most valuable contribution to the geography of a portion of our western country, previously almost entirely unknown. The great amount of faithful, conscientious labor bestowed upon it by Mr. Bechler, both in the field and in the office, is so evident that I need not speak of it in detail. An edition of the drainage portion, with the brush-work omitted, will be published during the summer, showing the geological formations with colors, by Professor Bradley. During the summer of 1872 Mr. Bechler resurveyed the Upper and Lower Geyser Basins of the Firehole River; and the two charts, on a scale of six inches to one mile, have just been very beautifully engraved on stone by Mr. Bien.

It is believed that all unkind criticisms of the labors of other scientific men are out of place in an official report, and in no instance will they receive the sanction of the geologist in charge. Each assistant is held responsible for the correctness of his statements in his report, and it is presumed that his love of truth is superior to his personal feelings. Problems are arising and will continue to arise about which there will be difference of opinion among true men of science. We shall accept the verdict founded on the evidence as soon as it comes fairly before us, regardless of our preconceived opinions.

In performing so great an amount of field-work, and in publishing so freely and rapidly as we do, an unkind critic may find defects in our reports which might not have existed with delay; but it seems not only necessary but eminently desirable to bring our results before the public at as early a date as possible. Should mistakes occur, (and they cannot reasonably be avoided,) we hope to correct them in future publications.

I regret that my own report has not been more carefully prepared this season, and that I have been obliged to omit several chapters in which I had intended to discuss some of the more important problems in the geology of the Rocky Mountain region.

The discussion of the Lignitic group will be continued by Professor Lesquereux. His views in regard to the age of this group are well known, and it seems probable that they will be sustained by future evidence. The stratigraphical evidence on this subject, so far as Colorado is concerned, will be subjected to the closest scrutiny the present season.

The present report of progress is submitted with the belief that it is a valuable contribution to our knowledge of the geography, geology, and natural history of a very interesting portion of the public domain. I would again extend my cordial thanks to the Secretary of the Interior and to Hon. B. R. Cowen, Assistant Secretary, for their continued aid and encouragement in advancing the objects of the survey.

Very respectfully, your obedient servant,

F. V. HAYDEN,
United States Geologist.

Hon. C. DELANO,
Secretary of the Interior.

PART I.

GEOLOGY, MINERALOGY, AND MINING INDUSTRY.

REPORT OF F. V. HAYDEN, U. S. GEOLOGIST.

CHAPTER I.

REMARKS ON SURVEY—THE GEOLOGICAL FEATURES OF THE EAST SLOPE OF THE COLORADO RANGE OF THE ROCKY MOUNTAINS, FROM CACHE À LA POUDRE RIVER SOUTHWARD TO PIKE'S PEAK.

In the third annual report of the survey for 1869 I described with some care the geological features of the east slope of the Rocky Mountains, from Cheyenne to Santa Fé. My investigations were more particulairy confined to the sedimentary formations as they are shown by their upturned edges along the immediate eastern base of the range. In this chapter I can do but little more than confirm the accuracy of the statements made in that report, and add a few new facts, referring the reader to the more detailed reports of Mr. Marvine and Dr. Peale.

Although the sedimentary rocks along the flanks of the mountains are of great interest, yet the general outline of their geology is comparatively simple. The vast plains to the west of Cheyenne are covered with the drab-yellow and light-gray sands, marls, and clays of the great fresh-water lake deposit, known as the "bad lands," (*Mauvaisses terres*,) and may be Miocene, or Pliocene, or both. This entire group of deposits juts up against the foot of the mountains, not conforming to the older beds, and in a horizontal position or inclining not over 5°. The Union Pacific Railroad passes uninterruptedly across this deposit from a point east of Grand Island, on the Platte, to the margin of the first range. As we pass southward from the railroad this lake-deposit soon thins out and disappears, and the full series of the older sedimentary rocks known in this region are exposed in their order of sequence. The fresh-water Tertiary deposits not conforming with the older rocks and jutting up against the sides of the front range almost to the summit, necessarily conceal the latter over a very long distance. For one hundred miles or more they are not visible, only as the former have been washed away, and for a considerable distance north of the Laramie River the fresh-water deposits conceal all the older beds, and rest upon the granites direct. About four miles south of a locality known on the maps as Spottswood Springs, the Lignitic beds begin to be revealed in the valleys of the little streams, and very soon the fresh-water deposits entirely thin out. So far as I have been able to ascertain, the older sedimentary strata perfectly conform, and we have here a series of uplifted ridges, showing all the sedimentary rocks of the region up to the Lignitic group inclusive, with remarkable distinctness. I am not certain that we have well-defined Carboniferous beds south of the railroad. Along the line of the railroad, between Hazard Station and Granite, the limestones of Carboniferous age are exposed to a limited extent. So far as I have observed, rocks of this age do not occur again until we reach Colorado Springs, south of the railroad. The brick-red group rests on the Metamorphic rocks, and, starting from the granite nucleus, we pass across the upturned edges of the sedimentary beds, as they incline from the east slope of the mountains at various angles. We have been in the habit of calling the brick-red beds Triassic; but it is by no means proven, and as there are red beds of similar mineral character in the well-marked Carboniferous group below, and the Jurassic above, I have sometimes been disposed to refer them to one or the other, or to both, and regarding the Triassic as wanting. The thickness of the red group as exposed at different localities varies considerably, and it is oftentimes difficult to decide whether the difference is due to original deposition, or whether the beds have been crushed together, or concealed by newer formations. If the Triassic group is wanting in this region I cannot point out any locality where there is any marked unconformability between the Jurassic and the Carboniferous, and this fact might be used to favor the belief that the red group is Triassic. Above the red group is a series of variegated beds, which seem never to be absent along the margins or flanks of the eastern ranges of mountains from the north line of our territory to Mexico. North of the railroad the Jurassic marls are often filled with characteristic fossils, but south of that point they disappear, and they have not yielded any positive paleontological proof of their age to the numerous explorations as far south as Santa Fé. The lithological characters of the group, however, are well preserved, although from the line of the railroad far south to New Mexico the group is thinly represented. Above the Jurassic is a fair representation of the Cretaceous series. No. 1, or the Dakota group, is well shown and is always characteristic, though seldom containing any organic remains, but the other divisions, which are so well defined farther north, are here very obscure. The geologist studying these beds in their southern extension first, would hardly think of separating them into the five well characterized divisions of the Northwest. To one who has carefully studied the divisions along the Misssouri River the Cretaceous beds in Colorado and New Mexico may be separated into the five groups without much difficulty. No. 3 is represented by a thin bed of impure gray limestone and thin calcareous shale, with *Ostrea congesta* and a species of *Inoceramus*. The fossils are about the same as those occurring on the Missouri, but the rocks have little of the chalky texture, as observed in the Northwest and in Kansas. Nos. 2 and 4 are black shaly clays, and do not differ materially from the same groups occurring in other localities to the northward. No. 5 contains a great abundance of well-marked Cretaceous fossils, many of the species identical with those found on the Missouri River. This group passes up into the Lignite strata, apparently without any marked unconformability. In passing upward in number 5, one by one the mollusca of purely marine character disappear until only some varieties of oysters remain with the plants peculiar to the Lignitic group. I may say here that it is quite possible that a more thorough examination of the strata intermediate between those with well-defined Cretaceous fossils and the Lignitic beds would show at least an uncomformability of sequence. In the Laramie Plains there is a group holding this intermediate position of several hundred feet in thickness, which I have called beds of passage.

There is an interesting fact which may be stated just here, that there are no important flexures in the sedimentary group, whatever there may have been in the Metamorphic rocks, but the difference in the inclination of the former is very great at different localities. Sometimes the uplifted zone is ten to fifteen miles in width and composed of a great number of ridges, which are called in the country "Hogbacks." Sometimes the inclination of these ridges from the granite nucleus outward to the plains is not more than from 10° to 25°, gradually diminishing until the Lignitic strata assume an entirely horizontal position, so far as can be detected by the eye. Again, the entire group of strata will be crowded into a space of a mile or less, and stand at a nearly or quite a vertical position, but in suddenly passing from a very highly inclined position to an apparently horizontal one on the plains, we can see that however much the Metamorphic rocks which form the nucleus or body of the great mountain-ranges may have been folded by the shrinking of the crust, the sedimentary beds have been simply lifted up in a nearly or quite vertical manner. I have often stated in previous reports the belief, founded on most satisfactory evidence, that the sedimentary strata formerly extended uninterruptedly across the area now occupied by the Metamorphic mass of the mountain-ranges; that on the east and west slopes can be found the broken portions inclining in opposite directions, but showing most clearly that the intervening portions had been worn away in the process of upheaval. The sections across the range will illustrate this statement most clearly. So far as can be seen at the present time the process of upheaval has been very slow, long continued, and uniform in its action. In many instances the sedimentary group seems to have resisted the central force, and thus the strata were broken off, and the edges turned up very abruptly over a very narrow belt or zone, as at Golden City, and many other localities south of that point. Again, the uplift seems to have influenced the strata for a long distance from the Metamorphic nucleus into the plains, as at Cache à la Poudre, where the inclination of the beds is nowhere very great, and gradually diminishes eastward until they become quite horizontal ten to twenty miles from the axis of power. In many instances the force from below seems to have acted so nearly vertically that only the Lignitic and perhaps a portion of the Cretaceous strata are exposed on the flanks of the nucleus, and thus beds are broken off so abruptly that the detached portions are thrown past a vertical and incline away from the mountain mass; in other words, the great Metamorphic mass that forms the nucleus of a range has been pushed up so directly vertical that the operation did not materially disturb the sedimentary group except immediately around the flanks. This phenomenon is not uncommon over the eastern portion of the Rocky Mountain district. As the details of the geology of the different districts are more fully worked out these points will appear more clearly to the mind of the reader. It will be seen that the geological structure of the Rocky Mountains is comparatively simple in its general outlines, but that in its details it is remarkably complicated.

In the third annual report of the survey, season of 1869, I noted an interesting feature in the structure of the mountain-ranges along the eastern flanks, from Cheyenne to Santa Fé. I directed attention to the curious anticlinal ridges that seemed to extend down from the main range and die out in the plains. Thus the great range or mountain mass that fronts the plains from our north line to Mexico is made up of a vast number of smaller ranges grouped together; and while the great mass, as shown on our maps, has an aggregate trend about northwest and southeast, the front range from Laramie Peak to Santa Fé seems to strike about north and south. If we examine the eastern flanks of the range we shall find, from point to point, smaller ranges or spurs extending down from the main mass toward the plains, with a trend about northwest and southeast, and soon dying out, leaving between the end of the spur or minor range and the main mass a broad open valley, which forms the sources of the more important streams. Most excellent illustrations of this structure are seen where the Big Thompson and Saint Vrain's Creeks emerge into the plains. Great notches are there formed from point to point along the east front of the mountains, from which some of the most important streams, or their branches, emerge into the plains. Cache à la Poudre, Big Thompson, Saint Vrain, Fountain Creek at Colorado Springs, and the Arkansas River near Cañon City, are excellent examples. This feature in mountain structure is shown in a still more emphatic manner farther to the northward, where the front group flexes to the northwest, leaving, however, somewhat separated the Black Hills of Dakota, the Big Horn range, and the numerous smaller ranges on the Upper Missouri. These ranges, large and small, are all linked together at some point more or less apparent by anticlinals. By examining a general map of the Western Territories it will be seen that the Black Hills of Dakota are connected with the front range near Fort Laramie, and that the Big Horn Mountains are united farther north at Red Buttes by a low anticlinal that crosses the interval, revealing no rocks older than the Cretaceous. These lines of connection are best shown by colors on a geological map.

The illustration (section 1) will show quite clearly the dying out in the plains of one of these spurs or ridges. It is also a fine example of an anticlinal. Big Thompson Creek cuts its channel through the south end. The portion thus separated forms a conical hill about 120 feet high above the south base, or about 200 feet above the valley of the Big Thompson. The Upper Cretaceous beds pass off in low semicircular ridges southeast. The main mass of the hill is triangular in shape, and is composed of the rocks, of various textures, which make up the Dakota group. The character of the group is well shown in this locality. The pudding-stones, made up of small rounded pebbles, seldom more than one-fourth of an inch in diameter, smoothly polished, sandstones and quartzites of almost every texture, with slicken on a marked scale, and with the surface lined with white amorphous quartz.

The stream, which separates the triangular end of the anticlinal, cuts directly through the ridge at right angles, and exposes in the section the red beds very distinctly. The trend of the ridges is about 20° west of north, with the uplifted ridges on either side inclining 16° to 20° east and northeast; on the west side of the ridge, No. 1 presents an almost vertical wall for a mile or more, rising from a few feet to 100 or 150 feet in height, resembling the broken wall surrounding some old city. This will always be pointed out to the traveler as one of the curiosities of the region, aside from its geological interest. Just inside is the rather thin group of Jurassic beds; in the aggregate about 200 feet in thickness, made up of irregular thin layers of indurated arenaceous clay and sandstone, with two or three beds of limestone. Not a trace of a fossil could be found, although a hundred and fifty miles north well-marked Jurassic fossils are abundant; and twenty-five miles north they occur to some extent. The thinning out of the Jurassic group in its southward extension is well marked, unless we include the red beds among rocks of that age. Below the well-marked Jurassic group the red sandstone appears, forming several small, rather low, ridges, with thin beds of bluish-gray limestone, quite impure, but used for burning into lime. Here and there, in close proximity to these limestone layers, we have irregular deposits of gypsum. It is only in the red group that these gypsum-deposits are sufficiently developed for economical use. Gypsum in some form occurs in all the formations above the Carboniferous; but in the Cretaceous and Tertiary formations it is found mostly in the form of selenite. The origin of the gypsum is so well known that I will not refer to it in this place. It may be

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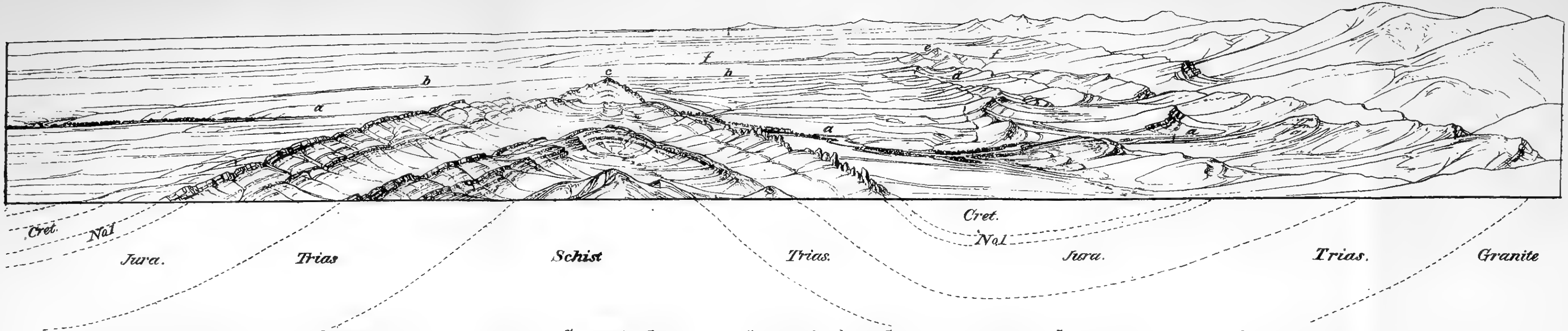
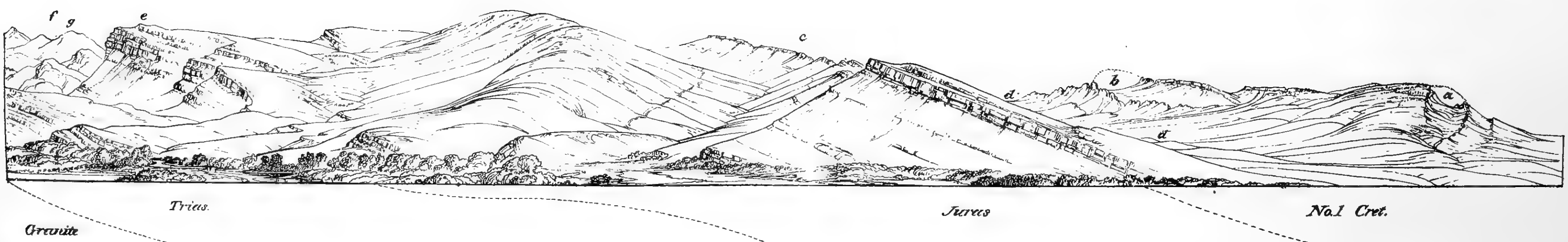
Section I.



a Big Thompson Cr. b Little Thompson c End of 1st anticlinal spur d End of 2nd antcl. spr. e End of 3d antcl. spr. f St. Vrains Cr.

Southern End of Anticlinal
on Big Thompson Creek.

Section II.



Section on St. Vrains Cr.

a and b Oral Openings in Puffs. c Ridge of No. 1. Dakotah Group. d Synclinal Valley. e Red Sandstones, Triassic. f Granites.

stated, however, that the absence or presence of large deposits of gypsum seems in no way to affect the beds of limestone, although the gypsum occurs in greater or less quantities all along the eastern sides of the mountains wherever the group of red beds is exposed. There is a very plain thinning out of the calcareous rocks as we proceed southward. North of the railroad the Carboniferous limestones are quite thick in some places; near Fort Fetterman they reach a thickness of 1,000 to 1,500 feet, while south of the railroad the aggregate of the limestone layers would not amount to more than 25 to 50 feet. The beds or deposits of gypsum are much more extensive to the northward, around the Black Hills, reaching a thickness of 40 to 60 feet, amorphous, and of a snowy whiteness.

The central portion of this anticlinal is a rather low grassy valley, with one or two low ridges rising 2 to 4 feet above the surface, the brick-red edges of the softer intervening strata outcropping here and there where the rock is rounded. The intervening valleys between the ridges are of various widths, depending upon the thickness of the indurated calcareous sandstones. From their irregularity in weathering there must be a very great variability in the texture of these brick-red sandstones from point to point at not very great intervals. This difference is shown all along the base of the mountains. Sometimes the ridges are very high and the upturned portions form a belt of considerable width, composed of quite compact sandstones and quartzites; then, within the space of a few miles, the greater portion of the group will appear to be made up of indurated sands, which yield readily to atmospheric agents. The irregularity in the wearing down of these ridges is undoubtedly due in part to other causes, which will be discussed in another portion of this report. In the valley between the two sides of the anticlinal are several lime-kilns, and the limestone is taken from a bed 2 feet in thickness, rising above the surface a few feet and standing nearly vertical. On either side of the limestone the arenaceous limestone and sandstone are very cellular, looking much like a spring deposit of tufa. It is certainly very gypsiferous all the way through. There are two or three of these thin beds of limestone about the middle of the red group, but no fossils have ever been detected in them. This anticlinal valley, although so short, is very beautiful. At its upper end it is about half a mile wide, tapering to a point on the southside of the Big Thompson, so that it is about three miles in length. The west portion of this anticlinal forms also the east side of the beautiful synclinal valley, through a portion of which the stream flows. The eroding agents have smoothed out this concave synclinal valley, which is almost entirely grassed over, so that no formations can be seen newer than No. 1. The quartzite wall on the east side, which stands 80° at least, must have been broken off, so that the underground portions cannot be very deep, but pass beneath the valley and rise up on the opposite side, inclining at a very moderate angle. This peculiar arrangement of the ridges produces a very curious drainage for the Big Thompson and its branches. On the south side of the valley of the Big Thompson the long, low, Cretaceous ridges can be seen from a high point extending across the surface to the north, but stopping abruptly at the creek, while the synclinal interval gradually closes up to the northwest, in the valley of the East Fork. South of the main stream, and on the west side of the synclinal valley, the No. 1 ridge is very prominent, and runs up to Big Thompson close above the Red Stone Creek, as seen on the maps. Between the end of the anticlinal south of Big Thompson, and the same ridge as it rises on the south side of the same stream, the distance across the synclinal valley is about three miles. As we pass up the axis of this triangular anticlinal we find within it an open triangle; or, in other words, high ridges of sandstone incline east, west, and south from the nucleus of mica schists. The sandstones forming the ridges of this inner triangle are much more compact in texture, varying from a sandstone to quartzite and pudding-stone. The pebbly portions are scattered irregularly through the mass, showing everywhere that the sediments were deposited in shallow and disturbed waters. Indeed, it is seldom that the red groups give any evidence of long periods of quiet deposition.

Passing over the ridges of sandstone, which rise above the anticlinal valley about 200 feet, we ascend a ridge of black mica-schist, which, on account of its peculiar texture, I have called "bird's-eye schist." The surface of these slate-like shales is covered with circular pits, while the mass of the rock has a wavy texture, the whole reminding one at once of a kind of timber common in our Northern States, known as "bird's-eye maple." The south end of the schist-ridge rises 1,100 feet above the valley of the Big Thompson, at the old stage-road. The second ridge, still farther north, is 1,450 feet, while the highest part of the spur is over 2,000 feet. The highest point is not over 8,000 feet above sea-level. It will be seen at a glance that this ridge or tangential spur, as it might be called, is a remarkable feature in Rocky Mountain structure; that the internal forces should strike off at a tangent, as it were, elevate a branch ridge from the main chain, and so suddenly, and in many cases abruptly, die out in the plain, is difficult to comprehend. We shall endeavor to present the facts from time to time with as much detail as possible, leaving the primary causes to become more clearly known as we can accumulate illustrations. The synclinal on the southwest side of the spur continues up until the spur joins on to the main nucleus of granite. The ridges forming the east side of the anticlinal extend continuously along the east base of the mountains to Cache à la Poudre, while the west side is cut off by the schist-ridge. The synclinal is closed up in a sort of pocket or *cul de sac*, forming the drainage of the North Fork or Red Stone Creek. The red beds lie close up against the granites, while the branches of the Little Fork have cut their way through the ridges, as shown in the small chart. The schists in the spur extend down as a sort of tongue between the uplifted ridges of sedimentary rocks on either side. The schists all incline west or south of west 60° to 80°. The strike of the schist-ridge or spur is about northwest and southeast. The "hogback" ridges on the east side, extending along the base of the mountains to Cache à la Poudre, are quite regular, and incline 20° to 25°. There is usually an interval or valley between the schists and the first ridge, as shown on the surface, though beneath the valley the red sands and sandstones jut up against the upturned edges of the schists. About five miles to the northward, on the east flank of the mountains, a group of massive red feldspathic granites rise up beneath the schists, and the surface has the appearance of a great morainal deposit, so rounded are the detached masses of granite. These worn blocks were scattered over the sedimentary as well as the Metamorphic rocks and show marked signs of former glacial action. Such examples may be found everywhere along the mountain sides. The subject, however, may be more fully discussed in another place. At this point remnants of the lower sandstones lie high up on the granites, inclining 60° to 80° southwest, while the upper sandstones dip nearly 20° east. The sandstones, as they lie in contact with the granites, filling up the irregularities of the surface, are composed of a loose aggregate of quartz, pebbles, and other Metamorphic rocks, with a coarse quartzitic sand as a cement. There were many deep depressions, which are filled up in a remarkable manner. These tongues or ridges of granite extend down from the main range in many places, but seldom so far as to break the regularity of the upheaved sedimentary ridges. Between Big Thompson and Cache à la Poudre there are quite wide grassy intervals between the ridges, which produce excellent grazing for cattle. These ridges are well defined; there are usually about two principal ones of the red group, and one very high and prominent ridge, composed of No. 1, underlaid probably with the Jurassic group. The Dakota group ridge is immensely developed all the way to Cache à la Poudre. On the inside of the ridge vast blocks of quartzite and pudding-stone, 20 feet cube, have fallen down into the valley or lie thickly scattered on the sides of the ridge. At Spring Cañon, nine miles north of Big Thompson Station, there is a splendid section of the entire sedimentary group. The little streams seem to have cut their channels direct from the mountain-sides through the series of ridges at right angles. The Dakota group is at least 250 feet thick, and is composed of beds of fine-grained sandstone or quartzites, which are much used for building purposes. So much has already been written in regard to the Cretaceous group, as shown south of the railroad, that I do not know that I can add anything new in this chapter. The very minute and accurate sections of Mr. Marvine will make the succession of the beds, as well as the relative thickness from point to point, perfectly clear. Between Cache à la Poudre and Big Thompson, the ridge composed of No. 1, or the Dakota group, is most conspicuous, forming a peculiarly symmetrical roof. This ridge is higher and more uniform than any of the others on either side of it, due probably to the fact that the texture of the rocks of the Dakota group is so much more compact and resists the wear of the atmosphere more effectually. The slope of the roof is about 20°, and although much of the surface is bare, the upper portion is covered with scattering cedars of a stunted growth. At irregular but short intervals inverted conical notches occur, produced by the little streams, which have worn their way, to a greater or less depth, directly through the ridge. The more important streams have cut deep channels from the mountains through into the open plains, but in the intervals are numerous depressions, like those shown in the illustrations, that indicate the erosion of temporary streams, thus giving a wavy outline to the outcropping edge of the ridge. We may say here in this connection that the Dakota group is one of the most widely-distributed formations in the West. To attempt to describe the variations in structure from point to point would be an almost endless task, and yet, when carefully studied in one locality by the geologist he never fails to detect its presence at other points where it exists, if exposed. All over the great middle belt of the West, so far as I have observed it, between the parallels 47° and 34° and the meridians 97° and 114°, it maintains enough of its peculiar lithological character to be readily detected, and thus, although in most instances destitute of, or containing very imperfect organic remains, it forms a permanent basement-floor for the great Cretaceous formation of the West, as well as a most important *datum* line for determining the age of the rocks above and below. The numerous species of plants, with a few invertebrate fossils, which have been found on the Missouri River and in Nebraska and Kansas, have fixed the age of the group, so that we believe it passes beneath all the more modern beds from their points of appearance at the East to their exposure along the flanks of the mountains. The eastern portions of this group are composed of a considerable thickness of dark iron-rust sandstone, in which the plants are found for the most part. In the West this sandstone is not found in so marked a degree. Volume 7 of the quarto series, by Professor Lesquereux, contains 30 plates entirely devoted to the plants of this group. The physical history of this group would be one of great interest if we had all the details, forming, as it does, the line of separation between two of the most important of the Mesozoic ages. Indeed I have sometimes regarded it as a sort of transition group between the true Jurassic and Cretaceous series. The exact line of separation between the Cretaceous and Jurassic I have never seen, unless it be the lowest layer of sandstone. The beds of sandstones, quartzites, &c., form the characteristic feature of the group, but the beds are usually separated by perhaps layers of indurated clay or shale, which are of variable thickness. It is also probable that the Dakota group passes gradually into the Jurassic through softer strata, for the sandstones are indurated with lower arenaceous clays. I hold the position that the sequence of all formations is to be sought for in all places; that while breaks not unfrequently occur, the normal condition is the entire absence of any line of demarkation, so that with the closest scrutiny the geologist cannot tell where one formation ends and another begins. Variability in texture and composition is regarded as indicative of transition from one age to another, and this peculiarity is so persistent in the Dakota group wherever it is known that I have been disposed to regard it as a transition series, although the organic remains do not fix it positively at the base of the Cretaceous. It is even possible that an unconformability of sequence will yet be found. All through the group the layers give unmistakable evidence of the shallowness of the waters of the ocean during the deposition of the sediments. It seems somewhat singular that so widely-distributed sea-deposited rocks should exhibit such uniform proof of shallow-water deposition. The rocks are usually in rather thin layers, with very irregular laminæ of deposition; the sediments vary from a fine to a coarse sand or gravel, also from a fine pudding-stone, made up of an aggregate of smoothly-worn pebbles from the size of a pea to an inch or more in diameter, sometimes so closely cemented together that the fracture of the mass is liable to pass through the pebble. In somewhat rare instances this pudding-stone becomes a coarse conglomerate. The average thickness may be stated at 200 feet, but vibrates between 100 and 250 feet. Between the sandstones are perhaps partings of indurated arenaceous clay, and about the middle of the group is a seam of impure Lignitic clay, which has often been prospected for coal. Along the Missouri River, in the vicinity of Sioux City, Iowa, and in Southern Nebraska and Kansas, this last is 2 to 4 feet in thickness, and has been wrought to some extent for fuel, but with poor success. Along the margins of the mountain-ranges there is no certainty of its appearance at all; still it crops out from point to point from the north line to Mexico. The entire group of sandstones show that shallow water and land were near, or at least areas where vegetation could grow, for all through the rock are fragments of leaves, stems or sticks, and sometimes coal. Many of the beds are sort of mud-sandstones, of a drab-brown, from the abundance of indistinct fragments of vegetable matter. Sometimes, in the more compact homogeneous layers, well-defined leaves are found, usually of a deciduous type. Leaves were found in these rocks, near Denver, along the line of the Union Pacific Railroad to Ogden, and in the Elk Mountains. The sandstones pass up into brown arenaceous clays, with rather thin layers of mud-sandstones, full of mud-markings, which resemble casts of sea-weeds with fragments of vegetable matter. Then comes black shaly indurated clay, which indicates quiet deposition in moderately deep waters, at least. This is what we have usually denominated No. 2, or the Fort Benton group, and sometimes attains a thickness of 200 to 600 feet, quite homogeneous in character. There is now and then a calcareous layer which is charged with fossils, as *Inoceramus*, *Ostrea congesta*, and other well-marked Cretaceous forms. Above the Dakota group the Cretaceous rocks have very little influence on the scenery further than that the dark saline clays of No. 2 and No. 4 give the appearance of an arid sterility to the surface. Nos. 2, 3, 4, and 5 are usually so soft and yield so readily to the atmospheric agents that, where the mountain-streams emerge from the Dakota group, they flow out into the plains. In some instances they have escaped erosion and occur in a series of low ridges which pass off eastward into the plains like the waves of the sea. This is well shown north of Cache à la Poudre, where the Lignitic group is involved in the uplift and the belt of uplifted ridges is several miles in width, but inclining at very small angles. No. 3 Cretaceous is not well defined, yet it has a representation in the yellow and gray limestones and shales or slates. The chalky limestones are often full of the characteristic fossils of No. 3. Along the base of the mountains in Colorado, No. 3 forms rather low, rounded ridges, grass-covered, and not easily studied except where the mountain-streams have cut deep channels directly through them. We can thus trace the continuity complete, so that we find the passage from No. 2 to No. 3, and from No. 3 to No. 4, then to No. 5, as gradual as if they were all united in one group without any possible line of separation. No. 3 varies from 50 to 100 feet in thickness, so far as can be seen, yet the difference in thickness at different points may depend somewhat on the clearness or obscurity of the exposure.

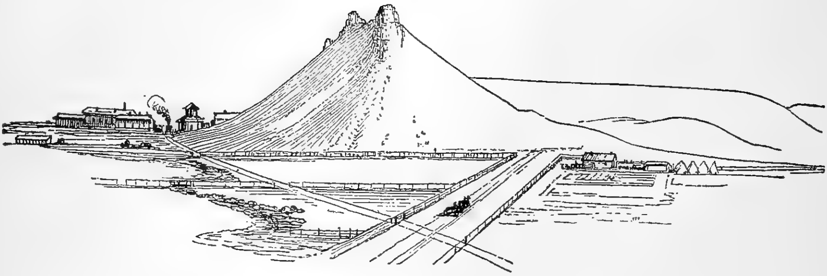
That all these groups vary in thickness at different localities would be expected, but I doubt very much whether from any exposures along the flanks of the mountains these variations can be determined with any degree of certainty. Nos. 2 and 4, made up as they are of indurated shaly clays, yield more readily to the eroding agents, and No. 3 rises up between them in a low rounded ridge from a few feet to 50 or 100 feet in height. No. 2 usually underlies the concave parallel valley or interval between the high sharp ridge composed of No. 1 and the low eroded ridge of No. 3. No. 4 forms the more slightly concave depression between Nos. 3 and 5. This series of parallel valleys between the ridges, with a general trend north and south, is a feature peculiar to the flanks of the mountain-ranges, and is best shown, on account of the vast continuous extent, on the eastern side. The intervals are usually softer materials, and have been worn out more or less smoothly by the elements and then grassed over, so that some of the finest farming and grazing lands in the Rocky Mountain districts are found here. These valleys are so inclosed that they are protected from the winds and storms, and in consequence old settlers are working their way up from the plains to the immediate base of the mountains in considerable numbers. As a range for stock these valleys are admirable. The pictorial sections will illustrate what I mean by these parallel valleys. The mountain-streams cut through them at right angles. I have already, in the annual report for 1870, called attention to the wide parallel valleys north of the railroad between the older rocks and the modern Tertiary or lake-beds.

In general appearance No. 4 resembles No. 2, yet the latter is more plastic and of a darker color than the former. No. 4 is an indurated clay, sometimes becoming a sort of slaty shale. South of the railroad it contains very few fossils. It is not a thick bed, rarely exceeding 100 feet, and gradually passes up into the yellow arenaceous clays of No. 5. No. 4 usually underlies one of the parallel valleys, and can only be studied to advantage when a stream flowing down from the mountains into the plains cuts a channel through it. In these localities the gradual lithological changes may be observed. A low ridge is formed by the beds of transition between Nos. 4 and 5, which is sometimes so regular and continuous that it looks like the ruins of an old wall. The shale gradually becomes dull brown, indurated clays alternating with thin layers of mud-sandstone, and finally rising up to rather thick sandstones of various degrees of brown and rusty-yellow color. In some localities the fossils are quite abundant, as in the valley of Cache à la Poudre, near Greeley, and in the valley of Big Thompson, west of the Denver Pacific Railroad. Here are found rounded concretionary masses, like huge cannon-balls, resembling those of the same formation on the Cannon-ball River, which empties into the Missouri River from the East, far up in Dakota Territory. These singular concretions contain quantities of well-marked Cretaceous fossils, *Ammonites*, *Baculites*, *Inoceramus*, &c., &c. This group of calcareous sandstones, which reaches a thickness of 100 to 200 feet in this region, I have regarded as the upper portion of the true Cretaceous groups. These pass gradually up into the Lignitic formation, about the age of which there is some discussion among paleontologists. North of Saint Vrain's Fork, the Lignitic group, as well as the upper portion of the Cretaceous, is seldom lifted up at a high angle, usually 3° to 15°, the angle of inclination becoming less and less as the ridges die out eastward in the plains. The lower portion of the Lignitic group shows the influence of the forces that elevated the mountains, but soon they become nearly or quite horizontal, and far east of the Cache à la Poudre pass under the White River deposits. The latter thin out in their southern extension, so that they are not unfrequently worn down to the underlying Lignitic beds. About twenty miles south of Cheyenne there is a bed of coal 5 to 6 feet in thickness, and above it is a bed of oyster-shells 4 feet in thickness. Many of them are quite perfect, but they are mostly fragmentary and worn, as if they had drifted into this locality. In the lower portion of the Lignitic group it is very common to meet with seams or beds of *Ostrea*, of various species. This species resembles very closely a form holding about the same position on the Upper Missouri, in the valley of Grand River, known as *Ostrea subtrigonalis*. In both localities it occurs in the lower portion of the Lignitic group, and in the ascent gives place to purely fresh-water types. At the Marshall coal-mines, south of Boulder City, I have collected small forms of *Ostrea*, in strata above the most important beds of coal, and also along the Un on Pacific Railroad, at Point of Rocks, Black Buttes, and other stations, where the coal-beds are very numerous and their order of succession well shown. The various forms of the genus *Ostrea* are abundant, passing up through several hundred feet of the coal group.

It is not my purpose to enter into a discussion of the age of these beds in this connection. In a previous report I stated that the relations of the well-defined Cretaceous group with the Lignitic forms one of the most important problems in Western geology, and that no effort would be spared to accumulate all the evidence bearing on the question possible. I believe that the area for the solution of the question lies in the Laramie plains, and westward toward Salt Lake. There in the aggregate are 10,000 to 12,000 feet of Cretaceous and Lignitic strata. Contiguous districts may aid in throwing light on the subject, but with all that has already been done this region presents one of the most attractive fields of geological research on this continent. The relations of the fresh-water lake-deposits with the Lignitic is another interesting subject for investigation, and will probably be settled in connection with the former. So far as we have the more important problem considered we find the evidence from the vegetable remains wholly in favor of the Tertiary age of the coal group. The vertebrate remains, according to Professor Cope, place them with the Cretaceous group, while the proof from invertebrate fossils is not strong in any direction, although, perhaps, leaning toward the Tertiary. We must admit, however, that the lower coal-beds are of Cretaceous age so far as the evidence goes. For instance, the Coalville and Bear River beds are most probably Cretaceous, inasmuch as many undoubted Cretaceous types are found in strata above the coal. I admitted this evidence as far back as 1869 in a paper read before the American Philosophical Society. I am more convinced that farther south, in New Mexico, Arizona, and Utah, there are coal-beds of undoubted Cretaceous age. The main question, then, is this: *Are the vertebrate paleontologists, Cope and Marsh, justified in regarding the entire Lignitic group as Cretaceous from the evidence furnished by the vertebrate remains?* During the progress of the survey this subject will be discussed from time to time with all the light that can be gathered from every quarter. We have in the preceding pages endeavored to describe somewhat in detail the sedimentary rocks as exposed in the vicinity of the Big Thompson Creek, and either north or south of this point they do not differ materially in their general character. We may now move rapidly southward along the base of the mountains, noting here and there some peculiar features of interest which may have escaped attention in former explorations. About five miles south of the Big Thompson a shaft has been sunk to some depth, apparently in search of coal. It is just over the quartzite No. 1, and shows very clearly the relations of No. 2 to No. 1. The shales incline about 15°. In some thin mud-limestones *Ostrea* and *Inoceramus* were observed in great numbers, mostly in fragments. A considerable quantity of silicified wood was found here also. There is here an important ridge which seems to be made up of a fragment of No. 1 or a stratum of No. 2—most probably the latter. It is composed of a gray mud-sandstone about 15 or 20 feet thick, and in many places filled with vegetable impressions which must have been originally formed by sea-weeds. They are not distinct enough to determine, but have the forms of black irregular stems, and from the mass of these markings the sea-weeds must have grown here with great luxuriance. It is not uncommon for a series of the border layers, as alternate beds of mud-sandstone or quartzites, with shales or clays, to occur in many of the beds. These layers disappear again in shales. About two miles north of the Little Thompson we find the quartzites standing nearly vertical in a sort of fragmentary wall. This was accounted for by another of these spurs from which the greater portion of the Cretaceous beds had been worn away, leaving a sort of semi-quaquaversal, (section 2,) Nos. 2, 3, and 4 inclining from a convex or dome-shaped ridge or puff (?) of No. 1. This is certainly a very interesting example of the connection of the quartzites of No. 1 in what might be called an anticlinal. The trend of this puff (*d*) is about 30° west of north. On the west side of the puff there is an interval of half a mile, a synclinal valley extending down from the base of the mountains, underlaid with Nos. 2, 3, and 4, which originally extended over the puff. About two miles south of Little Thompson there is another of these convex ridges (*d*) which shows the *en échelon* tendency of the mountain-ranges. It extends out tangentially several miles from the base of the main range into the plains between Little Thompson and the north branch of Saint Vrain's Creek. Just as the Saint Vrain emerges from the Hogbacks in the plains, the valley expands to a width of at least five miles, (*c*,) so that there is only this main ridge or spur between the drainage of the Little Thompson and Saint Vrain's Creek. This ridge is also partially domed over, although a portion of the Upper Cretaceous beds incline away from the ridge on all sides. On the east side an oval mass has been removed through the quartzites of No. 1 and the Jurassic group, just exposing the red beds in the bottom of the depression. The quartzites stand up nearly vertical on the east side, forming a semicircular wall, while on the west side the summit rises 830 feet above the valley of Saint Vrain, with a dip of only 20° or 30°. The layers of rocks are quite massive, 4 to 6 feet thick, composed of a beautiful pudding-stone, the pebbles rounded and as smooth as glass. There is here at least 10 or 15 feet of solid pudding-stone, and the pebbles all through it have the same elegant smoothness and are sometimes an inch or two in diameter, but usually smaller. The depression as well as the sides of the ridge are covered with huge cubical masses that have fallen down. The last two smaller spurs do not appear to have interrupted to any extent the trend of the ridges. On the north side of the Little Thompson and inside of the uplifted ridges the short rounded schist-spur is distinctly seen trending northwest and southeast, which has produced the puff. The oval opening (*d*) in the puff is about half a mile wide and a mile long, produced by erosion. To one traveling between the Hogback ridges and the granites these tangential movements of the internal forces do not seem to have disturbed the symmetry of the principal series of ridges. The Little Thompson in passing through the main ridges cuts them at right angles, and on the north side a fine, regular vertical section is shown, with the beds all in their normal position, while on the south side the same beds incline toward the north from the ridge or puff that extends down into the plains, (well shown in sections 2 and 3.) The Little Thompson, after emerging from the sandstone ridges, cuts a deep channel through the calcareous shales of No. 3. The bed is here 200 to 300 feet in thickness. These unusual developments of a group show the difficulty of obtaining the exact thickness of these uplifted groups of strata at different points with any degree of accuracy. We may call this spur an oblong quaquaversal, for the beds incline at greater or less angles from both sides, and come around the end, forming quite distinct semicircles. Nos. 1, 2, and 3 form distinct ridges from the end of the spur, and the plains below show clearly that they are underlaid by the softer materials of the Upper Cretaceous. On the south side of the spur there is a triangular-shaped valley, through which the north branch of the Saint Vrain flows from the base of the mountains. The upper part of this triangle is a synclinal, as is so well shown in the illustration. South of Saint Vrain's Creek the ridges begin to close up rapidly, so that at Boulder Creek they form a narrow belt. Two or three fragmentary ridges of Lignitic sandstone rise above the surface 20 or 30 feet, not over three miles from the foot of the mountains, and the strike would carry them close up against the very base near Boulder Creek. The coal-strata continue to approach nearer and nearer, until between Boulder and Clear Creeks they form a portion of the foot-hills.

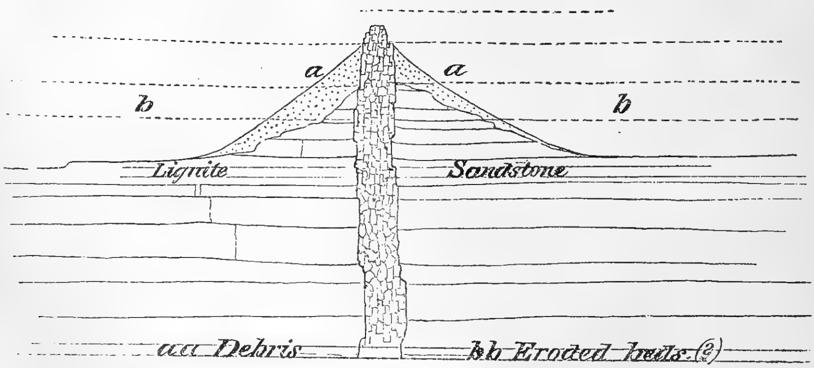
The terraces along the base of the mountain are very remarkable, and will be noticed more fully in another place. As they are composed of superficial deposits the ridges pass under them at times, and are hidden

Fig. 1.



Dyke at Valmont
end view

Fig. 2.



Ideal Section of Dyke

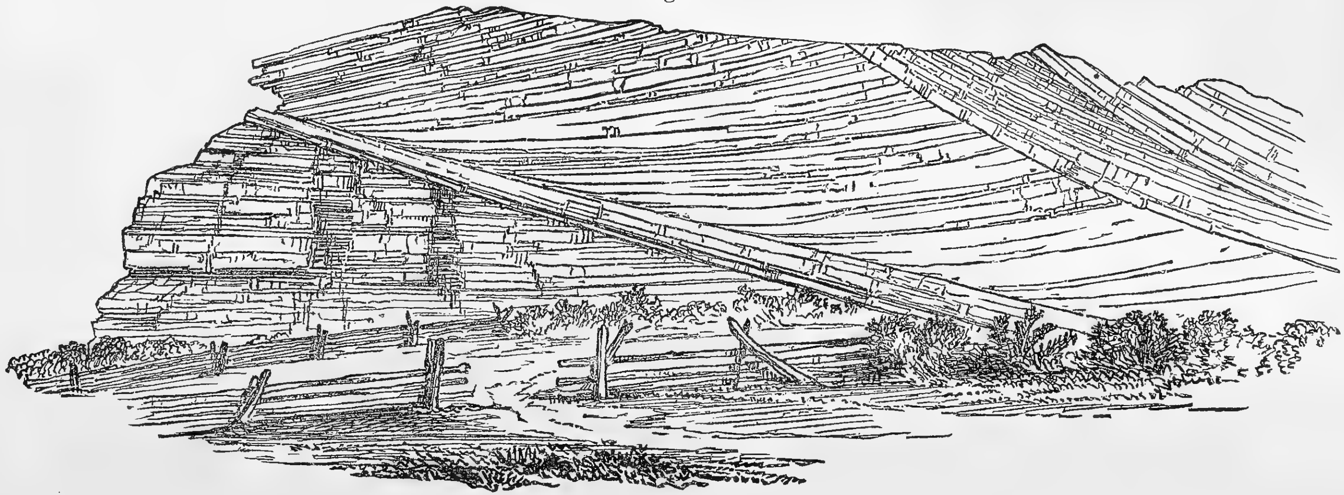
from view. We will allude to these terraces again, under the head of glacial effects, which are very conspicuous everywhere, and nowhere more so than in the valley of the Boulder.

Near Boulder City the ridges hug the base of the mountain closely, while between North and South Boulders they are worn away, mostly exposing the granites. The terraces, as well as the lower valleys, are literally paved with water-worn bowlders of all sizes. The origin of the agencies which have produced these effects is evident from the fact that as we recede from the mountain the bowlders diminish in size as well as quantity, until far down in the plains they almost entirely disappear. There is no evidence that the superficial deposits are of remoter origin than the immediate mountain-side. At Valmont, in the Boulder Valley, about five miles below Boulder City, there is a singular dike of augitic dolerite, which rises up nearly through the horizontal Lignitic strata like a wall. Its strike is about south 67° west. It runs directly up the valley and parallel with it at right angles to the mountain-ranges, and evidently had a much greater extent than at present. It has been uncovered for the most part, and perhaps entirely, by the wearing out of the valley of the Boulder. Originally the igneous material must have been forced up vertically, filling the fissure like a mold; and while the soft yielding sandstones and clays that surrounded it were easily swept away by the eroding agencies, this dike, by the great hardness of the rock, has resisted so that it remains like vertical walls. The highest portion is just at Valmont, and is 300 feet above the base, while at either end in a line with the main mass is a raised ridge covered with the fragments of dolerite. At the top it is 30 feet wide, but expands to 50 feet or more at the base, while farther down, where the dike is much broken, it appears to be 150 feet. It undoubtedly varies in width from 50 to 150 feet. The south side of the dike is washed by the Boulder, and is nearly vertical and loose, while the north side is covered with the broken fragments and the sedimentary beds jut up against it without any evidence of much disturbance. From the summit of the highest point the view up and down the valley is very fine, and nowhere in Colorado can be gathered within a single scope of the vision so abundant and so great a variety of the resources of Colorado. The railroads are in operation here, and the broad valley from the mountains down for thirty miles or more is covered with fields of grain and other products of the farm. On the south side in the high hills numerous openings for coal may be seen, and between Boulder Valley and Clear Creek the bulk of the coal of Colorado exists. The valley near the base of the mountains is full fifteen miles in width, but gradually narrows as the long benches that extend down on either side approach each other, and the little branches all unite in one stream. So far as we can determine from the surface, the dike extends about four miles in a direct line, and from the west end to the east end the strike is about north 30° east. The Lignitic beds incline down the stream, or about west 1° to 3°. About half a mile north of the dike, on the north branch of the Big Boulder, there is a fine exposure of the yellow-gray sandstone, apparently horizontal. Indeed, wherever any of the underlying Sedimentary rocks are exposed, they do not seem to have been disturbed by the forcing up of the igneous matter, and we may therefore conclude that it merely filled an original fissure as a mold.

I will now pass hastily over the remaining portion of the country to Colorado Springs, presuming that the reader will find a general view of this region, with a pretty clear exposition of the great features of the geological structure, in my report for 1869, but calling attention to the more detailed work of Mr. Marvine and Doctor Peale. I may say here that soon after leaving the base of the mountains we have what are usually called the plains, and the slope is generally to the eastward, becoming less and less to the Mississippi River. Ten miles from the foot-hills the general elevation is from 5,000 to 6,000 feet above the sea; the surface is rolling, and in traveling from north to south we gradually rise to the summit of one water-divide and descend into the valley of some stream which flows from the mountains. These streams are usually, on an average, about ten miles apart, and from one margin of descent to the opposite side it is from five to eight miles. These valleys have been worn out slowly by causes which will be noted in another portion of this chapter. In a former part of this chapter I described in detail the series of sedimentary beds from the granite nucleus of the mountains eastward into the plains. From Cache à la Poudre far southward to the Arkansas the plains are underlaid by some portion of the Lignitic group. The superficial deposits are so extensive and the exposures of the underlying beds so rare that it will always be difficult to work out the succession of the beds in detail. It is most probable that Denver is underlaid by the lower portions of the group, and that the divide far southward between the waters of the Platte and Arkansas is composed of upper beds of this group. The aggregate thickness of the entire group, as seen in Colorado, cannot be less than from 3,000 to 5,000 feet. On a geological map attached to my final report of Nebraska I represented the fresh-water lake deposits as overlapping the Lignitic and extending far southward toward the Arkansas. It is probable that some portion of that area is occupied by the Lignitic group alone. That the Lake or White River group covered a larger area southward along the base of the mountains is most probable, but that has been worn away so that the present area occupied by them would extend around to the southeast, much as shown on the map. I am not positively certain that they extend south of the line of the Kansas Pacific Railroad. We know, however, that they cover a large area south of the Union Pacific Railroad. East of Denver the Lignitic beds must extend two hundred miles without interruption. It is possible, also, that somewhere in this great area basins occupied by more modern Tertiary deposits may yet be found. It is probable that the Carboniferous group does not occur continuously, as colored on the map, from the line of the Union Pacific Railroad to Colorado Springs. Near the sources of Fountain Creek both the Carboniferous and Silurian beds appear, and then southward, interrupted here and there, the former group occurs along the flanks of the mountains. The more carefully-prepared maps, which will be made hereafter by the survey, will correct all local details, though in a general way this map was very correct.

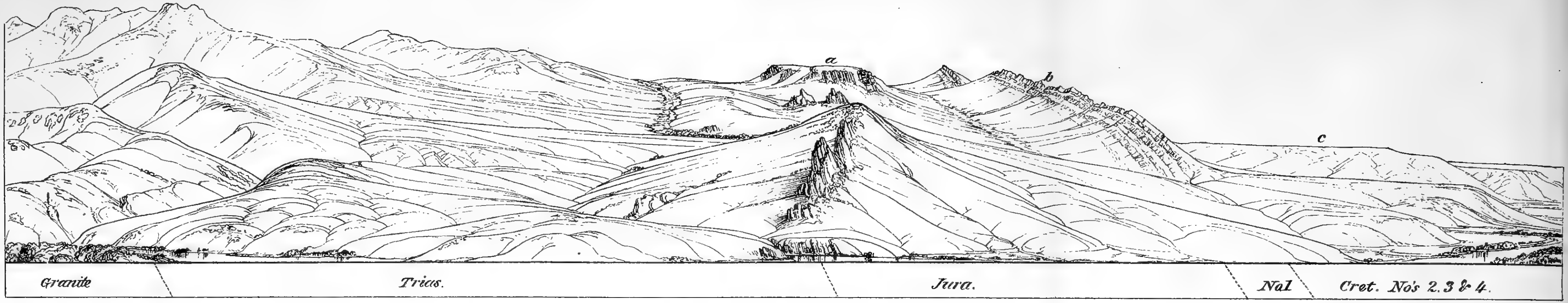
I have already alluded to the fact that the belt of uplifted sedimentary ridges became narrower at the Big Boulder. Between the Big Boulder and Clear Creek all the strata were lifted up at a high angle. Even the Lignitic strata are close to the granites, and stand at high angles, varying from 40° to 70°. South of Clear Creek the belt is not wide, but it expands somewhat wider now and then, but south of Platte Cañon hugs the mountains even more closely, the inner or lower strata lying high on the sides of the foot-hills. Nowhere along this belt, from Big Boulder to Plum Creek, do we see any traces of undoubted Carboniferous beds. The lowest strata exposed next to the granites vary somewhat in color and texture; the prevailing color is brick-red, or reddish brown; but in some places the lower beds are composed of a rather coarse conglomerate cemented quite closely together. In the vicinity

Fig. 3.



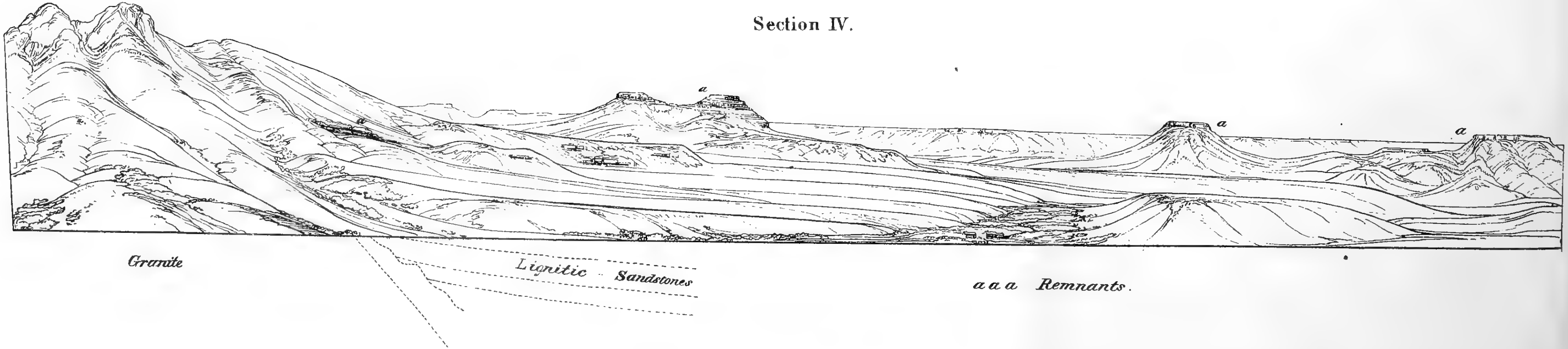
Irregular Layers of Deposition
St. Vrain's Cr.

Section III.

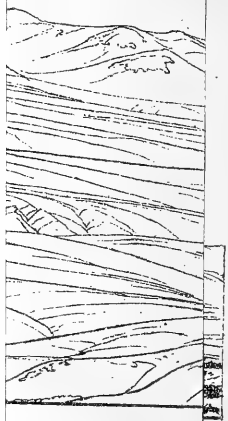


Section at Platte Cañon.

Section IV.



Looking north from near divide between Platte and Arkansas River's.



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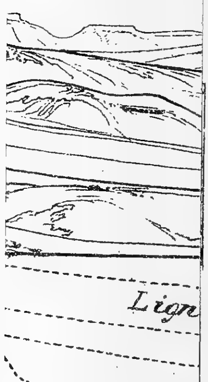


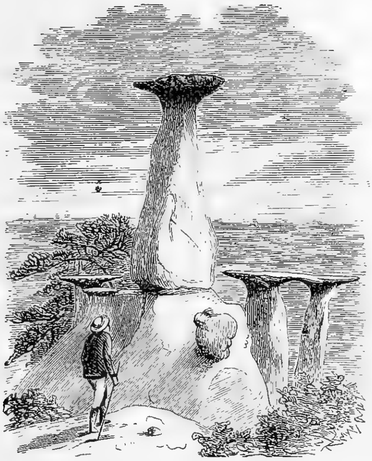
Lookin

of Bear Creek and its branches these lower conglomerate-beds fit into the irregularities of the surface of the Metamorphic rocks in a marked manner. Little streams flowing from the mountain-sides have cut excellent cross-sections, showing the original deposition of the Triassic (?) sandstones in deep depressions of the granite nucleus. We may say here that the coarseness of the sediments of the lower beds of the Red group is not the only evidence of the disturbed condition of the waters that deposited them; all through the group are quite remarkable illustrations of irregular and oblique lamination. These examples are shown on a grand scale immediately after the Saint Vrain emerges from the granites. There is a considerable valley between the coarse, reddish, feldspathic granites and the first principal ridge of sandstone which has been worn out by the water, but remnants of the conglomerate have been left, filling up the irregular granitic surface. The Saint Vrain here runs southward parallel with the ridges for about three miles, and then turns to the east and cuts through the ridges at right angles, and flows into the plains past Longmont. Just south of the point where the creek cuts through the belt of sandstones, the parallel valley closes up and the ridges lie close up on the sides of the mountain. Here the group of sandstones which we have usually classed as Triassic exhibits a great variety of structure. The conglomerates rest on the coarse feldspathic granites, and the basset edges of the sandstones rise like a wall on the east side of the creek. There are alternate beds of sandstone of various degrees of firmness as well as hardness to resist the atmosphere, and softer layers of sandy clay. The beds of sandstone thicken or thin out at remarkably short distances. At one locality on the east side of the creek, the most important bed of sandstone expands within a distance of 200 yards from 50 to 250 feet in thickness, and affords some of the most remarkable examples of oblique lamination, the lamina inclining 10° to 17°. Here we have quite a broad interval for several miles or more between the granite foot-hills and the uplifted sedimentary ridges, produced by the excavation for the drainage of the Saint Vrain. Soon the ridges lie close on the sides of the granite, and continue more or less closely to Clear Creek. South of Clear Creek narrow intervals occur again to a point about five miles south of the cañon of the South Platte. Just south of the Big Boulder the red sandstones seem to have been partially changed by heat, and the ridges rise in lofty walls 1,500 to 2,000 feet above the plain, presenting a front which has no parallel in any other locality along the eastern flanks of the mountains, from the northern boundary to New Mexico.

About five miles south of the South Platte Cañon we come to the divide between the drainage of the main Platte and Plum Creek, where the sedimentary rocks jut up against the sides of the mountain so that the slope is continuous from the tops of the granite foot-hills down into the valley. This divide is quite narrow, and southward we soon descend into an interval again between the granite foot-hills and the sedimentary region. Between the Platte Cañon and this divide there seems to have been an unusual hardening of the Red group, and the action of the eroding agencies must have been peculiar, for the sandstones present a more picturesque appearance than at any other locality, not excepting the "Garden of the Gods" at Colorado Springs. The main ridges seem to have split up into a multitude of irregular ones, and the fragments now stand up inclining eastward 30° to 50° in the shape of leaning columns and spires, the ragged upper edges presenting almost every variety of form which the meteoric forces could produce. These fragmentary forms rise out of the grass and bushes which grow abundant all around their base, and one can wind about among them like meandering the streets of some old ruined city. The view from either end, that is from the north end southward, or the south end northward, is very fine, but presenting a confusion of unique forms, the varieties of color, red, mottled, &c., adding much to the picturesqueness of the scene. The roof-like sides of many of these broken ridges are peculiarly marked by the vertical furrows down which the rains of heaven have fallen for ages. The opportunity for the study of forms presented here would rouse the enthusiasm of the artist to any extent. It was difficult to estimate the thickness of the Red group, but it appeared to be at least 1,500 or 2,000 feet. The ridges of No. 1 Cretaceous outside formed a continuous wall about 30° dip. The Jurassic as well as Cretaceous beds are well shown.

From the divide between the South Platte and the Arkansas there is a marked change in the character of the sediments composing the rocks above those, usually understood as Cretaceous. This divide rises from 1,000 to 1,500 feet above the valley of the Platte, near Denver, and also about the same elevation as at the north end of the valley of the Arkansas, near Pueblo at the south. The strata are very nearly or quite horizontal, except near the base of the mountains, where they have, in many instances, been slightly disturbed. The full series of beds from the Red Triassic to the summit of No. 5, inclusive, are quite well shown to be the main water-divide near the source of Monument Creek, though obscured here and there by a modern deposit of what seems to have been swept from the mountains, and must be of the Post-Pliocene age. This latter deposit is made up of the decomposed feldspathic granites and schists of which the immediate foot-hills of the mountains are composed. The red beds also have contributed their portions to this modern deposit. From the source of Plum Creek to the Arkansas it seems to have filled up the irregularities of the surface more or less, and it is only when it has been swept away that the outcropping edges of the ridges are exposed. There is a certain degree of obscurity about the geology of this district. The modern appearance of the group of coarse sandstones and conglomerates above the true Cretaceous beds and their position with reference to the granites induced the belief that they belonged to the Miocene period, and in my third annual report of 1869 I gave them the name of the "Monument Creek group." For a distance of from fifteen to twenty miles they appear to jut up against the base of the mountains with an inclination of not more than 15° at the highest, and usually not more than 3° to 5°; and there is also an apparent unconformability with the older formations. For example, the red sandstones at the north end lie on the sides of the granite foot-hills at an angle of 70° to 80°, and suddenly disappear under the nearly horizontal beds of coarse quartzose-sandstone. It is out of these sandstones that meteoric agencies have carved the remarkable forms which have given names to the little streams and other localities in this region. There is one locality in the valley of Monument Creek called Monument Park, from the great number of columns which are, standing thickly over the surface, each one surmounted with a cap of harder material. The shaft of the column is usually thick at the base, rising up 10 to 20 feet, tapering to the cap, composed of a coarse aggregate of quartz-grains, small pebbles, all water-worn, very loosely held together with rather coarse sand cement. The cap is a deep rust color, composed of sand cemented with oxide of iron, and by its greater hardness has resisted more effectually the eroding agencies. I cannot believe that all the effects which we now see were accomplished by the ordinary atmospheric influences at present in operation in this region,

Fig. 4.



Columns in Monument Park. Tertiary.

Fig. 5.

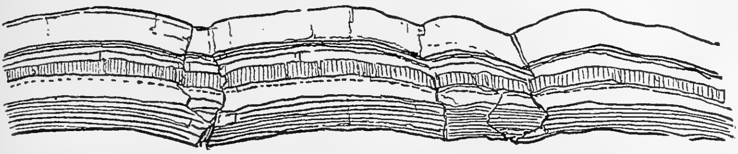
although the air, rain, and snow may have done much to give the monuments their present forms. The greater portion of the erosion must date back into the past, at least to the Post-Pliocene period. It is very probable that water had much to do with the formation of these monuments at a time when there was a far greater supply here than there is at this period. The entire surface of the country must have been on a level with these caps at least, and probably much higher. The caps themselves are nothing more than concretions mostly rounded and flattened, while intervening materials have been slowly worn out and carried away. There is another form of erosion which is characteristic of this formation, and that is the mesas, or table-buttes, which are scattered thickly over a broad belt east of the Denver and Rio Grande Railroad. Most of these mesas are capped with a purplish porphyritic basalt which originally flowed over the surface, doubtless covering a broad area. These buttes, with their flat summits, were also carved out of the horizontal strata, and vary in height from 100 to 150 feet. The rocks composing the "mesas" are mostly of a finer material; and above the coarse sandstones of the monuments some of these mesas are nearly round, others square, others oblong. On the east side of Monument Creek and near the divide they assume curious castellated forms, so that they look in the distance like the ruins of old castles. These may be seen in considerable numbers in the distant plains as far south as Colorado Springs. There is a large area in the plains east of the Denver and Rio Grande Railroad line, from Denver to the Arkansas River, which is not well known to the geologist as yet. The pine-covered ridge from which so many streams rise flowing northward into the South Platte and south into the Arkansas, forming what is located on the maps as the Bijou Basin, must be underlaid by rocks which I regard as belonging to the Monument Creek group; whether this group as shown here is only a portion of the great Lignitic group or not, the few observations we have made do not determine. The plants found in a number of localities in Monument Creek Valley and near Colorado Springs indicate that it is a part of that group—perhaps the upper portion. This group contains beds and seams of impure coal, with deciduous leaves, some of which are identical with species occurring in the Lignitic strata from New Mexico to the Upper Missouri. Indeed, the general aspect of the rocks in this region is much like the Lignitic group on the Yellowstone and Missouri Rivers near their junction and in the vicinity. The Monument Creek group has not yet yielded many fossils, and these are not usually well preserved. The rocks are extremely soft, usually disintegrating easily, and too coarse in texture to preserve plants well. Not an invertebrate fossil has been found as yet, though it is supposed that some very interesting vertebrate remains came from it. More careful explorations will undoubtedly reveal the existence of fossil evidence. Plants are abundant in several localities, and other forms will most probably be found farther east, toward the interior of the basin.

Unless these deposits are of modern Tertiary age I am at a loss to account for their position in relation to the metamorphic foot-hills, as well as the older sedimentary beds. A great portion of the Lignitic group has been lifted up at a moderately high angle, as is shown on either side of the divide, but for about ten to twenty miles a group of beds of very coarse texture, an aggregate of crystals of quartz and feldspar, jut up against the sides of the mountain at an angle of nearly 15°, but usually not more than 8° or 10°. The beds which lap immediately on the metamorphic rocks have the appearance of coarse feldspar granites, and as we recede eastward from the base of the mountains the sediments become finer and finer, until the whole group contains a very small portion of the coarse aggregate. It would appear that the sediments of these beds were derived from the mass of metamorphic rocks in the vicinity after they had risen to or near their present elevation.

The variety of coloring is not so well shown in the Monument Creek group as in the Triassic sandstones of Pleasant Park. The metallic oxides have given a good share of beauty to the former, enhancing the attractions of these singular freaks of nature. Pleasant Park is located among the uplifted ridges of the Triassic, Jurassic, and Cretaceous groups, and the peculiar forms that are worn out of the variegated sandstones are not even as wonderful as the variety of rich, beautiful shades of coloring. Far north of this point, and south, in the Garden of the Gods, and many other localities, the red sandstones are displayed on a grand scale, but nowhere else are the rich colors, consisting of all shades of red, pink, yellow, gray, and white so well shown. The tints were unusually vivid, and contrasted so as to produce fine effects. This whole region would be a paradise for an artist. The unique forms which have been carved by the elements out of the sandstones are most conspicuous. Near Koontz ranch is a group of weathered masses of sandstone that look like hay-stacks. These rocks are stratified, with the layers inclining from the mountains to the east 10°.

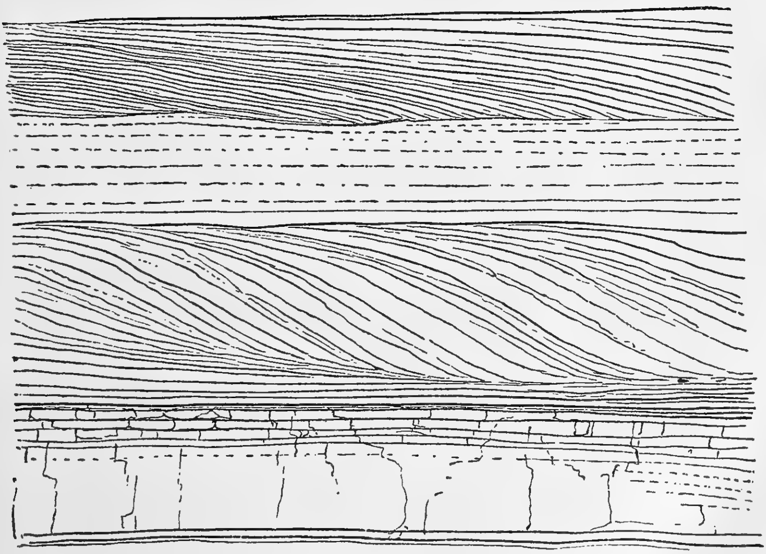
The next point of interest is the district around the east base of Pike's Peak, in the valley of the Fountain Creek. This little stream rises up in the mountain-range of which Pike's Peak forms a part, flows southeast, cutting through the upheaved Sedimentary ridges, after emerging from the mountains, nearly at right angles. The ridges on the north side of the creek trend a little east of south, but immediately on the south side flex toward the mountains at a sharp angle, trending west of south and very soon apparently striking the granite mountain-sides and are thus cut short off. The entire group thus forms an obtuse angle, and Fountain Creek has carved out its channel pretty directly through the angle. The channel therefore affords a most excellent opportunity for the study of the formations in their consecutive relations. But the question arises, how is it that they are developed to such an enormous thickness so suddenly? Has there been an increased deposition of sediments at this particular locality? I have already alluded to the absence of all rocks below the supposed Triassic or red beds along the flanks of the mountains from the Union Pacific Railroad to Colorado Springs. We may, then, ask why it is that there should be exposed here so suddenly, not only an unusual development of the Triassic or red group, but below it 1,000 to 1,500 feet of reddish and gray sandstone-quartzites with intercalated beds of clay of varied thickness, probably Carboniferous, and below this a group of limestones more or less impure resting unconformably on the Metamorphic rocks containing well-defined Silurian fossils. There cannot be less than 4,000 feet of sedimentary beds below the Cretaceous No. 1 exposed in the valley of Fountain Creek, while for a distance of one hundred and fifty miles north of this point the aggregate thickness of the Triassic and Jurassic groups is probably not over 1,500 feet at any locality. The little streams that flow down from the mountain-sides have cut deep cañons through the Silurian beds as they lie high upon the granite foot-hills, and deep into the granites also; so that the opportunity for special studies is as complete as could be desired. Most excellent sections can be obtained in Williams's Cañon, Chiann Cañon, and in a dozen gorges extending along the mountains for about five miles. My time was so limited that, even with

Fig. 6.



Crushed Strata.

Fig. 7.



Oblique Laminæ.

the facilities afforded by these natural sections, only a partial examination was made. There is an area here of about ten or fifteen miles square that must ever remain an interesting field for the practical geologist and deserving of a special exploration. One may follow Williams's Cañon up two or three miles above the springs through a narrow gorge with walls rising 300 to 500 feet on either side. At the entrance to the cañon the red beds rest on a yellow-gray limestone which passes down into an arenaceous limestone with a reddish tinge containing well-marked Silurian fossils. The inclination of all the beds is about 35°, and the mass runs high up on the mountain-sides, resting unconformably on the coarse feldspathic granites, as shown in the illustration. The lowest beds of sedimentary rocks are rather coarse sandstones, and conglomerate made up of water-worn quartz-pebbles, with very irregular laminæ of deposition, the whole reminding one of the Potsdam group. About two miles up the cañon the Silurian beds, inclining southeast 8° to 10°, rests on the feldspathic granites, which are most distinctly stratified, the strata inclining about north 35°. The sedimentary beds fill up in a remarkable manner the inequalities of the original surface of the metamorphic rocks. The Silurian group was noticed by me in 1869, and a collection of fossils was made, but the fossils were not identified by Mr. Meek until it was too late to use them in my third annual report. In the fourth annual report, 1870, on page 295, several species of Silurian fossils are mentioned by him belonging to the collections from this locality. One of the species, according to Mr. Meek, is a well-known form in the Calciferous group of New York, *Ophileta complanata.*

There is considerable variety in the aggregate of beds here, which may be regarded as Silurian, and we may conclude that the Potsdam group is quite well represented, and that it is possible that some of the higher divisions occur. These rocks require a still more careful study, yet it is an interesting fact to know of their existence in this locality. In the lower sandstones I found a species of *Lingula*, the present season, probably a Potsdam form. I have never known of any Carboniferous fossils being found here, but I am confident that there are 1,000 to 1,500 feet of these beds between the Silurian group and the true red beds or Triassic. They are composed mostly of sandstones, quartzites with partings of clay variegated. About four miles to the north the Silurian limestones form high ridges on the sides of the mountains for a short distance, then disappear entirely. There seemed to be an apparent unconformability here. I studied the structure of the upturned edges from every point of view, and I could not decide on a real nonconformity. There were localities where the Silurian group is entirely separated from the red beds, and inclining at different angles, but at the upper end of the "Little Garden of the Gods" the order of sequence appeared to be unbroken. We may now ask how 2,500 to 3,000 feet of rocks disappear so quickly and mysteriously, as we go north of Fountain Creek. The red sandstones that we have been in the habit of regarding as Triassic rest upon the granites as if they had been deposited there by water originally, but partook of the elevation of the mountain-range. We may suppose that the Silurian beds once covered this entire region, and that over large areas they were worn away prior to the deposition of the overlying beds, and that the portions we see at this locality are remnants that escaped the great erosions, or we may suppose that they were not deposited. I believe the former is the true interpretation, that the Silurian rocks once covered the entire country and may still exist to a greater or less extent under the vast thickness of more modern beds which underlie the plains from the east base of the mountains to the Missouri River.

The plateaus between Monument Creek and the upheaved ridges are formed to a great extent of a thick deposit of materials of quite modern origin. There are ashen-brown and gray clays covered with a considerable thickness of a sort of unstratified drift material, composed mostly of the *débris* of the Metamorphic rocks, the red feldspathic predominating. This curious deposit fills up the inequalities of the surface in many places produced by the disturbance of the older sedimentary beds. Between the railroad-depot at Colorado Springs and the "Little Garden of the Gods," the road passes over a beautiful plateau, from which the view of the country in all directions is exceedingly fine. This plateau is underlaid by the modern deposit, and here it must reach a thickness of 200 to 400 feet at least, and possibly more. The origin and time of this deposit is somewhat obscure as yet, but an attempt will be made to clear up its history in another place. It is undoubtedly Post-Pliocene, and belongs to some portion of the Post-Glacial era of this region. The deposit may be seen with a greater or less thickness all along the eastern flanks of the mountains, and is composed of the materials worn from the rocks in the immediate vicinity. In treating of the influences of water and ice in carving out the present mountain-forms, I shall dwell more fully on this subject.

CHAPTER II.

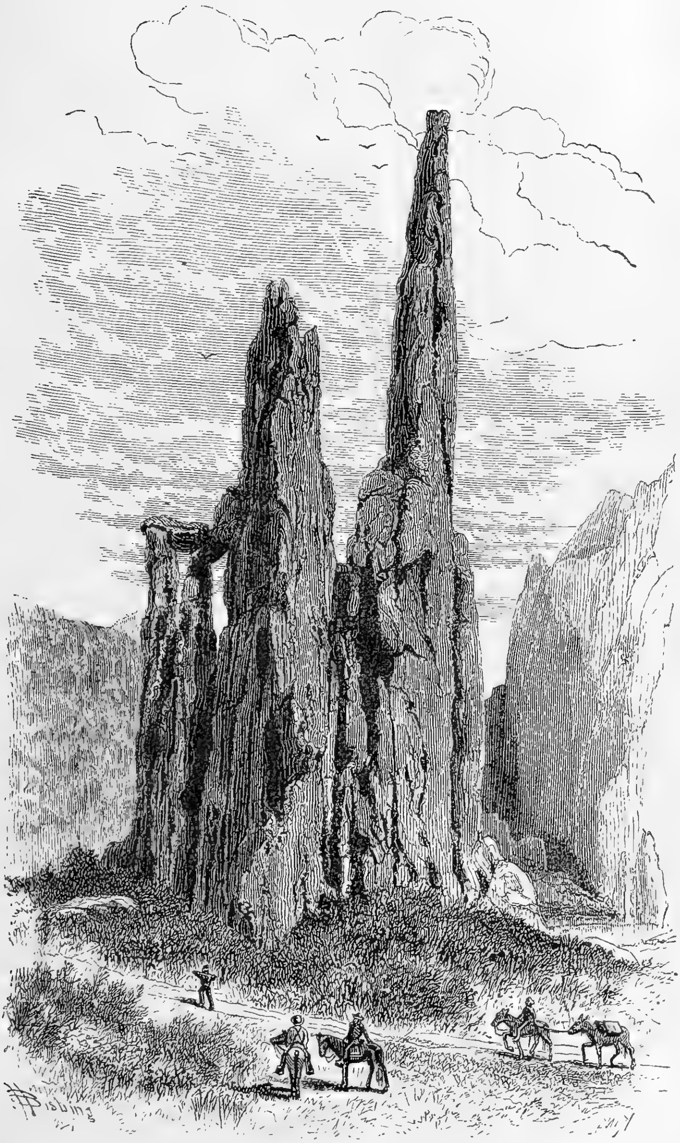
COLORADO MOUNTAINS, SOUTH PARK, PARK RANGE, UPPER ARKANSAS VALLEY.

In order that the annual reports may be read with greater interest by the general public, I have presented the matter in a narrative form as far as possible, stopping here and there to discuss a topic more in detail as it is suggested by some peculiar feature along the route. This plan has enabled me heretofore to introduce more readily local details of interest, both of a practcal as well as scientific nature.

Our starting-point was Denver, the most important town in Colorado. The country between Denver and the mountains has already been described in so much detail that we will hasten on toward the South Park by the old stage-road. After passing the base of the mountains we meet with only changed rocks, until we descend into the depression, or basin, known as the South Park. The metamorphic schists and granites in their almost numberless varieties which compose the central portions of these mountain-chains will be discussed by Mr. Marvine, who spent most of the season among them.

We entered the mountains by way of the Turkey Creek Cañon; here we had a most excellent opportunity to study the connection of the Triassic rocks with the underlying metamorphic. The coarse sediments of the Triassic were deposited upon the irregular surface of the schists, oftentimes filling up deep depressions. The cañon has been carved out of the schists so that they can be studied with ease on either side, and as the stream passed through the sedimentary beds toward the plains the most perfect cross-sections were made. The stratification of the schists is even more distinct than that of the sedimentary beds. The south side of the cañon is very rugged and precipitous; the inclination of the schists

Fig. 8.



Cathedral Rocks—Garden of the Gods, Colorado.

is such that the basset edges project from the south side, while on the north side the slope is quite moderate. The cañon is partly one of fracture as well as erosion. The stream has not cut the strata quite at right angles, but slightly across the dip. The principal rock is a very hard, black gneiss or schist, with seams of yellow feldspar, varying from a few inches to several feet in thickness, running across the strata at different angles. Some of the seams contain quite large masses of quartz, but feldspar predominates. Sometimes the quartz is interstratified with the schists for a short distance, running out, however, at both ends. In cutting the road along the north side of the Turkey Creek Cañon an old dike is exposed, with feldspathic quartzite on one side and a seam of feldspar on the other. The dike-matter is filled with masses, of greater or less size, of the adjacent schists. This dike would never have been exposed but for the wearing out of the gorge by water and ice. Igneous rocks of different ages are thus exposed at various localities all through this front range; seams of quartz or feldspar are so numerous, intersecting the schists in every direction, that it would require a most detailed study to describe them properly. Pockets of mica occur frequently in these seams. About a mile up the cañon are two dikes of syenite 10 to 15 feet wide, rising up in the form of a wedge, but separated by about 8 feet of feldspathic granite. The schists here present to the eye the appearance of utter chaos. The study of the details would reveal a warping of the bedding that would be quite remarkable. Layers several feet thick are warped, or dished, at least half the circumference of a circle. The aggregate inclination seems to be 20° east of south. The lower thin layers of schist are in some places crushed in a remarkable degree, while higher up toward the summits are thick massive beds of feldspathic granite in a horizontal position.

For about five miles up the cañon the scenery is very rugged on both sides, the valley widens out somewhat, and the mountains on either side soften down and are covered more or less with *debris* and thin soil, on which grow grass and pine trees. Near the junction and for some miles beyond the rocks are massive granites, of which the great mountain-peaks in the vicinity are composed. The surface is covered with groups of weather-worn granitic masses resembling old ruins. The peculiar forms of these masses determine to a great extent their texture. The coarse feldspathic granites disintegrate easily, and peel off in thin, circular layers, giving to them a smooth, rounded appearance, while the finer-grained, more compact granites are still angular. The varieties in texture give form to the surface-scenery over a very large area, and nowhere is this fact better illustrated than in these mountain-districts. The great orographic lines were undoubtedly determined by upheaval, but the present surface-forms were due largely to erosion. We shall endeavor to show, from time to time, that sufficient importance has never been attached to this agent in molding the lineaments of the earth's surface; that although the proofs of upheaval are everywhere apparent, and in many localities most probably those of depression, yet the immediate forms of the surface thus produced have almost entirely disappeared under the effects of erosion or weathering. Many of the water-courses have probably followed lines of fracture, so that the two agents, upheaval and erosion, may have united to produce many of the mountain-valleys. There is one interesting feature in connection with the mountainous districts of Colorado, which is now apparent in the valleys of the Colorado or front range. These grassy areas are fast being occupied by a mountain-population, sparse, it is true, but a very thrifty one. The grass not only covers the valleys in the elevated regions, but grows high up on the mountain-side, so that it is remarkably well adapted for dairy purposes. A large amount of the best butter and cheese is made, and the demand is greater than the supply, as yet.

Most of the hardy garden-vegetables and some of the cereals grow well at an elevation of 6,000 to 8,000 feet. These mountain-ranches are every year filling up the more elevated regions of Colorado, so that we may conclude that no portion of the Territory, even aside from the mineral wealth, is practically unavailable to man.

From the high mountain-hills that border the north side of the South Park we have a fine view of the great basin-like depression. The surface of this basin is not entirely a plain, but is covered to a greater or less extent with low ridges and hills, which trend about southeast and northwest. The dish-shaped character of the depression, as well as its origin, is plain, when we come to examine the borders. We find the sedimentary rocks lying high up on the sides, showing clearly that these strata incline in every direction toward a common center. In other words, the South Park may be regarded as an immense quaquaversal. On the north border, the sedimentary rocks are very much obscured by the great deposit of mountain-drift and the igneous rocks that seem to concentrate there to a great extent. Fragments of sandstone, apparently of the Triassic group, cover the hills, and here and there we see an outcrop of the main beds, but not sufficient to make a connected section. At one locality there was a circular depression surrounded with a wall of trachyte, with a small lake in the center, which was undoubtedly an old crater. There is also a great thickness of trachyte here in layers, varying from an inch to a foot in thickness, inclining from the hill at first 45°, then increasing to 65°, showing that after the first outflow had cooled there were subsequent outflows elevating the cooled portions at a high angle.

Passing along the road to the southwest, toward Fairplay, we see all along the borders of the park a terrace, which seems to have such a uniformity of level that it points to the existence of a lake here at a comparatively modern period. There is also a very beautiful valley-like area here, which occupies about one hundred square miles. Near Lechner's ranch a shaft has been sunk about 30 feet deep, cutting a coal-bed about 12 feet in thickness, with a dip of 45° northeast, and a strike south 45° east. The clay above the coal is about 6 inches, and below the coal 10 inches thick. Below the lower clay is a sandstone, at the bottom of the shaft, and above the upper clay a bed of yellow soft sandstone. About 200 yards to the west another shaft has been sunk, exposing a bed of coal 6 feet thick. I am inclined to think there are two different coal-beds here, though there may be but one. The slope underlaid by the coal strata extends up close to the sides of the mountain, and the surface is so covered with drift that it is only by means of these shafts that the Lignitic beds can be seen at all. A few fragments of deciduous leaves have been collected here, showing clearly that a portion of the Lignitic group, as seen on the east side of the mountain-range, occurs here.

As we pass along the road to Fairplay, we travel over the entire series of sedimentary beds known in the park. Long ridges extend across the basin, composed of the black shales of the Cretaceous, containing *Inoceramus*, *Ostrea*, *Scaphites*, the well-known *Baculites ovatus*, &c. The entire series of Cretaceous, Jurassic, and Red or Triassic group are well shown. Toward the center of the park are some long ridges of trachyte, which must have been produced by the outflow of igneous matter from an extended fissure. The sedimentary beds are exposed more or less all along the east side of the park. They slope up close on to the east side of the Park range, but the wash or drift from the mountains has so covered the slope that the beds in contact with the Metamorphic rocks can seldom be seen.

Along the valley of the Platte the drift-material, consisting mostly of water-worn bowlders, is immense. The entire mass of drift-deposit, in which the placer diggings are located, has been washed down from the valleys of the little streams of the South Park. The local origin of the drift, so far as our Rocky Mountain districts are concerned, is illustrated in a remarkable manner in the park.

The area of the park is about 1,200 square miles; its greatest length is northwest and southeast, about forty miles, and in the opposite direction about thirty miles. The shape is elliptical. The general elevation varies from 8,000 to 10,000 feet above the sea. The drainage is from the northwest to the southeast. Before presenting any details of the geology of the Park range I will state briefly what I believe to be its relation to the great Sawatch range, on the west side of the Arkansas River. I am of the opinion that the Park range is a portion of a gigantic anticlinal, of which the Sawatch range is the central axis; that the Park range is a portion of the east side of the Sawatch range, and that the great valley of the Upper Arkansas is mostly the result of erosion through the granite rocks. The eroding agents began their work in a fissure produced by the uplift, but once a depression or opening formed for the accumulation of water and ice, the work of disintegration would commence. The subject of earth-sculpture, or erosion, as it is illustrated in myriad forms in the Rocky Mountains, and nowhere in the West on a grander scale than in the mountains of Colorado, will be touched upon frequently in this report, and will be treated more fully, under a separate head, at some future time.

The Park range is very irregular in elevation. Portions of it are low, while several peaks rise about 14,000 feet. Mount Lincoln is 14,183 feet, and upon the very summits are found the sedimentary rocks. The action of the internal forces has been very irregular also, sometimes lifting the granite nucleus up to an elevation of 12,000 to 14,000 feet in the form of puffs, as it were, the sedimentary beds inclining at various angles and in different directions from its sides. The aggregate inclination of the strata is plainly to the eastward, and the gentle slopes are on the east side of the range, while on the west the sides are very abrupt, and in some instances the rocks overhanging, so that the general form or outline of the Park range would indicate that it might be regarded as a portion of an anticlinal.

All along the east side of the Park range are numerous gorges, which extend down from the crest and gradually expand out into moderately wide grassy valleys. Immediately after leaving the gorge, however, the drift-material is very great, covering the valleys and lying high upon the mountain-sides. These gorges usually commence near the water-crest in a somewhat extended amphitheater, which is constantly enlarged by the breaking down of the sides. These gorges all point to a common origin, and have no doubt been carved out by the combined action of water and ice. The morainal matter brought down by the old glaciers is shown most abundantly in the lower portions of these gorges as they expand out into the valleys that open into the plains. The evidences of ancient glacial action are quite abundant all through the Park range, but far more remarkable proofs are found in the Sawatch range. These facts will be noted more fully in another place.

From Fairplay we follow up the valley of the South Platte for ten miles, and arrive at the base of one of the spurs extending from Mount Lincoln, known in the country as Mount Bross. The entire mountain is so thickly covered with surface-deposits that the angularities are smoothed off, and the grass and flowers are quite abundant almost to the summit. We find, however, on the summit, and around the sides of the upper portion, remnants of the sedimentary beds, quartzites and limestones, but the nucleus is a schistose granite. Silver-mines are opened everywhere on the sides both of Mounts Bross and Lincoln. On the latter peak there are mines of considerable value, which are wrought by a company, full 14,000 feet above the sea and within a few feet of the summit. The Montezuma mine is located within 100 feet of the top. The silver-ores are confined mostly to the limestones and quartzites, and are segregated, as it were, in the fissures in the most irregular manner. There seem to be no regular lodes, but they are like the silver-mines in the limestones and quartzites of Utah. Indeed, the formations are so similar that a description of one locality would apply substantially to the other. The mountain is composed mostly of schistose gneiss, with the lines of bedding very distinct, and unconformably upon it rest the secondary beds. The quartzites, mostly crystalline, partially changed by heat, rest on the edges of the schists, then comes a blue impure limestone full of pockets and seams of quartz. Above comes a thick bed of quartzites again, the whole mass a thousand to fifteen hundred feet in thickness. The summit of the mountain is a dike of porphyritic granite, which seems to have burst up in the form of a wedge through all the sedimentary beds. The sides and summits of the mountain are so covered with the broken masses of rock, mingled with igneous, granitoid quartzites and limestones, that it is very difficult to obtain a clear section. On the east side of the mountain a sort of gorge has been worn deep down between Bross and Lincoln, exposing in the vertical sides the order of superposition quite clearly.

The view from the summit of Mount Lincoln is wonderful in its extent. To the east, far distant, is distinctly seen Pike's Peak, with the contiguous ranges which border the east side of the park and extend northward toward Long's Peak, all of which are granitoid. On the west and northwest side of the park is a vast group of high mountains, gashed down on every side with deep gorges with vertical sides, revealing the strata of quartzites and limestones resting on the schists with dikes of the trachyte. To the southward can also be seen the granite nucleus, a remarkable range of mountains, the Sawatch, which, with its lofty peaks—among them Mounts Yale and Harvard—looms up like a massive wall, with a wilderness of conical peaks along its summit. To the east and southeast the park lies spread out to the view with its variety of low ridges and meadow. These ridges are composed of all the sedimentary beds uplifted known in this region. Some of them, covered with basalts, with a trend nearly north and south, extend in regular order far across the park, eastward. From the top of Mount Lincoln more than fifty peaks rising to an elevation of 13,000 feet and upward, and above two hundred over 12,000 feet, can be seen. Probably there is no portion of the world, accessible to the traveling public, where such a wilderness of lofty peaks can be seen within a single scope of the vision.

The limestones and quartzites incline down the north slope of Mount Lincoln to Hoosier Pass, which separates the waters of the Platte from those of the Blue River. The trend of the curious dike that caps Mount Lincoln is about southwest and northeast. Silver-ore occurs to a great extent in pockets, some of which is very rich, yielding $500 to the ton. Much of it is the decomposed carbonate, like the gulch-ores.

On the east side of Mount Bross is located the Moose mine, which has yielded a large amount of valuable ore. The greater part of the ore is taken from the limestone. Before going further I will state what I believe to be the age of all the limestones and quartzites which seem to cover the highest mountains, and in which most of the valuable mines are found. I think there is no doubt that they belong to the Potsdam group, though I was unable to discover any fossils. Doctor Peale found a few obscure forms which indicated that the group is of the same age as those next to the granites in Utah, which we now know are of that age. In Mosquito Gulch we find the sedimentary beds dipping southeast 20° to 25°, and toward the head of the gulch the schists incline 15° in the same direction. There are most remarkable faults by which the mass of sedimentary beds are dropped down 200 to 400 feet directly, so that the schists jut up against the limestones or quartzites; these faults are very common. The underlying metamorphic rocks are made up in part of quartzitic sandstones, full of rounded pebbles of quartz, which would indicate that they might belong to the Laurentian series. The slides in this gulch are a prominent feature. Immense masses have slidden down from the sides of the mountain, in some instances a thousand feet or more, forming irregular terraces. The faults are really very remarkable on both sides of the gulch. The slides produce broad depressions near the base of the walls, in which the waters accumulate, forming lakes, and these are the sources of the little streams. The hundreds of gorges which have been carved deep down into the sides of the mountains form channels for the little streams that are fed by the melting of the snows near the crest. All these little streams eventually uniting form the larger streams that traverse the plains. Each one of these little branches starts from one of these small emerald lakes, far up in the amphitheater, near the very water-divide. Thus we can see that the miniature lake is a prominent feature of mountain-scenery, and from the summit of some high mountain-peak hundreds of these little emerald lakes may be seen nestled high up in the very head of the gorges. They are not large, varying from 100 feet in diameter to half a mile or a mile; seldom more. On the summit between Mosquito, Birdseye, and Evans Gulches, broken masses of the quartzites and trachytes seem to have moved down a considerable distance from their places, and are deposited in the form of windrows, as if there had been glacier movements here. It is undoubtedly due to the combined action of water and ice, so that there was a slow movement of the masses of ice and snow down the slope, and in gradually melting left those singular rows of rock. At the head of Evans Gulch there is a fine exhibition of a dike parallel with the strata in a nearly vertical wall 2,000 feet high. The quartzites and limestones pass beneath 1,000 to 1,500 feet of trachyte. The latter present the appearance of having been elevated with the stratified rocks, and incline in the same direction. The dip of the trachyte is 10°, and the underlying limestones and quartzites about 10° to 15° southeast, then about 1,000 to 1,500 feet of the quartzites and limestones. There is here a portion that inclines in an opposite direction, west, toward the Arkansas, but this is probably caused by the sliding down of the mass. The drainage of Evans and Birdseye Gulches flows into the Arkansas. Great masses have fallen down on the sides of the mountain, so that prodigious faults occur everywhere, and the form is that of irregular steps. Although examinations were made here in midsummer, yet the sides of the mountains were covered with little streams of water fed by the melting of the snow, and the great loose masses of superficial earth and fragments of rock moved slowly down the slope like a glacier.

One of the peculiar geological features in this range is the trachytic beds, which appear to be interstratified with the older sedimentary rocks. These igneous layers vary much in thickness, and appear or disappear, reach a thickness of 1,000 feet or more, and diminish in a short distance to a few feet, or disappear entirely. And yet, upon the outcropping face of the great uplifted ridges, or in the deep gulches where not unfrequently 2,000 vertical feet of rocks are shown in their order of superposition, these trachytes seem to have flowed out over the surface of the Silurian quartzites, or, in other words, are interstratified among the old Silurian limestones and quartzites, as if they might be of the same age and have been elevated with them. It is probable that they are not older than the Tertiary period.

On the summit of the pass or divide between Mosquito Gulch and Evans Gulch, where the great vertical walls which face the Arkansas are so well shown, we have several hundred feet of the quartzites inclining at a small angle, and resting directly on a great thickness, 800 feet at least, of unstratified trachytes. At the base, resting on the schists, are quartzites with micaceous sandstone; pudding-stones, made up of rounded pebbles of quartz, passing up gradually into a yellow arenaceous limestone, then into a blue limestone rather cherty, then up into a brown quartzite upon which the trachytes rest. This peculiar structure includes all the prominent peaks of this range, extending in a nearly north and south line from Buffalo Peak, south, to Quandary, north, and I know not how much farther. There are so many points dependent on the completion of the topographical maps, and the detailed reports of the assistant geologists, that these preliminary reports must necessarily be very imperfect. The summing up of these detailed and preliminary reports, which must constitute our final labor, will unite the whole work, the same as the great preliminary triangulations link together into one whole the detached topographical districts, on the final map.

An examination of the map will show the water-divide between the source of the South Platte and its branches and the Arkansas. Each one of these little streams cuts a deep gorge from the crest down 1,000 to 2,000 feet, with more or less vertical walls on either side. Nearly all of these gulches, or gorges, have been worked for gold, and the mountains prospected for silver; thus the miners have given them local names the origin of which is in most cases obscure. The superficial deposits have been in many cases almost entirely worked over by the enterprising miner for gold. Placer-mining all over this region has yielded great and brilliant results, but of course they can never be of a permanent character. All along the west side of the Park range, from Quandary Peak to Buffalo Peak, we pass from one gulch to another in quick succession; each one of which has employed the enterprising miner to a greater or less extent in search of gold. Not less so the east side; but we will follow our line of travel, examine the west side for a time, and then return to the east slope again.

One of the most noted of the mining gulches in Colorado is the California Gulch. About four millions of gold have been taken out of the placers. There are a few parallel lodes that run about 10° west of south and east of north. Three of the lodes would average about 10 inches between walls. The Five-twenty lode has been worked to the depth of 125 feet and 200 feet in length. The Pilot is a "chimney" lode, and is sometimes 80 or 90 feet wide, then closes up and disappears. About $40,000 of gold has been taken from it. Many of these lodes spread out in every direction in small branch seams, and lines of fracture run in every direction, filled with ore, occasionally very rich. Sometimes these branches will come together in one lode and again spread out, thus becoming a great source of perplexity and cost to the miner. The Printer Boy is probably the most valuable lode in this gulch, and has yielded rich results to the company. It is managed by two very polite and intelligent gentlemen, Mr. J. Marshall Paul, formerly of Philadelphia, and Mr. Charles Hill. This lode has now been explored for a horizontal distance of 3,000 feet. The width between the walls varies from 4 feet to 10 or 12, but sometimes pinches up to not more than an inch. The group is mostly decomposed clay with now and then masses of quartzite. One hundred and twenty thousand dollars of gold have been taken out of this lode, which inclines about 6° to the west. Carbonates of copper and lead, iron pyrites, zinc blende, &c., are found. The walls are remarkably well defined. Up to this time only the decomposed ore has been taken out. There is connected with this mine a successful 15-stamp mill, to which 10 stamps more are to be added. It is supposed there that the yield of gold will be $1,000 per day. In California Gulch, as in all the other gulches, the drift material is very great and entirely local. Trachytes, quartzites, and some limestones compose the rocks; the iron ores are abundant, and in the lodes there is much iron pyrites. The vast amount of the oxide of iron, mingled with the loose detrital deposits, gives character to them. The clays have an intense rusty-yellow color, and the broken rocks and pebbles are often cemented together into a conglomerate. The oxide of iron covers and permeates all the superficial deposits, which are very thick. These thin out toward the head of the gulch, but thicken down to the expansion of the gulch into the Arkansas Valley.

At the head of Stray-Horse Gulch a very valuable iron mine has been opened. The stray masses of hematite that cover the surface, mingled with the drift, are abundant, but the detached masses from the mountains cover the lower portion of the slope to such an extent that, even in the channels of the little streams, it is difficult to find the basis rocks. The prospector followed the float-ores up to a certain elevation on the side of the mountain, and where it ceased to appear he sunk a shaft and found the vein at no great depth. This vein is well shown in places in Iowa Gulch, extending directly across the strata in a direction a little west of north and east of south, and here it is at least 100 feet in thickness. It appears high up in the south wall of the gulch, so that its relations with the other rocks are apparent. The vein is at least 100 feet in width, and must have been segregated in a great fissure passing down through the quartzites into underlying schists. It must extend along the sides of the mountain for several miles, for the distance from the opening near Stray-Horse Gulch and Iowa Gulch is about six miles. This indicates a vast body of iron ore in this region. The iron-ore bed trends about north and south, and extends down nearly vertical through the quartzites. The iron ore is said to carry gold enough to pay moderately. Excellent galena, carrying silver, is found in the quartzites near the iron vein.

On the south side of Iowa Gulch there is an immense accumulation of trachyte, gneissic, and quartzite bowlders, the former predominating. The quartzite has fallen down from the north side of the gulch, while the gneiss has been brought down from the head of the gulch by glacial action. In the side of Iowa Creek we find the blue limestone lying over the speckled trachyte, quite compact, without lines of bedding, and much changed, showing the effect of the igneous rocks below. We can see here that the igneous rocks must be of comparatively modern origin, and must have been intruded between the strata, forming a conspicuous agent in the uplift.

At the head of Iowa Gulch, on the south side of the stream, the massive granites rise up 1,000 to 1,200 feet, with a cap of the quartzites. It is from this exposure that the great masses of granite scattered over the lower portion of Iowa Gulch were derived. At the head of the gulch the strata are greatly faulted. The varieties of texture in the granites are numerous, and it appears more massive and older than any before seen in this range. It is much broken by irregular jointing, but no lines of bedding can be seen. The great amount of broken masses, most of them more or less rounded, which are scattered over the sides and bottom of these gulches, is marvelous. There is less of this glacial evidence in the California Gulch than in any of the gulches on either side. This granite nucleus, or uplift, seems to extend across the heads of the gulches in a north and south course, while the streams that flow down the west side of the range cut through this granite nucleus and have their origin in the stratified rocks that incline from the east slope. This, however, is not an uncommon occurrence. There is a constant tendency in these mountain-streams to wear these gorges back beyond the true axis on either side. Each one rises in a sort of amphitheater which has been formed by the breaking down of the sides of the gorges by the water and ice in the fissure, and the melting of the snow sweeps the fragments slowly down into the gulch. This gnawing process, as it might be called, at the mass of the mountain has been going on for ages, so that in many places the crest is a single sharp ridge between the amphitheaters on either side. In many places this crest is worn through, and many of the low passes were once high walls wholly inaccessible.

The great mass of sedimentary stratified rocks of which this range is largely composed inclines away south of east from this granite nucleus, showing clearly its anticlinal structure. The granite, as seen in Iowa Gulch, is a true "wedge," the quartzites capping the summits inclining in opposite directions, a portion dipping west at an angle of 10° or 12°. Although, in general terms, many of the mountains are illustrations of the single wedge structure, I have never seen a clearer exhibition than this, where the granite is capped with the quartzite strata, and the eroding agents have sliced it down vertically, so that the relations are seen perfectly. The amphitheater at the head of Iowa Gulch is about 10,500 feet. In passing over the crest into Horseshoe Gulch we are obliged to climb an almost vertical wall for 1,500 feet. Resting upon the granites at the bottom are about 200 feet of quartzites distinctly stratified! Above the quartzites are 800 to 1,000 feet of unstratified sombre-gray porphyritic trachyte, breaking off in vertical columnar masses. Over the trachyte comes quartzite and arenaceous limestone, passing up into about 50 feet of very cherty, partially metamorphosed, limestone, in which the galena mines are located; above this are alternations of quartzites with beds of limestone, 2,500 to 3,000 feet in the aggregate, in the range. The summit of the divide is about 12,500 feet; the high peaks, north or south, rise upward of 13,000 or 14,000 feet. The summits and sides of the range are covered with fragments or *débris* of broken trachyte mingled with quartzites, the former predominating.

At the head of Empire Gulch the granites rise up nearly to the summit, while the stratified quartzite cap only the highest peaks of the Horseshoe and other cones in the vicinity. The quartzites here are very hard, but brittle, breaking into small fragments greatly metamorphosed, though distinctly stratified, and remind one of the quartzites of the Uintah Mountains. Below the massive quartzites are very hard limestones, out of which considerable quantities of silver-ore are taken. Below the limestones are 50 to 80 feet of a peculiar rock, composed largely of yellow jasper. The dip of the strata in the north branch of the Horseshoe is about 21°, and in the Horseshoe itself about 19°, north of east, though it is quite variable. The Horseshoe is a most singular mountain-form. The excavation here has wrought out a circular or semicircular form, which suggested the name of Horseshoe Mountain. On the south side a ridge runs down the gorge-like valley for four miles, with an average dip of 13°, and then a high mountain occurs, in the base of which the gneiss projects up 500 feet, while on the east side and on the summit the lowest quartzites are again seen in contact with the gneiss. The most remarkable faults in the strata occur here. In the carving out of the Horseshoe amphitheater the granitic schists are exposed at the bottom, and continue down for a short distance, when they are concealed by the *débris*. Only the stratified beds are seen in the walls of the gulch on either side. Here and there the schists rise up to considerable heights. The sedimentary beds may rest on the schists lower down in the valley, or on the high peaks 2,000 feet above. The remarkably irregular surface of the underlying schists is hardly due to erosion prior to the deposition of the sedimentary rocks, but to the internal forces that have thrown all the rocks in this region into such a remarkable chaotic condition. We do not find here the intruded beds of trachyte on quite so large a scale as on the west side of the range. The trachyte, however, shows itself about four miles below the depression of the Horseshoe, changing all the rocks to a greater or less extent with which the igneous material comes in contact.

This gulch has really three heads, of which Horseshoe forms the middle. The evidence of the gradually slow excavation of these amphitheaters is well shown in each. That the wearing out of the depressions may have been more rapid in former times I do not doubt; perhaps, during Glacial or Post-Glacial times. We shall hereafter discuss the subject of the great Glacial period, which must have held sway over all this region. Ice, snow, and water are still important agents, though their action is slow and the results hardly perceptible in a century. It would be difficult to fix any very definite angle of inclination for the stratified rocks. Sometimes it is nearly horizontal, and again nearly vertical. In the Horseshoe district the dip will vary between 12° and 25° generally. A typical section of the sedimentary rocks in this region may be found in the gulch to the south of the Horseshoe. The strata which rest upon the schists there present a nearly vertical wall for about 800 feet. The schists as they occur in the bed of the stream appear to be vertical, with grayish brown quartzites resting directly on the edges, passing up into a cherty limestone. This is quite variable in texture, though the jointage and lines of stratification are clear. On the southeast side of the gulch, at the very head, there is a massive wall of quartzites and limestones 800 feet high; then comes a bed of intruded porphyritic trachyte, about 400 to 600 feet thick, and above this comes 300 feet of very hard dark brown quartzite, evidently partially metamorphosed. Then comes an interval, obscure on the surface, but composed of a dark slaty shale, with layers of dark impure limestone. There are alternate beds of limestone, quartzite, sandstone, and shale through what I estimated to be 1,500 feet of Silurian strata, and 2,000 feet of Carboniferous beds. The upper portion of the latter is nearly all coarse, rusty, or gray sandstone, while the lower half contains many beds of shale, with layers of limestone containing great numbers of well-marked Carboniferous fossils, as *Trilobites* and *Productus*.

In the Silurian group the first bed of trachyte is quite massive, and must correspond with that seen on the west side of the range. The jointage is perfect, and the mass breaks into huge cubical blocks. Some of it is laminated vertically, as if composed of thin layers tipped on end. Higher up are several beds of the trachyte, varying from 15 to 30 feet in thickness. It was not possible to fix a line between the Silurian and the Carboniferous groups, in most instances. I shall only speak of these formations in general terms, referring the reader to the carefully-wrought section in Dr. Peale's report. As a general rule, it is only at the very heads of these gulches that the basis rock can be seen. The process of grinding to powder, as it were, by ice and water, has been carried on to such an extent that the entire valley is covered thickly with earth, filled with more or less worn rocks, of every size, from that of a pea to several feet in diameter. The snow, melting upon the crests of the mountains, saturates these superficial earths with water, and they slowly move down the gulch much like a glacier. This is another process of grinding the underlying rocks, smoothing and grooving them. Underneath these superficial deposits is what the miners call the "bed-rock," and it often involves immense labor to strip them off to reveal the mineral lodes.

As we pass down Horseshoe or Four-mile Creek we soon find that the vast amount of loose material covers everything, rendering the succession of strata very obscure above the Carboniferous, yet we know that there is a full series of the red beds, Jurassic and Cretaceous, up to the summit of the Lignitic group, inclusive. The upper group inclines away from the base of the main Park range far eastward into the Park. Passing northward from Fairplay to the Little Platte or Twelve-mile Creek, we find the foot-hills correspond to the more modern sedimentary beds, inclining at all angles. In the channel of a little stream, about ten miles south of Fairplay, the Triassic and Jurassic beds are exposed to some extent, dipping 30° to 40° east or southeast. The foot-hills all along the west side of the Park appear to be composed mostly of the red group, lapping on to the sides of the mountain. The Carboniferous and Silurian groups are seen on the sides and summits, higher up. A few of these details will afford us a glimpse of the wonderful complication of forces that have thrown these mountains into chaos, as well as the tremendous power of the eroding agents which have aided to increase the difficulties in some localities and to decrease them in others. As we move westward to the Sawatch range, or the Elk Mountains, we shall meet with a repetition of the same results, only on a far grander scale.

South of Horseshoe Mountain the main range continues 12,000 feet and upward to Buffalo Peak, rising far above timber-line. The rocks are mostly granitoid, but there are remnants of the quartzites even on the crest; but rather low down on the sides, perhaps 1,000 feet below the crest, the Silurian limestones and quartzites crop out here and there, though much obscured by the *débris*. In the valley of the Little Platte, close to the foot of the mountains, is a considerable thickness of a group of very peculiar gypsiferous strata, the same as those around the salt-works about twelve miles to the southeast. The surface has a volcanic appearance, as if covered with slag, and yet the clays, sands, and other rocks of both the Cretaceous and Jurassic are incrusted with the chloride of sodium as well as the sulphate of lime. Again, on the north and east side of Buffalo Peak the unequal elevation of both the granites and the sedimentary rocks is apparent. They may be seen here in contact at the base of the Peak, or near the summit, 2,000 feet above the base. Twelve-Mile Creek rises near Weston's Pass, flows for a short distance, about six miles, east of south, then bends so that the course is a little south of east after emerging from the range. The deep gorges are very numerous, and seem to be carved out of the massive granites, presenting on either side remarkable sections.

The crest of the divide at the head of the south branch of the Little Platte presents a fine view of the valley of the Arkansas toward the west, with the grand range of the Sawatch on the west side, like a gigantic wall, with its wilderness of peaks, upward of 13,000, and many of them over 14,000 feet. Nestled at the base of the Sawatch, at the mouth of the Lake Creek gorge, are the beautiful Twin Lakes, separated from each other by a belt of morainal deposits only about 200 yards wide. To the southeast may be seen distinctly the ranges about the San Luis Valley, with Ouray and Uncompahgrè Peaks rising far above all the rest. To the east we have the South Park full in the foreground, looking like an immense meadow. The ridges which run across it in different directions are softened down by the distance. Pike's Peak, with the ranges of mountains on either side, shuts off the vision from the broad plains beyond; it rises so far above the rest that it becomes a most important landmark for a radius of fifty to eighty miles in every direction. To the northeast and west is the splendid group of peaks of which Mount Lincoln is the crowning one; while to the northwest are the sources of the Arkansas with the Tennessee Pass and its associated ranges of mountains. The Blue River range can be seen dimly beyond. Such are the geographical features of this remarkable region, and I describe them from time to time, to convey to the reader the fact that the variations are kaleidoscopic, and from every important mountain-peak a fresh and equally grand view may be obtained.

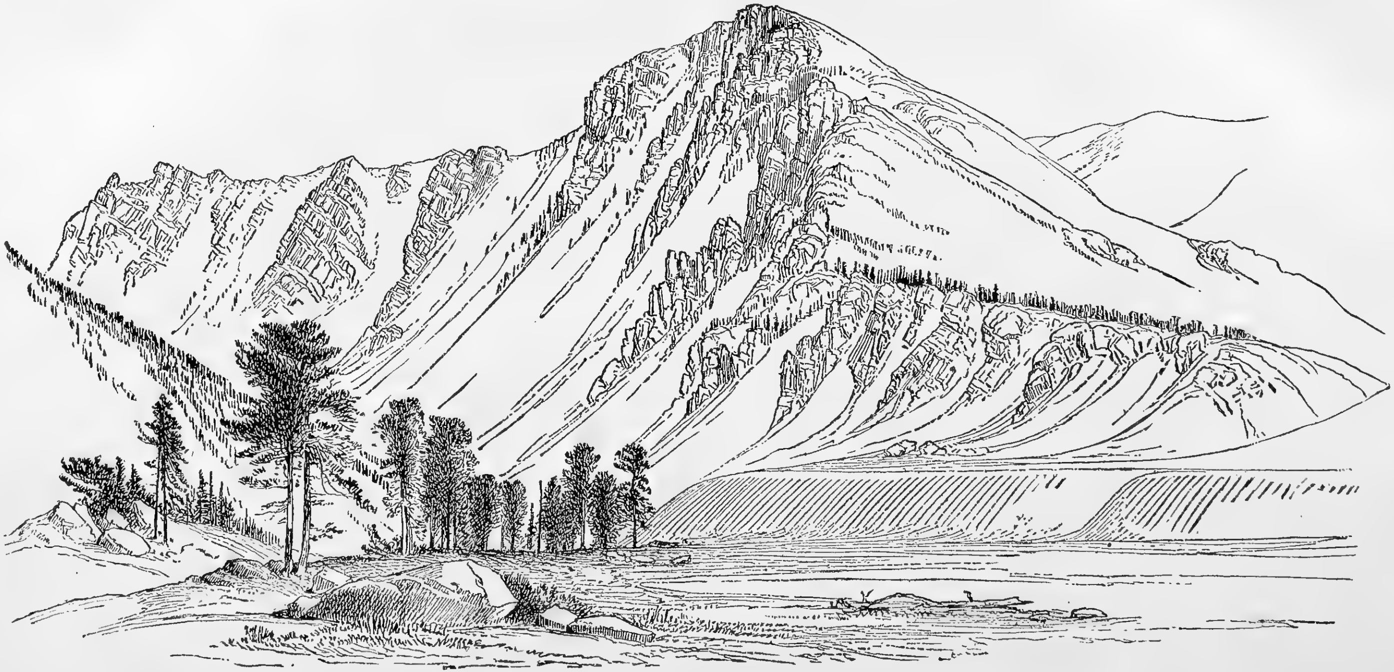
As I have before stated, it is my belief that the range of mountains on the west side of the South Park is a portion of a grand anticlinal of which the Sawatch range is the central mass or axis. Therefore the general inclination of the great body of the rocks of the Park range is eastward, metamorphic as well as sedimentary. On the east side of the crest the dip of the strata is obvious, and the granitoid nucleus is exposed in comparatively few places, except in the gorges, where the eroding forces have cut deep down through the sedimentary beds into the schists. But on the west side the granites are visible everywhere, while the sedimentary rocks are the exception. The action of two forces are indicated in this range; one which acted uniformly and slow, elevating the vast series of North and South ranges from the plains on the east to the Colorado River, and perhaps farther, and a second force operating synchronously, but probably spasmodically, tossing the granites as well as the sedimentary group into chaos. The one acted in long lines of fracture, forming regular anticlinals with the stratified groups, inclining from either side of the central axis in regular order; the latter bringing to the surface the igneous rocks, and producing those wonderful faults of which we find so many illustrations in the Park range. The general form of this range also reveals its anticlinal character, through the fragments of the sedimentary groups which have broken down from the crest on the west side. In the California Gulch, and to some extent in other localities, the igneous rocks have been poured out over the mountain side covering both granitic and sedimentary beds, but the granitic rocks predominate, and all others occur only in detached portions that seem to illustrate a series of remarkable faults.

The Arkansas Valley, from its head in Tennessee Pass to the point where the river cuts through Front range and opens out into the plains, has been worn out of the granite mass to a great extent. The valley is partly a fissure, but is mostly due to erosion. The drainage was undoubtedly started by the fissures produced by the great uplift, but, as broad and deep as it is, it is undoubtedly due mostly to erosion, and by this illustration we may form some conception of the work of this powerful agent in giving form to the surface of this mountain-region. From the crest of the Park range across the Arkansas Valley to the crest of the Sawatch the distance will average from ten to fifteen miles, in a straight line, and the average elevation above the water-level of the Arkansas River must be about 1,500 feet. Now, it is probable that three-fourths of this vast space from the Tennessee Pass to the Poncho Pass, near the head of San Luis Valley, a distance of one hundred miles, has been worn out by erosion, and the greater portion of the material carried down the river and distributed over the plains. It is probable, also, that this great space was at no very ancient period filled with one vast glacier, which doubtless performed the greater part of the grinding up of the rocks and the wearing out of the valley. The glacier-worn sides of the mountains on either side of the valley extending nearly to the summits, the remarkable morainal deposits in the main valley and on the sides of the gorges, point strongly to that conclusion. We hope in the succeeding chapter to describe more in detail the phenomena of ancient glacial action, which is so admirably shown on both sides of the Sawatch range.

The remarkably rounded and grassy appearance of these high mountain-ranges in many instances is quite surprising, and we ask how so great a thickness of superficial earth could have accumulated so far above timber-line? Besides, this drift-like deposit is covered with masses of rock of various sizes, more or less worn, mostly granitic, and mingled with the finer materials are numerous bowlders, so that there must have been some agent that acted quite generally in grinding down the surface. All along the west side of the Park range the granite rocks crop out, but from a point opposite Tennessee Pass to Buffalo Peak this old glacial deposit covers a great portion of the surface. When the underlying or basis rocks do crop out to any extent the abrupt side faces west toward the Arkansas, and the gentler slope is toward the east, so that even the granitic nucleus testifies to the anticlinal character of the range. This is very well shown on the west side of Buffalo Peak, and southward where the granitic rocks rise in high, conical peaks, with the abrupt, wall-like face to the west, and sometimes even overhanging at the summit. The heavy snows that fall on these mountains, melting in the spring, thoroughly saturate these surface-deposits, and great masses become more or less movable, depending upon the steepness of the slope. The degradation of the underlying rocks is constantly going on, and the movements of the great masses of earth produce results much like those of a glacier.

About five miles below the mining town of Granite the upper valley of the Arkansas begins gradually to expand in width. Terraces have been formed on either side, which show the former existence of a lake. It is most probable that the lake-waters set high up the Arkansas River, even to its source; but the greater portion of the waters were gathered into the lower part. By Upper and Lower Arkansas I mean the portions above or below the cañon. In the lower portion of the Upper Arkan-

Fig. 9.



East side, granite anticlinal, Upper Arkansas Valley.

sas I described, in my third annual report, for 1869, a group of light-colored marls, 800 to 1,200 feet in thickness, under the name of Arkansas marls. I then regarded them as of Pliocene age, and noted their inclination as 3° to 5°, which would imply that they were deposited before the great Sawatch range had reached its present height. It is plain that at a period comparatively modern in date there was a lake here at least forty or fifty miles in length, and from five to ten in breadth, and that in the lower portions several hundred feet in thickness of fine sediment were deposited in moderately quiet waters. The numerous little streams that flow from the Sawatch range toward the Arkansas cut deep channels through this modern deposit. The quantity of rounded bowlders of various sizes in the vicinity of these streams is immense. Even after the lake-waters had passed down the Lower Arkansas, through the cañon, there must have been tremendous glacial as well as aqueous forces operating from the deep gorges in the mountains, transporting a vast amount of drift material into the valley. Just how much of this broad expansion is due to erosion it is difficult to determine, but I am inclined to the belief that there was originally only the fracture of elevation, and that the old lake-basin is mainly due to erosion. On neither side of the valley do we see any of the older sedimentary rocks. From Poncho Pass to the very source of the Arkansas, a distance of 80 miles, no rocks but Igneous and Metamorphic can be seen upon the east side.

The Sawatch range is one solid mass of granite, intersected to a greater or less extent by dikes. If we follow any of the little streams that flow from the range on the east side, up to the sources of Trout Creek, for example, just before reaching the borders of the South Park, we shall find the full series of the sedimentary rocks, from the Silurian, resting on the granites, up to the Cretaceous, inclusive, at least, inclining in an easterly direction. The tendency of the waters of the Arkansas River was to gravitate to the extreme eastern side of the valley, from the slope given by the anticlinal character of the elevation. The abruptness of the east side of the granite rocks on the east side of the valley, from one end to the other, shows the part which they sustained in the uplift. From a point about two miles below the mouth of Pine Creek the Arkansas River flows through a very narrow, tortuous channel, with the granite rocks of a great variety of texture projecting over the base in some instances, and rising in a precipitous wall a thousand feet high. Below the mouth of Trout Creek the eastern portion of the anticlinal becomes the Front range. I have dwelt so long on this great anticlinal because it constitutes the key to the physical structure of a great area, and also because it will throw much light on other portions of the Rocky Mountain region. It seems to illustrate a statement that I have often made, in previous reports, in regard to the simplicity of the structure of the eastern portion of the Rocky Mountain region.

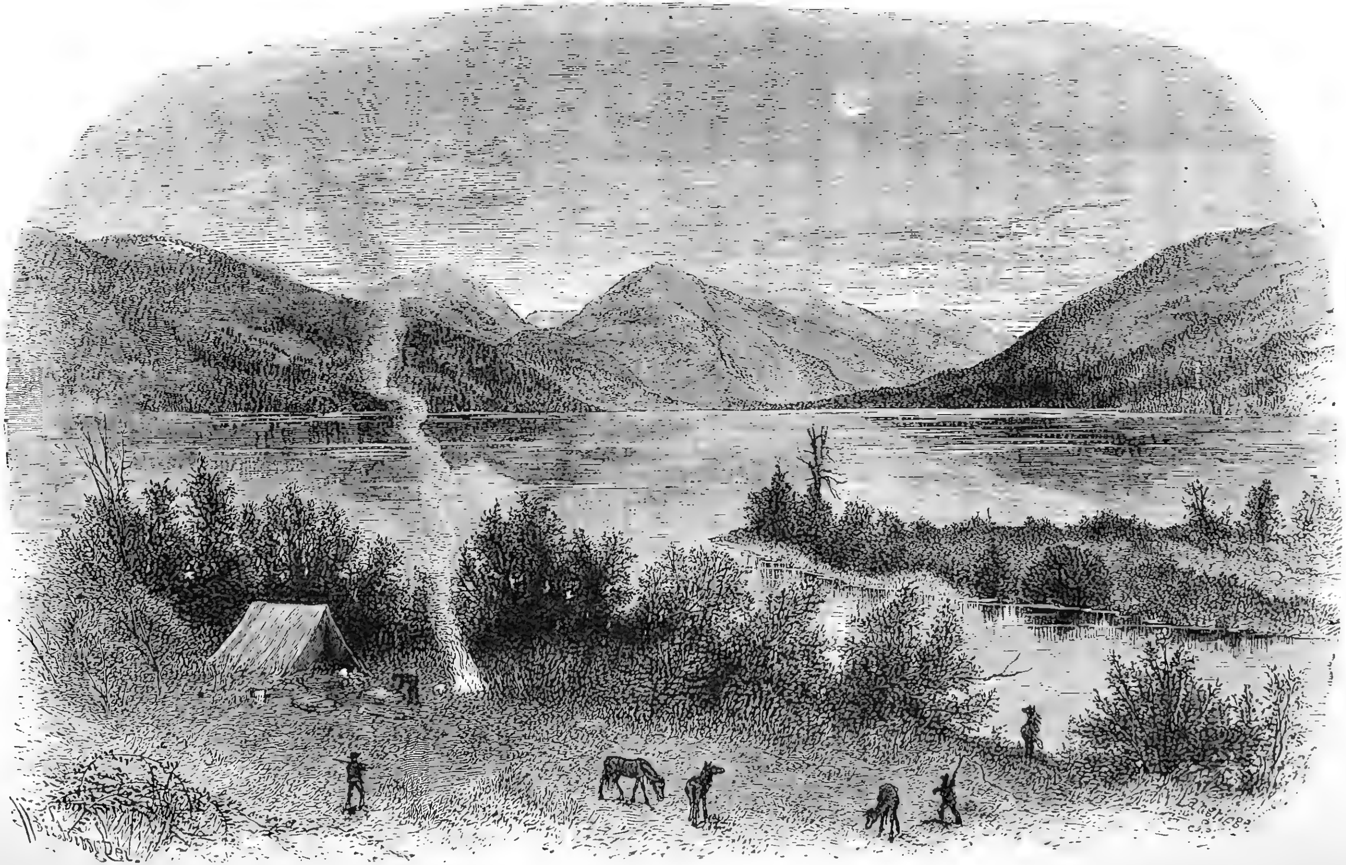
In general terms, while the details are extremely complicated, we may express the structure of a belt of country known as the Sawatch range, eighty miles in length from north to south, and at least forty from east to west, as a single wedge of granite, thrust upward, and the sedimentary rocks inclining from either side. The illustration of which the Sawatch range is the central mass is probably on a grander scale than any other in the West, but there are abundant examples of smaller size. The Black Hills of Dakota, the Laramie range, Big Horn, Wind River, and many others are of the same type.

Our last movement, July 22, was along the divide from Weston's Pass to the base of Buffalo Peak. We have described the splendid view we obtained of the entire Upper Arkansas Valley, from the Tennessee Pass to the cañon, a distance of eighty miles. Our camp was on the north base of the peak, above timber-line, at the very sources of some of the little branches of the Platte. The granite rocks cropped out all around us, although the greater portion of the surface was covered with grass, and the moist valleys were peculiarly fresh and green. The lower portion of the Upper Arkansas Valley is indeed a park, and far more beautiful, though not so large as the South Park; but its origin is very different. The South Park is an area of depression, that is, it is a basin surrounded by lofty ranges of mountains, underlaid with rocks of the sedimentary group, which shows that it has never been elevated equally with the surrounding mountain-ranges. The Arkansas Park is an area of upheaval and erosion, and nowhere in it are any sedimentary rocks exposed older than the modern lake-deposits. A few small streams flow into the Arkansas River from the east side, but the main drainage is from the west side. Descending into the valley on the west side of the Park range, from the base of the Buffalo Peaks, we found the traveling very difficult; the sides of the mountains covered with *débris* and very precipitous. The fallen timber adds also much to the labor of traveling. The autumnal fires sweep over the sides of the mountains, killing the pines, and the winter and spring winds lay them down in every direction, forming a perfect net-work. Reaching the valley nearly opposite Mount Harvard, we camped for two days on the bottom to make a study of this interesting region. By following our route of travel in our narrative, we are enabled to note down the local details of the geology from point to point, on which any general remarks we may make are founded. The maps, which will soon be published, will enable the geological reader to follow these routes with ease; and, in connection with the sketches and sections, we hope to make our observations clear.

The point from which we will start now on our march up the Arkansas River is at the head of the Arkansas Park, a little below the mouth of Pine Creek. The valley here begins to expand out somewhat, and is about half a mile in width. There are several abandoned farms on the bottom. Lower down in the main park, or valley, are some excellent farms and prosperous settlements. The decline of the mining interest has caused the upper portion of the valley to be almost entirely deserted. A few years ago there were many thousands of miners in the valley, and every gulch was filled with placer-diggings. Granite bid fair to become a city and spread itself over a considerable area on both sides of the mines. Now the buildings are all fast going to decay. A few miners still linger among the old "placers," but the mining period has passed away.

I have spoken of the finer sediments which were deposited in the ancient lake, in the lower portion of the valley to the southward. The waters that rushed down from the north lost the greater part of their force in the broader, deeper waters of the southern portion. Here the fine material which was ground from the granite rocks by water and ice to the northward was carried, and the greater stillness of the waters then allowed it to settle on the bottom more quietly, forming a group of marly strata at least 1,200 feet in thickness, which have weathered into the peculiar architectural forms which characterize the modern lake-deposits farther north in which the remains of so many extinct vertebrate animals have been found. As we ascend the valley from the lower end, these lake-deposits become coarser and show evidences of deposition in more turbulent waters, until at the upper end the huge rounded bowlders predominate. Near the bridge about five miles below Granite are long, lone ridges of the coarse drift or detrital matter on

Fig. 10.



Upper Twin Lake, Colorado.

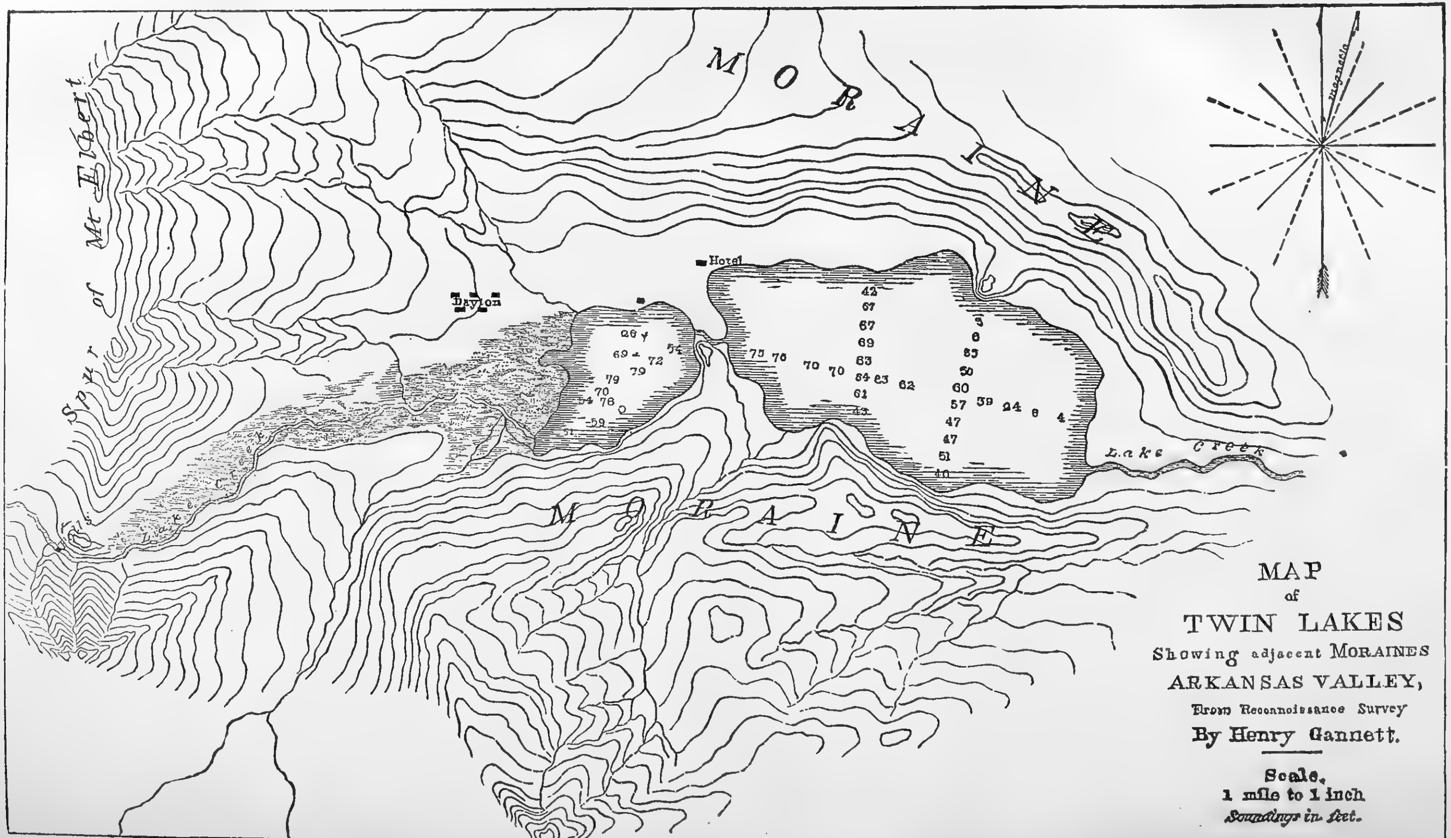
the bottom, parallel with the river. The surface is covered with huge granite bowlders on both sides of the river; long, high, rounded ridges of worn bowlders are piled up as if they had been left by the melting masses of ice. We find the granite rocks in place much worn as we ascend the valley, but no signs of grooving. The coarse texture of the granite permits them to disintegrate readily, and they have a tendency to become rounded by a process which I have termed exfoliation, or a tendency to peel off in thin concentric layers. This is a very common feature in most of the varieties of rock in the West, and the great variety of scenic forms, as well as much of the loose *débris* or soil in the mountains, is due to this process. Whenever the fires run over the sides of the mountains, burning the forests of pine, the most compact granite rocks scale off in this manner, and undoubtedly the sun's rays, expanding the surface by the heat, produce similar results. Just below the mouth of Pine Creek a high vertical point juts out from the east side of the Arkansas, over the river, of a harder texture and more compact than the contiguous rocks. The jointage, which is nearly vertical, presents strikingly smooth faces and sharp angles. The great variety of texture in the granitic rocks is continually shown, varying from a close fine-grained feldspathic or quartzitic mass, scarcely affected by atmospheric agents, to a very coarse aggregate, readily falling in pieces. Iron in some forms is a very powerful agent also in destroying the cohesion of granites. This hard point seems also to have extended across the river and to have resisted in part its power, so that falls, or rapids, of 25 feet descent have been formed. Just above this point there is a low ridge of granite, which in the wearing out of the valley escaped, while on the east side of the Arkansas there is an old river-bed. These remnants serve to indicate in some degree the nature and extent of the forces that have operated here. They prove that the valley is, for the most part at least, one of erosion. There is a narrow bottom on the west side of the river, with small gulches coming from the hills in which are quite extensive placer-diggings. Small log huts, or miners' cabins, are scattered here and there among the huge granite bowlders, presenting a unique appearance from their diminutive size, compared with the bowlders themselves.

Perhaps the most interesting and novel features of this region are the great morainal deposits, the remains of ancient glaciers. These proofs of glacial action occur everywhere along both the east and west sides of the great Sawatch or Mother range. But up the valleys of some of the side streams the morainal deposits are more marked and regular than in others. The finest illustration occurs in the valley of Clear Creek, a small stream that flows into the Arkansas River from the Sawatch range, about six or seven mills below Lake Creek. This little stream rises high up near the crest of the range, in a number of excavated amphitheaters, and flows for several miles through a close cañon until it opens out into the foot-hills on the east side of the range. The valley at once expands to about one-fourth of a mile in width, and at the junction of the creek with the main river has become three-fourths of a mile in width, with a detrital ridge on either side rising 300 to 500 feet above the little creek that meanders through it. These detrital ridges show the loose character of the deposits by their rounded forms, being covered over with grass and other vegetation. The question would arise, whether the immediate valley of the stream was originally filled up with the glacial detritus, or whether the materials composing these ridges were left on the sides of this branch of the great Arkansas glacier which must at one time have occupied the entire valley. I am inclined to think that the valley through which Clear Creek meanders so beautifully is a modern result, and was worn out of the great detrital mass by water after the close of the true Glacial period. Between the detrital walls in the valley are mounds or ridges of the detritus that has been brought down Clear Creek and lodged near its mouth. The last glacial movement was checked by the remnant of the granite mountain in place at the lower end of the expansion, and as the ice melted the *débris* was left behind in irregular mounds. Rounded masses of granite of immense size, 100 feet in diameter lie scattered about the mouth of this creek, now going to decay by the process of exfoliation. Between Clear Creek and Lake Creek the slopes are rather smooth, with the granite rocks cropping out here and there, but revealing the effects of abrasion in a marked degree. The surface is covered mostly with a thick deposit of the detrital matter. The placer-mines are very extensive over this area, and the working of them in several localities has exposed a glimpse of the old channels worn deep into the underlying granites and covered with the bowlder-drift. If this thick drift-deposit could be stripped off it would expose a granitic surface worn down by the movements of vast masses of ice and snow, perhaps grooved and scratched, and the entire area cut through from the mountains on either side with the old creek-channels. We believe, also, that this space between the main river and the base of the range, a width of about six miles, has been worn down from an elevation but little, if any, lower than the front portions of the range that now remain. All the evidence points to the existence here of aqueous forces at a comparatively modern period, of which the present is but an insignificant remnant.

On both sides of the Arkansas up to its very sources the drift phenomena are very remarkable, but much more extensive on the west side, so that there is a slope from the immediate base of the Sawatch range to the river; but the terraces and bowlder-deposits are well shown on both sides. On the west side the valleys of the mountain-streams are now much used for the pasturage of large herds of stock during the summer-season, the owners driving them south into the San Luis Valley during the winter.

By glancing at the map it will be seen that there are a considerable number of those little branches which run high up near the crest or water-divide of the Sawatch, cutting deep channels or gorges through the mountain-sides, and deep valleys after emerging into the slope, or foot-hills. The slope, or foot-hill, forms a peculiar belt from four to six miles in width between the base of the main range and the river, and in a general way slopes down to the river. The difference in elevation between the bed of the Arkansas and the junction of the slope with the mountain-side would vary somewhat, but must be 1,000 to 1,500 feet. Viewing this slope from the crest of the Park range on the opposite side of the Arkansas we can see clearly the gorges and gorge-like walls of the principal streams at intervals of a few miles apart. Between the main valleys the interval is singularly rolling, consisting of rather deep grassy valleys, extending down from the mountain-sides to the Arkansas, while between them are rounded ridges, or rounded oblong hills, covered over with *débris*. In many cases the abrupt sides are toward the mountains, and the sides and summits are covered with immense bowlders, as if the masses of ice had lodged on them, and melting had dropped their contents there. This furrowed condition of the surface continues to a greater or less extent up to the sources of the Arkansas in the Tennessee Pass. The great morainal ridges on the south side of Lake Creek are as much as 500 feet to 700 feet high

Fig. 11.



Spur of Mt Elbert
MORAINE
MORAINE
Dayton
Hotel
Lake Creek
Lake Creek
MAP
of
TWIN LAKES
Showing adjacent MORAINES
ARKANSAS VALLEY,
From Reconnoissance Survey
By Henry Gannett.
Scale,
1 mile to 1 inch
Soundings in feet.
magnetic

above the lakes or valley. For about fifteen miles the Arkansas flows through a gorge-like channel, commencing about four miles above Lake Creek, when there is a moderate expansion with quite a broad bottom, and on either side well-defined terraces. The terrace on the east side of the Arkansas rises about 500 feet above the river-bed. In a dry gulch the horizontal strata of sandstone crop out, showing that it is composed of the modern lake-deposit. On the west side the first terrace rises 40 feet, the lower portions of the second or main terrace 250 feet rising up, by a slope to the mountains, to the height of 700 feet. One gulch is quite wide, half a mile, as it opens into the valley of the Arkansas, with small, terrace-like steps on either side. The east fork of the Arkansas also presents a broad, open valley for some distance along its junction with the main stream. Passing up the west branch we find a broad, open, meadow-like park, a mile in width, with the granitoid rocks cropping out here and there on either side from beneath the great accumulation of detrital deposits.

We can see, therefore, that this entire valley of the Upper Arkansas was at no very remote geological period, a fresh-water lake, probably at the close of the glacial period. I am now inclined to think that this period extended back further into the past in the Rocky Mountains than geologists have accredited it in other regions. It seems to me that the evidence, though not clear as yet, points to the Pliocene era as its beginning, at least, and that it extended pretty well toward the present period. It was evidently a period in which powerful forces were in operation, which carved out the surface-forms much as we find them at the present time.

CHAPTER III.

SAWATCH RANGE—MORAINAL DEPOSITS OF TAYLOR'S CREEK—ELK MOUNTAINS, ETC.

We will now ascend the valley of Lake Creek, and wend our way over the great Sawatch range. The valley of Lake Creek is filled with the morainal deposits for which this range is so remarkable. It would seem that the great glacial force moved here in a direction a little south of east, inasmuch as the great mass of the detrital matter is heaped up on the south side. The two lakes are about 350 yards apart, with a small stream, perhaps 20 feet wide, flowing from one to the other. The interval is made up of worn detrital matter, but over it and around both lakes are mounds or oblong ridges of the drift. Scattered over the surface are masses of granite, coarse in texture, with crystals of feldspar, 1 and 2 inches in dimensions, aggregated together. The rock has the appearance of a feldspathic breccia. The lower lake is about two and a half miles in length, and one and a half miles in width. The upper lake is one mile in length, and half a mile in width. The bases of both these lakes are undoubtedly the result of glacial action. The greatest depth found by sounding was 76 feet. The accompanying topographical sketch of Mr. Gannett, with the soundings which were made by Messrs. Stevenson and Holmes, will convey a true idea of the form of these basins. We know by the land contiguous to both these lakes that they have been slowly diminishing in area. Above the Upper Twin Lake there is a half-mile in width of boggy meadow which at no distant period must have been covered by the lake. At the head of the valley, or where the gorge begins, there is a sort of natural bridge. The stream has worn a narrow channel through the rocks. At the summit the gorge is about 8 feet wide, and in it a huge bowlder has lodged. The stream rushes down its steep, narrow, winding channel with great force. On the north side there is a huge bowlder just ready to topple off into the channel, which is 50 feet in diameter. On the sides of the channel are several most remarkable rounded cavities worn in like pot-holes, 6 to 10 feet in diameter. One of them occurs 20 feet above the water-level of the creek at the present time. About 100 feet above the bridge the stream flows through a narrow gorge not over 4 feet wide, and the water shoots down as in a flume 10 or 15 feet, producing a picturesque effect. In these rocks the jointage is very distinctly defined. The dip of the rock is north about 30°, and the channel has been worn through the rock, so that the north side overhangs the water, and the water and ice, aided by the jointage, have removed masses like blocks from a quarry. There are two or three sets of master-joints which break the mass into a multiplicity of forms. Sometimes the broken portions are wedge-shaped. The rocks are a coarse, massive granite of a gray color, with large crystals of grayish-white feldspar. The worn rocks, or *roches moutonnes*, are most admirably shown everywhere, and portions crop out in the bottom of the valley to indicate the force as well at the extent of the erosion. It is quite possible that if all the *débris* could be stripped off the gorge and valley, the grooved or scratched surfaces would be apparent. On both sides of the gorge the worn rocks are seen to the height of 1,000 to 1,500 feet above the bed of the stream. One immense mountain mass on the north side seems to have resisted the eroding forces, so that from base to summit, a height of 1,000 feet, it is smooth like enamel. The vast glacier which must have filled up the channel must have been obstructed in its slow downward movement by this projecting point of the mountain. In the side near the base are quite deep, rounded cavities, 2 to 4 feet in diameter, produced by the same causes as the pot-holes. About 2 miles above the falls there is an extensive dike of trachyte. It occurs in the form of a vein, 6 to 10 feet wide, running about northeast and southwest. There are many other dikes in this gorge, of different sizes, and I suspect some of them would prove to belong to different ages if more closely studied. The great branch-glacier of Lake Creek must have been 1,500 feet or more in thickness. The valley or gorge is nearly uniform in width, about one-fourth of a mile, and the glacier must have plowed its way along, paring off a great thickness of the gneissic rocks on either side and on the bottom, the low, rounded remnants of which can be seen cropping everywhere from the detritus. The sides of the gorge for 1,000 to 1,500 feet are worn smoothly, and in some places immense blocks of granite have been wrenched from their places and carried down the channel, so that the sides look like a quarry. The most striking feature is the very smooth surface of the sides of the gorge to so great a height, like glass. About six miles above Twin Lakes, in a straight line, Lake Creek forks, one branch extending up northwest, and the other southwest. Both separate again soon into a number of smaller branches, which end in amphitheaters near the crest.

About four miles up the North Fork a remnant of the gneissic rocks, left in the wearing out of the valley, has a dip of 50° NW., with a strike southwest and northeast. There are a number of these low ridges rising up in various portions of the valley, showing most clearly that the entire gorge has been carved out of the mountain mass. The dip of the beds would indicate a fracture for the water and ice to commence their work, and, as the gorge increased in size, the power to excavate would be increased. The crest of the range is covered with trachyte for miles, and from that ridge extend down beautiful green valleys above timber-line. The sides as well as the circular end of these gorges or valleys are covered with *débris* composed of the broken fragments of igneous or metamorphic rocks. All seem to originate in the same manner, and are continued by the same forces. The igneous rocks seem to have flowed out over the gneissic rocks to a considerable extent, at least 500 feet in thickness, as is shown in this high mountain-valley, where the sides are nearly vertical, and the bottom of the valley here and there reveals the granitic rocks upon which the trachytes rest. So, we have in the main range the same phenomena repeated that we find in all the southern ranges, viz: a granitic nucleus or central mass, with dikes of igneous rocks to a greater or less extent. The movements that elevated these great ranges seem to have generated the heat that reduced the rocks in certain portions of the crust to a fluid condition, and they came to the surface in almost numberless places.

We will not now discuss the history of the glacial period of the Rocky Mountains, but simply state, in general terms, that the evidence seems to point to a time when the Arkansas Valley was filled with one enormous glacier, and that extending from it, on either side of the gulches, were branches of greater or less magnitude; that as the temperature changed so that it was gradually reduced, and the physical conditions approached those of the present time, the basins of the lakes were scooped out, the morainal detritus was deposited, and finally the immense granite bowlders were scattered over the surface. We shall endeavor to show in a subsequent chapter that this glacial period was one of great length, and that the gradual transition from the extreme glacial cold to the present climatic conditions was of great duration, and influenced the sculpturing of the surface to a very great extent.

Our trail over the mountains led up the south branch of Lake Creek. In many instances, these little branches have cut narrow channels into the solid rock 30 feet in depth. This must have been done subsequently to the melting away of the glaciers.

About four miles up the valley the *débris* begins to be made up of igneous rocks that have fallen down from the high ridges. There are, also, immense masses of volcanic breccia, very compact, composed mostly of granitic fragments of various sizes, some worn and others angular. We see again the high crests capped with the igneous rocks, which originally flowed from fissures in the granite, and, as the liquid rock was ejected, fragments of the contiguous granitic rocks were worn off and inclosed. This fork also branches off to the north toward Red Rock Pass, and the usual signs of the wearing out of these vast mountain amphitheaters can be seen. The valley, or gorge, here is unusually broad, and yet the abrupt walls on either side show its origin. The ridges are all capped with the igneous rocks, and, in some instances, they are a brilliant red. The gorge is cut deep down into the granitic rock, and, when it is not concealed by detrital matter in the bottom of the valley, is worn smooth.

We ascend the steep sides of the divide between the waters of the Pacific and those of the Atlantic, by way of Lake Creek Pass. The melting of the snow keeps the sides of the mountain, where covered with loose earth, in a boggy condition, which impedes traveling. Upon the summit of the pass is a little lake or reservoir for the water from the melting snows. On both sides are high walls about a fourth of a mile apart, between which is located the pass. It is not so very much lower than the crests around, being over 12,000 feet above sea-level, and 2,000 feet above our camp at the forks. But the pass itself is an illustration of the slow wearing away of the crest between the sources of the streams. The summit of the pass is very narrow, and on the top and sides are vast quantities of fragments of rocks fallen from the side-walls. There is no doubt in my mind that the crest of the mountain was at one time continuous, and far greater than at present, and that a mass of granite rock the width of the pass, and 500 to 800 feet high, has been removed by agencies not now in operation. Yet the slow process of the breaking down of the sides still goes on summer and winter, and the *débris* forms one of the remarkable features of this region. As we descend the west side of the pass, we have before us in full view one of the most spacious and regular amphitheaters we have seen, forming the source of Morainal Creek. It is in the form of a semicircle, with an irregular wall around forming the mountain-crest. On the west side are two mountain-cones rising up 13,000 feet or upward; on the east side, a high rounded peak covered over with *débris*, while the south side has been broken down so as not to be more than 300 feet above the base of the wall. Vast quantities of the *débris*, or talus, lie all around the base of the wall, while in the center is a forest of pines. We see, therefore, that although the evidence is clear that these amphitheaters have been carved out of the massive granite, no forces are now in operation to carry away the fragments of rock that are annually loosened from the walls by water and ice, but they gather on the slope, forming a talus of great magnitude. We shall have much to say, as we pass from point to point, in regard to mountain sculpture. We believe that geologists have hardly realized as yet the tremendous degradation of our high mountain-ranges, which has been carried on during, or since, the Tertiary period.

We descend to the west side of the mountain to the little creek, and find ourselves in the midst of the most striking examples of morainal ridges yet seen in the West. These extend from a point near timber-line down to the valley of Taylor's Creek, a beautiful stream that occupies in part a valley parallel with the Arkansas on the west side of the main range. I have spoken previously of the anticlinal structure of this region. On the west side of the Sawatch or Mother range there is an irregular parallel depression, extending northward to the Mount of the Holy Cross, and southward far down the Gunnison Valley. Yet the drainage is not continuous north and south like that of the Arkansas. The drainage tends toward the northwest in the valleys of Roaring Fork and Frying-pan Creek, and to the southwest in the valley of Gunnison and its branches. While between the waters of the two systems the divides are quite high and almost impassable, still the inclination of the great mass of the rocks is toward the west in general terms, and the anticlinal structure well illustrated. The interval between the ridges is much more broken, and has not been worn out by one continuous river like the Arkansas.

The morainal deposits are best shown on the west side of the Sawatch range. Along the side of the mountains, rising 800 to 1,000 feet above the valley of Taylor's Creek, is a ridge entirely covered with the *débris* falling from the summits of the range, and morainal matter. It is most probable that the granite rocks form the nucleus, but that the ridge has been worn down by glacial action and covered over with the miscellaneous deposits of morainal drift. The ridge is quite rounded in form, covered in many places with pines, and extending up on the sides of the range nearly to timber-line. The second terrace, as it may be called, is very irregular, varying from 20 to 80 or 100 feet above the valley, and is full of irregular depressions like small lake-basins, but without any apparent outlet. Fragments of glaciers must have remained in this place which melting away, formed reservoirs of water, which finally dried up, the morainal matter accumulating all around them. Sometimes these depressions are oblong and tortuous like the old bed of a stream, and continue for a mile or so, and then close up in a sort of pocket. The surface is covered all over with worn bowlders of granite of various sizes, sometimes 20 or 30 feet in diameter. When streams have cut through it so that sections can be seen, which is not common, it appears to be composed of rather fine earth, evidently the result of the grinding of the granite rocks by ice, and more or less rounded granitic masses of all sizes from a small pebble to a mass of many tons' weight. The position of the morainal deposits would indicate that on the west side of the range also there was, during the glacial period, a vast mass of snow and ice filling up the open valley and running up the gorge like valleys on either side. The valley of Taylor's Creek, which will average a mile in width, is covered over with isolated morainal mounds or ridges, never more than 50 feet high. The enormous accumulation of the morainal matter on the west side of the range would seem to show that the great body of the glacier was there, though extending far westward are abundant signs of glacial action.

We shall speak of this subject again in describing the Mount of the Holy Cross and its surroundings. Far to the south, looking down the broad, open valley of the Gunnison River, we can see the modern lake-deposits much eroded near the junction with the Grand River. Still farther southward is the Uncompaghre range dimly seen on the horizon. To the west is a portion of the Elk range, with the wonderful mass of red rock and the great group of sharp peaks, which show a remarkable chaos of strata. To the northwest are the sources of the Gunnison, with the rounded granite mountains which have been so distinctly glaciated. Here and there the stratified rocks may be seen resting on the granites, and inclining at different angles. To the north is a wilderness of peaks, which form the Sawatch range, some capped with igneous rocks, others projecting their ragged, sharp, granitic points or crests high up among the snows, 14,000 feet and upward. The quite irregular ranges of mountains on the west side of the Gunnison show most clearly that they are subordinate portions of the great anticlinal we have been describing. The abrupt side or face is toward the east, while on the west side the slopes are usually gentle, and whenever the sedimentary beds occur they incline toward the west. The basis rock of the Gunnison Valley, underneath the great thickness of morainal detritus, is granitic, resembling very closely the granite rocks of Salt Lake Valley, Utah. The gray granitic rocks are full of black, apparently rounded masses, as seen in Cottonwood Cañon, which indicates that they were originally conglomerates, so changed by metamorphosis that only indistinct traces of the included bowlders are now visible.

The irregular range west of the Sawatch is undoubtedly, as I have before stated, a subordinate portion of the anticlinal on the west side. Fragments of the great mass of sedimentary rocks can be found at different elevations, especially on the west side, though the granite rocks predominate. About four miles up one of the small side-valleys of Taylor's Creek, to the west, we find low down in the bottom a patch of massive dark-blue carboniferous limestone with corals and stems of crinoids. Some of the layers are made up of fragments of organic forms. The whole is about 50 feet in thickness, inclining west 12°. It is simply a remnant of the great mass that once extended over the country from the plains across the South Park, the Park range, Sawatch, &c., interrupted, perhaps, here and there. We have already observed that the Carboniferous as well as Silurian beds are omitted for one hundred and fifty miles along the east margin of the mountains north of Colorado Springs, while far north and far south the same rocks are well developed in similar localities. So we may make the general statement that these beds covered all this great area prior to the elevation of the ranges.

As we proceed westward from Taylor's River, we enter a region in which the rocks have been thrown into a greater state of chaos than I have ever observed anywhere in the West. There is no doubt that the original inclination was toward the west from the Sawatch range, but the great number of dikes that intersect the crust in many places, have tipped the stratified rocks in every direction, elevated them to the summits of the peaks, and, in many instances, completely reversed their position, so that we have the oldest rocks overlying those of more modern date. It is not uncommon to see ridges of quartzite, or limestone, standing vertical, and, in some instances, inclining several degrees past a vertical. To solve all these problems well would require that every portion of the country should be studied foot by foot, and hundreds of detailed sections prepared. Our plans would not admit of this detail, and, therefore, much must remain obscure until we can gain the time to make special studies of the more difficult localities. Besides, we need better maps, which are now in an advanced state of preparation.

It is plain, however, that the sedimentary beds are essentially the same as those of the Park range, and that they have been subjected to greater overturnings than those of that range. There is at the base, and resting on the granites, a great thickness, perhaps in the aggregate 2,000 feet, of quartzites and limestone in alternate strata. Above these is a great thickness of limestones of a more modern aspect, with well-known Carboniferous fossils in them, and in some localities very abundant and well preserved. Above these comes a vast group of red sandstones assuming a great variety of textures, as well as shades of color, at different points. Above come in regular order the Jurassic and Cretaceous groups. In this district of chaotic overturnings we saw no rocks of more modern age than the Cretaceous, though it is quite probable that a more extended exploration would have discovered them. The main streams that flow toward the west have cut deep gorges directly through the uplifted ridges, as well as dikes, while the side branches have formed in many instances parallel valleys. In all cases the amount of detrital matter is very great. Huge masses of granite are strewn over the surface, sometimes in the valleys and sometimes on the sides of the hills or mountains. The peak named on the map as Italian Peak, 13,255 feet in height, is an example of the variegated colors of the rocks, due to the flowing upward through the fissures of the melted rocks, accompanied with a force that tilted the sedimentary strata in all directions.

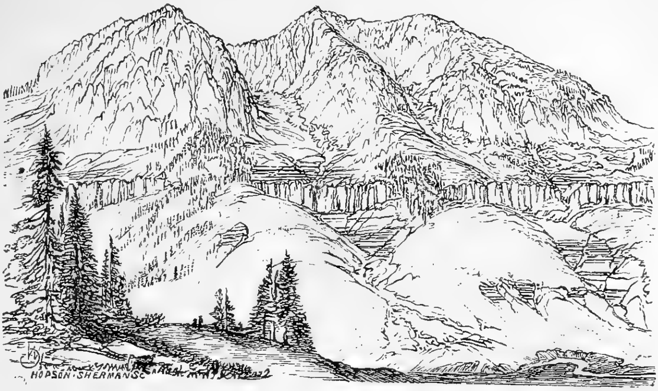
Leaving the valley of the Gunnison, we took a southwest course, up a nearly dry, rather broad, grassy valley, to the divide, and descended again to West Taylor Creek. These little side-valleys occasionally close up for a short distance in a sort of gulch or cañon, then suddenly expand out into an open oval one, covered with thick grass like a meadow. This is a very common form in these mountain-districts, especially where the granites prevail. Soon after passing the divide we find the sedimentary rocks cropping out everywhere. In the valleys there is a great amount of the superficial drift, forming rounded hills or long ridges, the surface being covered over with fragments of limestone, sandstone, and pudding-stone. About four miles below the divide the little stream cuts through a high ridge. On the south side the ridge is composed largely of laminated trachyte, inclining to the northwest at an angle of 60°. While on the north side the rock is more compact, hard, and full of masses of quartz, as if the old granite had been turned to a somber gray by the heat of the igneous rocks; this mass, which is very conspicuous and rises 800 feet or more above the little stream, appears very distinctly stratified, and inclines 60° northeast, while the limestone-beds dip northwest 30° to 60°. This is a most complicated piece of geological work, which would require more time than any of the party could devote to it to work it out in detail, though the report of Dr. Peale is more complete. We believe that the igneous rocks have been pushed up from beneath the overlying quartzites and limestones in the form of dikes, along a line trending about northeast and southwest. The peculiar bedding of the trachyte is so regular that it gives them strikingly the appearance of stratified rocks. There are several ridges nearly parallel which present somewhat the form of an anticlinal, the felstone porphyries being lifted up so that they present their basset edges opposite the outcropping edges of the limestone and quartzites; thus one side of the anticlinal is composed of igneous rocks, and the opposite side of sedimentary. Between the porphyritic rocks and the limestones there is quite a wide interval, 400 or 500 feet, worn out by the action of water, and covered with *debris*, but underneath are the upturned edges of quartzites, pudding-stones, and sandstones. The strike of the limestones is about southeast, with a dip northwest 60°. The limestones are 150 feet thick, and filled with corals, *Productus*, and other forms, which indicate Carboniferous age; the whole standing up like a massive wall 300 feet high. On the outer side of the wall comes 400 or 500 feet of soft sand, reddish-yellow and brown, with some harder layers of sandstone, inclining at the same angle, but worn down low, and covered with grass. Then comes another bed of trachyte, with the layers forming a synclinal with the Carboniferous limestones. Between the two trachytic ridges deep side-gorges are worn down to the stream that has cut its channel through all the ridges at right angles. About two miles farther, near the junction of the little stream that flows from the foot of Italian Peak, on the east side, the reddish sandstones occur with layers of a coarse conglomerate, made up of well-worn pebbles of limestone and quartzites, much like the conglomerate seen near Mount Garfield, in Montana. I think there is here an example of a great fault, where the old Silurian quartzites and limestones have been lifted by a force acting vertically, so that the strata are horizontal, while the younger beds, Carboniferous and Triassic, are inclined from the west side at an angle 60° to 80°. The valley is full of detrital matter, and at one point the stream cuts through a sort of moraine, showing a section of 60 feet on either side composed of gravel and huge bowlders much worn, while high up on the sides of the hills bordering the valley this drift conceals to a great extent the basis-rocks. The rather rounded wooded ridge on the west side of the branch is covered with the *débris* of the trachyte, which shows that the dikes penetrated the crust everywhere. The sedimentary rocks crop out here and there, so that we can infer their existence. Sometimes only the quartzites are left, and the igneous material has been poured over them; again, on the Carboniferous limestones, or the red sandstones of the Triassic, or even the black clays of the Cretaceous. All these formations crop out from beneath the trachytes in the vicinity.

We passed up the valley of a small stream that flows southward from Italian Peak. This peak is literally filled with dikes, which have so changed the contiguous rocks that they present a great variety of structure and color, and hence the name. Indeed, the peak itself is the result of pressure of the igneous matter from beneath. On the northeast side the great mass has been pushed up 1,500 feet, so that on the south side the unchanged quartzites, rusty brown and gray, stand vertical, and in some instances 35° past a vertical. The stratified quartzites are full of seams of crystalline quartz with what appears to be silver ore. The upthrust of the igneous rock has produced great chaos in the beds. Above this locality on the peak there is a fault in which the entire group of Silurian strata is thrown off from the dike so that one portion is separated from another and is lifted up vertically 1,000 feet above the original point of junction. In this district of igneous uplifts the faults are very numerons and striking. Thrust in between the strata are irregular layers of the trachyte, varying from a foot to several feet in thickness, and extending horizontally sometimes several hundred feet, thinning out at each end. One of these intrusions expanded to a thickness of 40 feet on the east side of the peak. From this peak we have a most remarkably extended view on every side. To the south is the East Fork of the Gunnison with the red and yellow beds in the foreground, and far distant the older rocks are thrown up at various elevations, apparently local uplifts. To the west is a vast group of sharp, jagged peaks and crests, saw-like, with stratified cone-shaped pyramids; some red, others dark ashen-brown, or maroon-color. All the rocks, as far as the eye can reach, appear to be stratified, though inclining in various directions. The general level of the summits of the peaks is upward of 13,000 and perhaps 14,000 feet. To the east we see with great distinctness the valley of Upper Gunnison with the Sawatch range beyond, and on the west of the range the ridges of stratified rocks inclining from it. These extended views from the summits of the highest peaks enable us to generalize to some extent the local details that we have already worked out. We see thousands of feet in thickness of stratified rocks, tilted in every direction by a great number of local upthrusts of the igneous rocks, so that we see strata of different ages sometimes on the summits of the highest peaks, over 14,000 feet above the sea. And again, in the lowest valleys we have a thick group of Silurian strata, quartzites and limestones, then above them a group of Carboniferous beds, then the red or Triassic, and in some instances the Cretaceous; but the latter are seldom seen on the high mountain-ranges. As near as we could estimate, there are near this peak 2,000 feet or more of Silurian quartzites and impure limestones; 1,500 to 2,000 feet of limestones and shales of Carboniferous age.

From the Italian Peak we descended the valley of the little stream that flows from its south base and runs southward into a branch of the Gunnison. On the west side of the valley, or gorge, a wall of quartzites rises up nearly vertical 2,000 feet. This valley presents an example of a synclinal in which the shales are most chaotically crushed together. The quartzites incline from each side of the valley or gorge. Dikes of trachyte pass across the strata from east to west, sometimes disturbing the beds so that they incline north and south, and again the dikes are seen without any disturbance of the contiguous rocks. Quite abundant fossils were found in the Carboniferous limestones; among them *Athyrus subtilita*, *Productus*, corals, crinoids, &c.

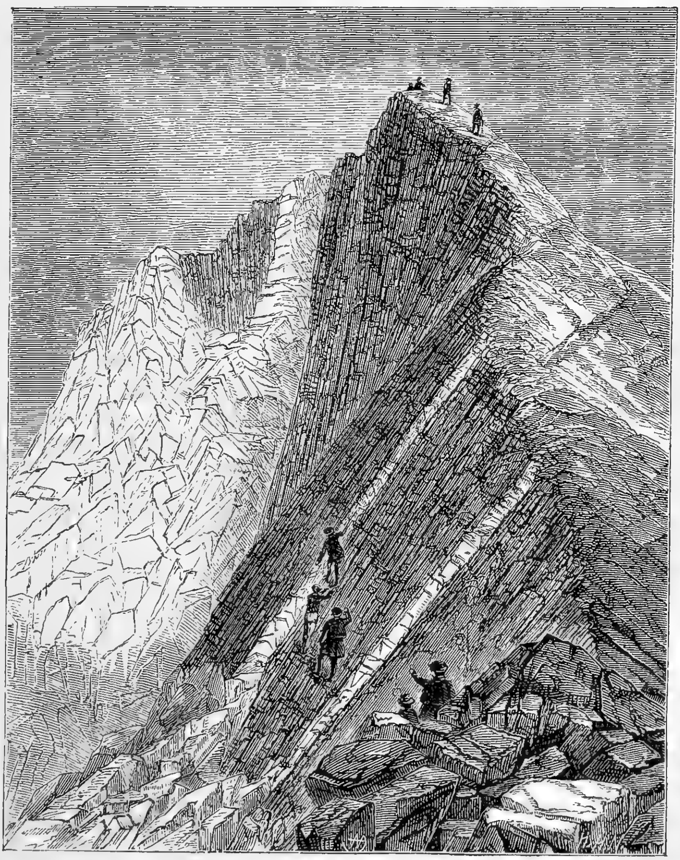
As we continue toward the west the red or Triassic beds in full development cover the surface as far as the eye can reach, interrupted only

Fig. 12.



Gothic Mountain, Elk Range.

Fig. 13.



Italian Mountain.

in restricted localities by the outflow of igneous matter. Between East Fork and the next branch a long ridge runs nearly west down toward the Gunnison 1,200 to 1,500 feet above the stream. On the north side of the valley of the east branch the dip is variable from 10° to 30°, and trending toward the west and northwest. There is really here a broad slope extending from Italian Peak to Teocolli, where the little streams have carved out deep gorges through the red sandstones and pudding-stones. The aggregate thickness here cannot be less than 2,500 feet, and it may be much more. The valleys or gorges have all been formed by erosion, and from margin to margin they are usually about a mile in width, sloping down more or less abruptly to the bottom, where the immediate valley varies from 100 yards to one-fourth of a mile in width.

The texture of these red beds is very variable. Conglomerates varying from a fine pudding-stone to a coarse aggregate occur all through the mass, but are not continuous. The entire group indicates deposition in disturbed waters. In tracing a bed horizontally sometimes it will thicken to a massive fine sandstone, then gradually thin out, and in its place soft, yielding shales appear. Sometimes a bed will be a coarse conglomerate, and in a short distance it will change into a fine sandstone or even soft sand loosely held together. The irregular laminæ of deposition and wave-marks are shown everywhere also, and the signs of quiet waters are local and of comparatively short duration. The map, when completed, will show a water-divide between the branches of the Gunnison and those of the Blue, trending about northwest and southeast, with Italian Peak at the southeast end, with Castle, Maroon, and Black Pyramid along the line, and ending in Sopris Peak. The numerous little branches will be seen extending down from this crest, uniting to form the larger streams on either side. All these little branches rise in broad amphitheaters which have been produced for the most part by erosion or the slow process of wearing out in a more or less circular or semicircular form by water and ice. These amphitheaters are numberless and occur on both sides of the crest. In many places the wearing out of the amphitheaters on both sides has been such as to remove hundreds of feet of the crest, thus forming a pass of greater or less elevation. In these amphitheaters vast bodies of snow accumulate during the winter, a portion of which, in many instances, remains all the season. In the spring the process of thawing and freezing commences, and the slow breaking down of the amphitheater walls is continued. Thousands of little streams are formed by the melting of the snow, and the water flows down to join the main streams.

All these great ranges of mountains are full of fissures, which, running in various directions, break up the entire mass. We can find these openings full of ice at almost any season of the year, and the well-known power of ice by expansion need not be stated here. This action will account for the vast quantities of *débris* all over the sides and summits of our mountain-ranges. The more prominent the range of mountains the more conspicuous is this feature, and the *débris* becomes most noticeable among all the great ranges of Colorado, as well as Montana. The Sawatch, Park, and Elk ranges are excellent illustrations of what I have attempted to describe above. From the crest or divide between the branches of the Gunnison and the Blue Rivers, the little branches have carved out deep valleys or gorges, narrow or wide, depending much upon the texture of the rocks through which the stream has cut its way. Many of these valleys are covered with thick grass far up on the sides, and even on the ridges between the streams, so that as a grazing region it must be excellent. At a period not far distant, this portion of Colorado must be settled to some extent by a pastoral people.

We find, therefore, that from this crest or divide two great plateaus descend in opposite directions, forming, in the aggregate, a huge anticlinal, cut deeply by the numerous streams that rise on the divide. This inclination, on the one side to the south or southwest, and on the other to the north or northwest, is interrupted here and there by dikes of more modern origin probably than the granite nucleus of the crest. Sometimes these dikes disturb the sedimentary beds, reversing their dip or producing great faults, and again they penetrate some fissures without changing their position. In the red sandstones that wall in the valley of the little branch just east of Teocalli Creek is a very interesting dike of the gray igneous granite, with a strike about northeast and southwest. It passes across a little fork just at its junction with the main branch, and is most distinctly seen at the summit of the wall on the west side. The igneous matter seems to have flowed up through the fissure without disturbing the contiguous strata of Triassic sandstone, which are nearly horizontal, and therefore there could not have been a great display of force. It is probable that the origin of this dike is synchronous with the main nucleus, for the materials are apparently the same. As the little mountain-stream flows across the dike its greater hardness has formed a beautiful cascade. We might dwell long on the great varieties of beautiful forms which the crystal mountain-water assumes as it flows down the rugged gorges. A dike about 50 feet wide passing across the channel, the greater local hardness of the sedimentary rocks, or a reverse uplift, will produce cascades of remarkable beauty.

Mr. Jackson, the photographer of the survey, has preserved a number of scenes from this region, and in each one of these almost numberless gorges that extend from the mountain-crest far down to the Green and Colorado Rivers, two hundred miles or more, there could be found many of these charming water-falls. Scenes of great beauty meet the eye at every step, and yet the area is so large that we must have left unseen by any member of the party views of even greater beauty and value. It is probable, however, that our determinations of the geological structure of the country passed over are substantially correct.

A great portion of the surface is covered with a thick forest of pines. In the autumn the fires not unfrequently sweep through these forests, destroying their vitality, and soon the winds prostrate them in every direction, forming a net-work over which it seems almost impossible for our animals to pass. These difficulties are met with in the mountainous portions of the West; and in Montana, 1871 and 1872, our work was very much impeded, and in many cases arrested, by the intricate masses of fallen timber. The Elk Mountains are not more difficult of exploration on that account than the Sawatch range. In our description of the Mountain of the Holy Cross we shall allude to this fallen timber again. It is difficult for any one not familiar with this country to comprehend how important an element of hinderance this is in making a detailed exploration of the country. Very frequently we are obliged to cut our path through the logs for great distances, making only a few miles a day.

At the head of Teocalli Creek is a high mountain-peak which we named Whiterock, from the fact that a seam of white or light gray igneous rock, 60 feet wide, passes through the middle of the summit vertically. The material is quite soft, disintegrating into moderately coarse sand. The rocks composing the mountain are quite varied in

Fig. 14.

Teocalli Mountain.

texture, though all evidently of igneous origin. The jointage is in many cases vertical, separating the mass into blocks varying in size from a few inches to 2 or 3 feet cube. This vertical jointage gives a sort of columnar appearance to the sides of the peak in the distance. The sides are also deeply furrowed. There are three sets of master-joints, with a multitude of smaller ones. The consequence is that the sides of the mountain and the several amphitheaters are covered with immense quantities of *débris*. The whole mass is filled with water and ice during the winter, and in the spring, as the ice and snow melt, it moves down the declivities slowly, like a glacier. Sometimes cavities or reservoirs are made, and the melted snows form beautiful little lakes.

From the summit of Whiterock Mountain, which rises 13,563 feet above sea-level, the eye sweeps over a scene of apparent chaos on every side. There is a wilderness of high peaks with deep gorges extending out in every direction, 2,000 to 3,000 feet deep. The entire range is composed of what may be called upthrusts of igneous granite; that is, the granite is thrown up most irregularly, at various elevations, from beneath the overlying sedimentary beds; sometimes carrying portions to the summits, or tilting them from the sides at various angles, or leaving them 2,000 or 3,000 feet below. While there are numerous points of upthrow in this region, there seem to be a number of foci of greatest power. The Snow Mass group and Whiterock Peak may be regarded as illustrations of tremendous upward force. From the summit of Whiterock Peak the deep gorges with nearly vertical walls for 2,000 or 3,000 feet in depth, showing sections of the rocks as perfect as if cut down by human agency, can be seen on every side. We can see the junction of the stratified sedimentary beds with the granitic core. The variety of coloring to these groups is due to the different degrees of heat to which they have been subjected. The lowest group of sedimentary beds, although exhibiting all the stages of metamorphism, is usually of a yellowish-brown color, and made up of quartzites and impure limestones. I regard them as of Silurian age, and most probably Lower Silurian; 500 to 800 feet are shown in this vicinity, but the aggregate thickness must be much greater. Then above this group there is a series of maroon or deep purplish-brown sandstones, quartzites, and conglomerates. These vary much in color, from a light brick-red to a purplish-brown or maroon color. They reach a thickness of at least 1,500 feet, and probably more. This group is probably of carboniferous age. It may be found capping the highest peaks of Elk Mountains, over 14,000 feet above sea-level, and is weathered into unique forms of cones, pyramids, &c. The third series is a bright brick-red, and is probably of Triassic age. No one has, as yet, found any organic remains in any of these beds, and therefore we can only express a belief in regard to their age, strengthened by observations in adjacent portions of the district. From the summit of Whiterock Mountain the view on every side is most remarkable, presenting the aspect of chaos, as if the entire group of stratified rocks, which originally covered the area now occupied by the Elk Mountains, had rested on a vast pasty mass of the granite, but which, by forces generated in this pasty mass, had been lifted up and tossed, as it were, in every direction. The faults are very numerous and of huge dimensions. Sometimes a group of strata is broken off, so that one portion is from 100 feet to 2,000 feet above the other portion. Sometimes 1,000 to 2,000 feet will be elevated by a force acting very nearly vertically, so that some of the loftiest peaks, as Maroon Peak, 14,000 feet; Black Pyramid, 13,000, and many others nearly as high, are composed entirely of stratified rocks inclining at small angles. Again, the beds are tipped off from the granite core at all angles from 10° to a vertical, and not unfrequently past a vertical, and there are in the Elk range the most wonderful instances of the complete overturning of immense groups of beds, so that for several miles there is a double series, from the Silurian up to the Cretaceous, inclusive, and then rising upward in inverse order, as is shown at the head of East River and near Snow Mass Peak.

Again, the two forces, one vertical and the other tangential, seem to have acted at the same time, throwing 1,000 feet or more of older strata directly over rocks of more recent age. The complications are so great in the Elk Mountains that we could only make a preliminary survey, and a special study must be made of this entire range. This we propose to do the coming season.

By looking at the map of Elk Mountains it will be seen that several streams have their sources in the Whiterock Peak. The little branch that rises at the north side and flows around to the southward has already excavated its amphitheater back nearly a mile, while the granite here is rounded or smoothed as if by the movements of masses of ice, though much of the erosion must have been performed by the movements of vast masses of loose earth and *débris*. From the real base of the mountain one can follow up this gulch for several miles, rising, as it were, step by step, on a series of irregular terraces, which are the result of these accumulations of *débris*. In this instance, the difference of elevation of the real base of the peak and the immediate foot of the crest is at least 2,000 feet, and the width from a fourth to a half a mile, so that one can arrive at a moderate estimate of the tremendous work of erosion which has been performed here. At the head of this amphitheater the crest is so narrow that it was with extreme difficulty that we could creep along it, and we could look down on every side into similar excavations. These mountain-ranges, of which the high peaks now form the conspicuous features, were originally of considerable width, varying from half a mile to several miles, but now the crest or divide may be represented on the map as a zigzag line; the sources of the little streams running not unfrequently from them, having already removed this crest for a little distance, thus forming a kind of low pass. The sides or walls of these gulches are usually very steep, in many cases vertical, but when the upper portions are composed of the easily disintegrating sandstone, the vegetation, of a most vivid green color, has crept high up on the sides, and the upper border is composed of a series of tongue-like points, which give to the picture a unique appearance. It would appear as if the grass had struggled ineffectually to scale the sides of the gulch to the very crest. In some instances these little tongues or points do extend 20 to 50 feet above the main mass below. The melting of the snow forms little furrows down the steep sides, and between them are the sharp points or tongues of vivid green vegetation.

Ascending the valley of East Creek near its source, we pass over the sands and clays of the Cretaceous group, containing a few characteristic fossils, as the *Baculites ovatus*, and several species of *Inoceramus*. As we proceed west and northwest the Cretaceous rocks increase in thickness and extent. The valley of the East Fork, as we see it near Gothic Peak, is a kind of monoclinal, the rocks apparently inclining in the same direction, the west side being abrupt, while the east side has a steep slope. Gothic Mountain is composed of a vast mass of igneous granite projected up through the superincumbent beds of stratified rocks, perhaps raising them to a greater or less extent, but apparently not changing the horizontal portion of the Cretaceous beds, which are all the sedimentary rocks that are visible around the base. There are the black shaly clays which occur above the Dakota group, and whenever they are in contact with the granite core, they are metamorphosed into slates. *Debris* covered with vegetation conceals the slates below the igneous core for the most part, but on the steep sides a considerable area is exposed here and there, and, so far as we can see, the disturbance has not been great. Just on the opposite side of the stream a bed of blue limestone rises up from beneath the black shales filled with *Inoceramus*, probably of the age of No. 3. This limestone is partially changed by heat. A little below the Gothic Mountain the stream cuts a gorge through this limestone, with walls 30 to 50 feet on either side, quite compact, and resembling mason-work. The black clays of the Cretaceous extend up Gothic Peak more than half-way above the bed of the stream, 1,000 feet or more. Near the top of the shales there is a band of trachyte which extends through the peak, along the side of the ridge, to the sources of East Fork, several miles above the peak. It is undoubtedly a dike separated from the main mass of the peak by a band of shales. As it appears to one ascending the valley, it seems like a rocky stratum of irregular thickness interstratified with the black shales. The valley is in part one of erosion. From margin to margin it varies from one to two miles in width. At the upper end the stream separates, one branch extending up into the ridge on the east side, and the other cutting its way through the cross-ridge that separates the East Fork Valley from the branches of Rock Creek. The west branch cuts through the cross-ridge of which Bellevue Peak is the prominent point. At the summit of the divide, which is full 800 feet below the summit of the ridge, there is a beautiful green lake fed by the melting of the snows; and it would be easy to believe that in seasons of high water the little lake drained both ridges into Rock Creek north, and into East River south. This might be given as a well-marked example of a two-ocean lake if it were situated on the main Rocky Mountain divide. On the east side of the source of East River are the red beds in their full development, and on the summit the quartzites, yellow, drab, and brown, varying in intensity, depending upon the amount of heat to which they have been subjected. The cross-ridge which separates the drainage of East River from Rock Creek trends about east and west. We pass over this ridge and descend into a deep gorge-like valley, with its side-gulches cutting deep through the ridges. This cross-ridge shows a complete subversal of the sedimentary group from the quartzites to the Cretaceous inclusive. Bellevue Peak is made up of two sets of Cretaceous beds, the upper series being reversed, so that the lowest portion caps the summit of the peak. This peak is literally riddled with dikes that have changed the shales into slates. This cross-ridge is a part of a long ridge of overturned strata with a trend west to north ten to fifteen miles in length, extending to Snow Mass Mountain. Dikes of trachyte project from the sides of the ridges at different elevations, varying from a few feet to over 100 feet or more, and resembling in the distance massive beds of gray sandstone interstratified with the shales and clays of the sedimentary group. Here and there these dikes are nearly vertical, or incline at a high angle in the side of the ridge.

From Bellvue Peak we followed a trail on the east side of Rock Creek Gulch, just below the summit of the ridge. The sides and bottom of the valley were composed of the Cretaceous clays with the beds of limestone containing characteristic fossils. As we ascend the ridge we find the entire Dakota group overlaid by the Triassic, passing up into red beds, showing most clearly that for ten to fifteen miles the great mass or aggregate of the sedimentary strata has been completely overturned. A careful, detailed study of this interesting locality would show very many instances of this overturning of the beds as well as faults of the most remarkable character. From Bellevue Peak we started for the Snow Mass range in a northwest direction. The dikes in the Cretaceous strata were very numerous. The igneous matter seems to have been forced up through fissures in the rocks which were produced by the uplift. On the west side of our trail the little stream which has worn out the deep cañon and forms the south branch of Rock Creek presents in the walls a wonderful display of the beds inclining about southwest 5° to 10°. The strata here indicate in a marked degree two primary movements, the vertical and tangential. The summits of the ridges on the west side of the high mountain-ridges, at least 13,000 feet above sea-level, are capped with the black clays and quartzitic sandstones of the Cretaceous group, while underneath are the variegated sandstones and quartzites, more or less changed by heat. These rocks present every degree of change to the most compact quartzites or slates. The whole must have rested upon a viscous mass, and by strange manifestations of the force the superincumbent strata have been tipped in every direction, and through the fractures thus formed was squeezed, as it were, the melted granite, forming the numerous dikes which occur everywhere and of every possible form and size. Sometimes an aggregate mass of several hundred feet of well-defined strata is bent in graceful curves. These examples of flexure are very numerous, and vary from a slight bend to an arc of a circle. The gorges which are cut deep down into the sides of these ridges display the flexure as well as the faults and dikes in a remarkably clear manner. The variegated color of the beds adds greatly to the picturesque beauty of the scenery.

The Snow Mass range presents one of the most marked examples of the complete subversion of the strata by the elevation of the great group of granite peaks which form the core of that range. Our camp was made in the valley of Rock Creek, on the south side of the range. The high ridge which extends down from the southwest side is composed of the double set of strata. The lower group, which holds nearly its normal position, inclines at a small angle, while turned completely over on this set or group is the same series in reverse order, like the overlaying of sheets of paper or cloth. The Cretaceous shales are at least 60° past a vertical, while the Jurassic, Triassic, and older beds incline at various angles, varying from 60° to 40° past a vertical. The great group of peaks which formed the center of the movement rises nearly 14,000 feet above the level of the sea, and is composed of massive granite. The jointing of this granite is very marked. One of the master-joints is vertical with a direction about east and west. The joints are not all as regular as the vertical, but they are so well defined that the mountain is much broken up, and easily yields to the influence of air and moisture. The sides and base of the range are covered with an immense quantity of *débris*, the masses of rock varying in size from a few inches to 20 or 30 feet in diameter. In some instances the sides of the mountain seem to be made of massive layers that break off in folio, as if the granite had cooled in concentric layers. The entire range is in this way slowly but constantly falling down, so that from base to summit the talus is quite remarkable in quantity. At the base, on the south side, there is a beautiful lake about 300 yards long and 150 wide, on which an abundance of water-birds were swimming and feeding. This is named on the map Elk Lake. The summit of the mountain is massive igneous granite, remarkably compact. From the top of Snow Mass Peak the view is very extended and grand. To the south we can see the country we have just passed over from the Sawatch range. In the foreground the series of sedimentary beds on both sides of Rock Creek, which have been subverted by the uplift of the Snow Mass group, the great sedimentary covering laid off from the granite as the covering of a bed is drawn over from the pillows. At the southeast the lower beds, or those that run next to the granites, are nearly vertical in position, but the newer or higher ones geologically are tipped far past a vertical. Farther still to the south, across the gorge, is a ridge covered with snow, from the sides of which ocher and maroon strata incline at various angles, on one side about east, and on the other west, while the nucleus is a mass of igneous granite. To the eastward, extending a great distance, the red beds can be seen inclining at various angles for the most part from the central mass, but full of dikes. It would seem that the cones and pyramids formed remarkable cross-sections, showing fissures of various widths, through which the igneous matter came to the surface. Twenty or thirty of these dikes of all sizes are in sight on the east side of Snow Mass Peak. These dikes present a great variety of forms. Sometimes the igneous material has flowed up through vertical fissures, as in the maroon ridge to the southeast. In the same ridge the igneous matter has come to the surface and overflowed, so that the ridge is capped with the granite. To the northeast there is a red ridge, with a wide vertical dike through which the igneous matter has come up from the central mass and overflowed, forming a cap to the ridge. At another locality to the northeast we can see distinctly the ocher beds, or the lowest sedimentary group, probably Silurian, resting on the granite, inclining 10° to 15°, and on these a great thickness of red beds, and on top of the latter masses of irregular thickness varying from 100 to 400 feet of the eruptive granite, and at either end the red beds again, resting upon the eruptive mass. In this case the eruptive material must have been pushed up through a fissure in the lower strata, and toward the summit lifted up the upper red beds, so that it now appears like an interstratified mass. For twenty or thirty miles from Snow Mass Peak to the northward between east and west, the red or maroon beds rise in high, long ridges, with immense valleys and gorges between. To the northwest are portions of the Snow Mass group and Sopris Peak, all, parts of the great central granitic mass or nucleus. Far in the distance, westward, thirty miles or more, is the valley or cañon of the Grand River, with stratified beds of a light red on either side. In the amphitheater on all sides of this granitic nucleus are quite remarkable glaciated rocks, with great numbers of beautiful green lakes, which form the sources of numerous branches of the rivers. These are reservoirs for the reception of the waters of the melted snows which lie in glacier-like masses on the sides of the mountains. The same proofs of the wearing away of these central masses is shown in this range which we have so often observed in the preceding chapters. The crest is a thin, sharp ridge, in many places so narrow that it is with difficulty one can creep along it. It is remarkably zigzag in its strike, enormous amphitheaters having been excavated on both sides, in many instances having broken through the crest, either from one side or the other.

On the east side of Snow Mass group there is a fine, large amphitheater in which are several small lakes with vast quantities of broken rock, and just above them, on the side of the crest, a vast glacier-like mass of snow and ice, from which, at this season of the year, (August,) water is flowing rapidly. We might suppose that in old glacial times each one of these amphitheaters was the abode of a glacier which each year slowly moved downward, carrying with it great quantities of earth and fragments of rock far below. The time for this action in its full force is now past, and the work of excavation could not have been performed, as we see it has been done in past ages, with the forces now in operation.

Between the two main peaks, each of which is nearly 14,000 feet high, the crest curves so as to form a full semicircle, and has been worn away so that it is now 500 to 800 feet lower than these peaks, though it must have been originally of the same height at least. We may see that it is most probable that much of the original form of these mountain-ranges has been lost, and that their present shape is the result of atmospheric forces acting through ages—from the time of the uplift to the present day. It is also evident that these eroding agencies operated with far more power in the past than at present, and that it is most probable this force has been decreasing slowly to the present time. The Blue River range is a fine illustration of the same process of excavation. The Snow Mass Peak is really a long, sharp ridge with two points, the northwest point being about 300 feet higher than the southeast one, while between the two the crest has been worn away so that it is 600 to 800 feet lower than the two ends. The shape seems to be given by the flexures of the jointing. The sides are deeply furrowed, down which it is probable that masses of snow and ice have slidden for ages. On the south side these furrows are very deep and regular, and at about the same distance apart, so that the curved form appears like a series of waves, extending from the summit down into the amphitheater. There can be no doubt but that they have been worn down by the combined action of water and ice. The square masses of granite stand up on these crests or ridges like druidical columns. The remarkably broken condition of the rocks composing the entire nucleus of these mountains would indicate immense wear, and that all these peaks which are now very lofty were once much higher than at the present time. On the south side of Snow Mass, near its base, there are vast masses of igneous rocks that appear to be of more modern age. Much of the basalt being porous like slag. It is most probable that the igneous rocks are of different ages, and while none of them in their present form may be older than the Cretaceous period, there may have been eruptions of greater or less extent all the way up to the present period. In tracing the channel of Rock Creek up from our camp, we find the black Cretaceous clays dipping past a vertical 50° to 60°. The channel of the little stream reveals a complete section of the beds in their order, as well as their position. We find two distinct sets of beds, the upper reversed, so that at the upper falls we find the quartzites of the Dakota group on the black clays of No. 2, and the latter over the limestones that usually characterize No. 3. Near the lower part I obtained quite a collection of well-marked Cretaceous fossils, among them *Baculites*, *Inoceramus*, and many small shells. In the gray limestone are numbers of a high, round *Inoceramus* identical with the species found on the east slope of the Rocky Mountains. In No. 2 I found *Ammonites*, *Ostrea congesta*, and a small shell with scalloped edges like O. larva. These shales and clays are more or less metamorphosed at different localities.

In the little streams that flow from the high mountains are numerous beautiful cascades. There is in most instances a reason why the water should be interrupted; and there are two excellent examples in this stream above our camp toward its sources. The upper falls are produced by the water flowing over the hard quartzites of the Dakota group, and thus the wearing out of the channel was interrupted by the great hardness of the rocky bed. The lower falls were formed by a dike, which commences on the left branch, runs parallel with the strata for 20 or 30 feet, forming the top of the falls, then drop down diagonally across the layers of shale about 10 feet, and on the opposite side rises again and is lost in the *débris*. At first the trachyte is above a hard layer of calcareous sandstone about 2 feet thick, but it passes through that into the softer clays below, where its thickness is increased from 2 to 4 feet. Both the upper and lower sides of the dike-layers the Cretaceous shales are changed into slates and are adherent. As we follow up the channel of the stream to a high hill overlooking the gorge, we see that the entire mass on both sides, and extending for miles, has been thrown over to the west and southwest, and that the occasional sagging or bending down of the mass produces a drainage-channel through which the little streams find their way. In the case of Rock Creek, the curve downward or sag is 600 to 1,000 feet. At another locality near this creek there is a dike 4 feet in width, nearly vertical, or running across the strata at right angles. We see, therefore, that the igneous matter was pressed up through every fissure of any form through which it could gain access to the surface, or relieve the pressure from beneath. Sometimes it is squeezed out between the layers or strata across them diagonally, or at right angles, in whatever direction the original fissure might take. As we descend Rock Creek the channel reveals the lower set of beds from the Cretaceous shales of No. 4, downward to the granites, with the various changes which they undergo. The shales, mud sandstones, and clays, of No. 4 and No. 2, as well as the gray limestones of No. 3, are frequently much changed. The black quartzites on Rock Creek, and the blue limestones, with all the intermediate steps of change, are most clearly shown. The gorge or channel is inclosed within narrow walls, which soon increase in height from 1,200 to 1,500 feet, inclining at a moderate angle, 5° to 10°, about northwest, or nearly opposite to the dip from Snow Mass range. Gothic Mountain, 12,315, and Crested Butte, 11,838 feet high, may be regarded as immense dikes, the melted matter pushed up through the superincumbent strata, but in such a way as not to disturb to any great extent the great thickness of yielding Cretaceous shales and clays, so that they surround the base of the mountains like terraces, apparently in a nearly horizontal position. Gothic Mountain presents an illustration not only of the vertical upthrust by which the central mass was brought to the surface, but also shows an irregular layer of the trachyte squeezed out between the strata of shale.

We have not been able in this chapter to present more than a glimpse of the remarkable geological features of the Elk Mountain range. It is the purpose of the survey to make a careful examination of this entire region as a special study, and therefore only a preliminary notice of it can be given in this report. We have frequently spoken of the chaos into which the beds seem to have been thrown by the numerous centers of uplift, and so it seems at the first glance; but our map will show that the massive peaks are located along a regular line which indicates a true axis of uplift, trending northwest and southeast. Studied in detail, the geologist will find faults and dikes without number, strata inclining in every direction and at all angles, and very often entirely subverted, yet the aggregate dip and strike may be reduced to a system, as we see it on the map, from Italian Peak to Sopris Peak.

CHAPTER IV.

FROM ELK MOUNTAINS TO MIDDLE PARK.

After a preliminary exploration of the Elk range was completed, the party returned by way of Twin Lakes around the Arkansas Valley and across the divide by way of the Tennessee Pass.

As we pass up the valley and examine the comparatively smooth terraces that are well shown on both sides, as well as the wooded foot-hills, we form no conception of the deep gorges or cañons which are found between the mountain-crests. Above the entrance of Lake Creek into the Arkansas, the valley is quite wide, though the immediate bottom is narrow, but the evidence of erosion in the subsequent deposits of detrital matter is very marked. Just opposite Massive Mountain the river-bottom is about a mile in width; then a terrace rises 40 feet above, and a second terrace of 500 feet, composed of horizontal strata of sand, clays, sandstones, and conglomerates, a kind of modern lake-deposit. The distance between the immediate base of the Park r ange on the east side of the Arkansas and the Sawatch on the west side is about ten miles in a straight line. A coarse bowlder-drift or detritus covers the foot-hills to a considerable depth, while beneath are the worn surfaces of the granite rocks, which have most probably been ground down from their lofty heights by the old glaciers that once filled the vâlley.

The evidence shows that the waters of the Post-pliocene lake were 1,200 to 1,500 feet above the present river-bed. In the mountains to the west of the pass some valuable silver-mines have been discovered, and the Homestake district laid out. Very little is known of them as yet, except that about seventy tons of ore have been taken out and transported to a smelting-furnace near Denver. The yield is reported to be from $100 to $200 of silver per ton of ore. The Tennessee Pass forms the water-divide between the sources of the Arkansas and some of the south branches of the Blue River, as the Roaring Fork. The height of the pass is 10,223 feet above sea-level.

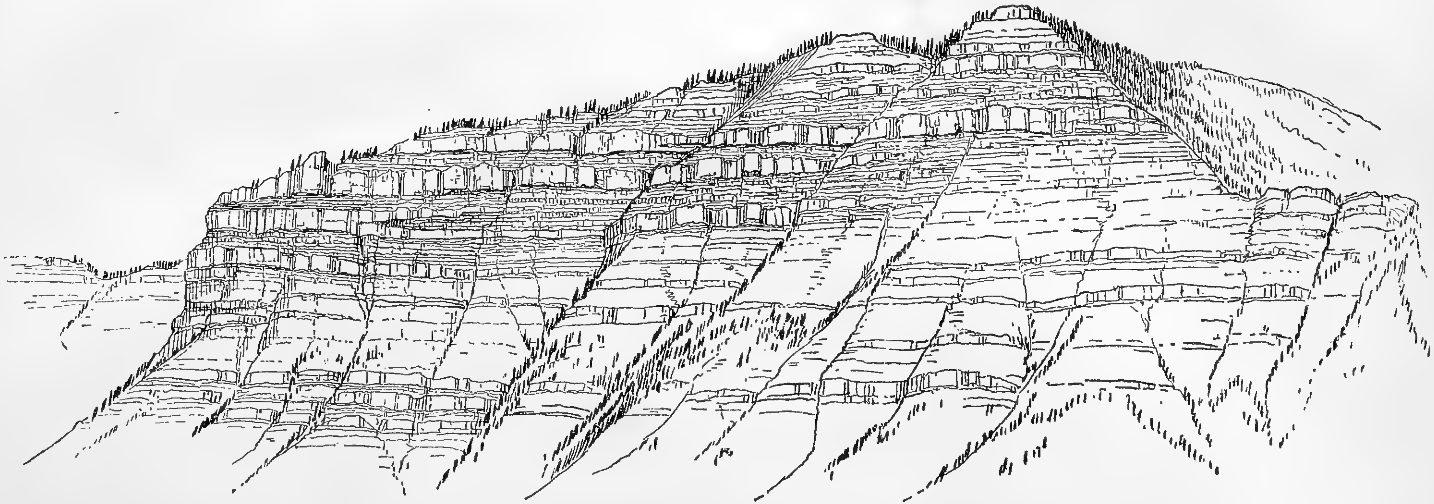
The country on both sides of the divide is covered quite thickly with pines, with here and there openings like meadows. The pine-forests are destroyed more or less every year by fires, which sweep over large areas. Unless the autumnal fires can be checked, the pine-forests of all these mountain-districts must disappear.

At the present time the various branches of the Arkansas are choked up with ties which are to be floated down the main river toward Pueblo for the use of the Atchison, Topeka and Santa Fé Railroad.

Remnants of the sedimentary rocks appear here and there about the divide, but the basis rocks are so covered with *débris* or detritus that it is hardly possible to determine them. It is most probable the granitic rocks prevail. As we descend the west side of the pass in the narrow gulch of Eagle Creek the gneisses, with well-defined bedding, are seen on both sides for two miles, when patches of stratified quartzites occur, resting on the upturned edges of the gneisses.

About ten miles below the Tennessee Pass, on Eagle River, on the sides of the gulch, we have gneiss, with dikes of trachyte; white quartzite stratified, 30 feet; reddish quartzite, full of seams of white quartz and much changed by dikes. The quartzite passes up into a quartzose sandstone, rather coarse, 100 feet; yellow-brown arenaceous mud, lime stone alternating with seams of shale and quartzite; coarse and fine sandstone of various textures, with layers of limestone interstratified,

Fig. 15.



Irregular Bedding of Carb. Sandstn. on Eagle River with partings of shale. The layers of limestone vary from 4 inches to 4 feet in thickness. As we ascend the sandstone predominates, and becomes coarser until layers of rotten coarse sandstone alternate with beds of pudding-stone and conglomerates. Some of the sandstones are quite coarse in texture, and might be called pudding-stones. Indeed, the whole section is a repetition of the one near Horseshoe Mountain.

The stratified beds are here over 1,000 feet in thickness above the bed of Eagle River. It would seem, therefore, that we have here on the west slope a series of quartzites and impure limestone, like those resting on the granites in the Park range, and most probably of the age of the Lower Silurian; above them a thick group of Carboniferous beds with numerous fossils, as *Spirifer*, *Productus*, and a trilobite, probably a *Phillysia*. These fossils are found quite abundantly as soon as the more modern beds occur. To the eye of the field-geologist this lower group of beds presents a much more ancient aspect, where it is seen, than the Carboniferous, although there are no remarkable instances of inconformability that have come to my notice. I think I can always detect the line of demarkation between the older group and the Carboniferous series in all cases without the aid of fossils or other proofs, merely by the difference in the general external appearance. As we pass lower down the valley of Eagle River, we find high bluff-walls on both sides of the river, with several hundred feet of rather loose arenaceous beds with hard layers of sandstone and quartzite alternating, of yellow and brown color, evidently extending the Carboniferous group 800 to 1,000 feet above the reddish-brown sandstone. This upper group of beds rises to the summit of the ridges as we ascend the river, and probably forms the upper portion of the Carboniferous series. The color of the rocks in this region cannot be depended upon as of any value in tracing groups of strata over large areas.

The same white quartzites which we have mentioned above as resting upon the gneiss a little farther below hold the same position, but are quite red. They may be white, gray, red, rusty-yellow, or brown, within comparatively short distances.

In the cañon of Eagle River the order of superposition is well shown. The cañon is undoubtedly one of erosion for the most part, though, like that of the Arkansas River, it is also monoclinal. At the present time the indications of any original fracture or fissures are only suspected by the inclination of the stratified beds on either side of the river. The dip is to the east and northeast from the great Sawatch range, of which the Mountain of the Holy Cross is the northern end. The erosion has been so great that the sides of the cañon for miles are nearly vertical, although the left or east side is much more abrupt.

Sometimes the quartzites that rest on gneiss will wall in the valley at the river's margin; again they will cap the summit of the ridges 1,000 feet or more above the bed of the river.

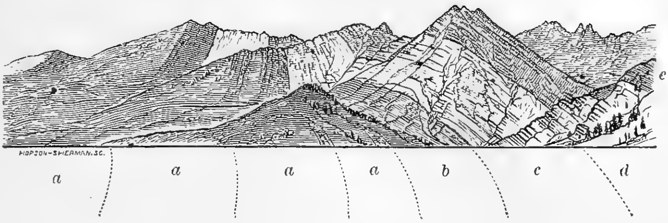
Both sides are penetrated with dikes to a greater or less extent. At one locality, above the Silurian limestone, is a bed of trachyte, apparently interstratified, with a bluff-front of 50 feet, with marked vertical and horizontal jointing. So far as I could discover, it does not extend horizontally more than 100 yards. Sometimes the igneous material rises up through vertical fissures without much disturbance of the contiguous beds, and again it throws it into chaos, so that while the general or aggregate inclination is north or northeast, the local dip is liable to be in any direction or at any angle, depending upon the force exerted by the igneous outflow. As we strike the main branches of Eagle River and they unite, the main river flexes slightly toward the west, and the monoclinal character of the cañon becomes more apparent. Fragments of the quartzites may be seen on the west side, high up on the granites inclining northeast; while on the right or east side they incline in the same direction and dip beneath a vast thickness of variegated sandstone and shales. At first the high mountain-ridges, 1,200 to 2,000 feet above the bed of Eagle River, are granite or simply capped with patches of the quartzite. As we descend the Eagle River an increasing thickness of the sedimentary beds is observed on that side, forming a steep slope, while on the right or east side the abrupt edges of the variegated sandstone and shale rise at least 2,000 feet, forming the high rounded ridge between the Holy Cross and Blue River groups. Opposite the junction of Roches Moutonnés Creek with Eagle River there is a very high, nearly vertical, bluff, showing a remarkable section of the variegated beds, which are probably of Carboniferous age.

We have already noticed the quartzites resting on the granites, and above the quartzites are impure arenaceous limestones. As we descend Eagle River, these rocks, which have a more ancient aspect, and which I regard as of Lower Silurian age, pass beneath the bed of the river, at the entrance of Roches Moutonnés Creek, and we have on the east or right side of the river the series of strata which may be described briefly as follows, in ascending order:

1st. A group of rather light-red sandstone, varying in shades of color, oftentimes in massive layers varying from a few inches to 30 feet thick, with partings of arenaceous shale, varying from a few inches to 6 feet in thickness. The two upper layers of sandstone are fine-grained, and break into quite regular vertical columns. The lower bed is about 12 feet thick. The layers or strata are all irregular in thickness in the horizontal extension, sometimes thinning out to a few inches, and then increasing to several feet. In texture the rock presents every shade from a fine-grained sandstone to a coarse conglomerate, and these changes may occur in the same stratum within a few feet. There are twenty-two layers of sandstone in this group, varying from 2 to 30 feet in thickness, and the aggregate thickness is about 500 feet. Some shade of red is the prevailing color.

2d. Then comes a series of similar beds, evidently portions of the same group, but in this locality marked by difference in color, being mostly yellowish-gray or brown, sometimes with a reddish tinge. The first bed is about 6 feet thick with the same vertical columnar fracture, which at a distance gives to the rock the appearance of basalt. This group comprises twenty-four beds of sandstone, varying from 2 to 40 feet in thickness, with shaly partings varying from a few inches to 4 feet. This upper group is much finer in texture than the lower group, yet all the layers indicate the deposition of the sediments in shallow as well as moving waters, by the oblique laminæ and the irregular thickness from point to point. The shaly partings are in many cases very micaceous, and might be termed micaceous shales; while the coarser sandstones, or pudding-stones, are made up of pebbles of quartz mostly, and so far I could detect no fragments of the sedimentary rocks. The shales are also variable in color from yellowish-brown to a light gray, then changed into what may be called mud-sandstone, in groups varying from 50 to 200 feet in thickness.. Sometimes the mud-shales are separated by a few feet of coarse sandstone or quartzite. The difference in the texture of these layers may be detected at a distance by the style of weathering; the sandstones fracture with a square vertical

Fig. 16.



Section of upturned strata, Snow Mass Range. (See page 66.)

a, Cretaceous. *b*, Jurassic. *c*, Triassic. *d*, Carb. *e*, Granite.

Fig. 17.

View on Roches Moutonnes Creek. (See page 73.)

face, while the quartzites weathered in rounded forms, the thin layers dropping off concentrically.

The composition of those rocks would indicate that the gneissic or granite rocks were very largely drawn upon for the materials. The two groups described above will aggregate at this locality about 1,200 or 1,500 feet in thickness; but as we descend the river we can see on the summits of the mountain-ridge a great additional thickness, so that the whole must sum up at least 3,000 or 4,000 feet. The character and texture varies much in different localities, but the description given above will apply to a great thickness of beds which extend over a greater or less area west of the Sawatch range to the Colorado River.

Our trip down the Eagle River had for its principal object the discovery of some way of access to the mountain of the Holy Cross. A little stream joins the Eagle River from the west side, which rises among the group of mountain-peaks of which the Holy Cross is most conspicuous. The valley of this stream varies from one-eighth to one-fourth of a mile in width, and is about eight or ten miles in length, and so covered with the rounded glaciated forms of granite that it was impossible to ascend it with our pack-trains. We were obliged to descend the river about three miles and then climb the steep mountain-side over a net-work of fallen timber. The obstructions to traveling were very great. We often labored for a day or two to find some path to approach the mountain-peak, and were obliged to cut our way through the fallen timber, and finally succeeded in getting within about five miles of the base of the peak.

The most remarkable feature of this wonderful region is the proof of a great ancient glacier which must have filled up the valley from mouth to source. The bottom, extending high up on either side, is covered with the rounded granite masses, varying in size from a few feet to several hundred feet length; so that, looking down upon them from a high point, they resemble a huge flock of sheep, and from this fact they have received from the Alpine geologists of Europe the appellation of "Roches Moutonnés." It is most probable the valley itself has been worn out of the granite mass. The mountains on either side rise to the height of 2,000 to 3,000 feet above the valley, and the glacial markings are visible 1,200 to 1,500 feet. The morainal deposits on the northwest side reach a height of 1,200 feet above the stream and form a sort of irregular terrace, which, when cut through by the little side-streams, show that it is made up of gravel and bowlders much worn. In some instances there are well-worn cavities in the sides of the mountains, showing how the running water, in connection with a mass of rock, formed the cavity much as a "pot-hole" is made in our streams at the present time.

Many of the "sheep-backs" are still covered with a crust like enamel, but usually this has peeled off. There is no doubt that all these rounded granite masses were originally covered with what may be called a glacial crust which has scaled off, so that only remnants remain at the present time. The rounded masses of granite are mostly oblong in form, or lie in parallel lines, as if the little stream had originally occupied a dozen or more channels parallel to each other.

The amphitheaters on the west side of the mountain are quite numerous, at least a half-dozen in number, giving birth to as many streams that flow down the mountain-side. These unite in the valley, and form a good-sized stream, 150 feet wide and 2 feet in depth.

At the upper end there is a boggy meadow covered with high, coarse grass. This meadow is about one-fourth of a mile in length and about the same distance in width. This must have been originally the bed of a glacial lake, scooped out by glacial action as a sort of reservoir for the sediment swept down from the mountain-sides. The sheep-backs commence at the lower end of this basin and continue for about ten miles, presenting undoubtedly the most remarkable illustration of this particular kind of glacial action ever seen on this continent.

The main mass of the peak, like the whole of the Sawatch range, is composed of granite gneiss. The summit of the Holy Cross is covered with fragments of banded gneiss. The amphitheaters on all sides have been gradually excavated, as heretofore described, and the more or less vertical sides show the intermediate steps very clearly. The characteristic feature of the Mount of the Holy Cross is the vertical face, nearly 3,000 feet on the side, with a cross of snow which may be seen at a distance of fifty to eighty miles from other mountain-peaks. This is formed by a vertical fissure about 1,500 feet high, with a sort of horizontal step, produced by the breaking down of the side of the mountain, on which the snow is lodged and remains more or less all the year. Late in the summer the cross is very much diminished in size by the melting of the snow which has accumulated in the fissures. A beautiful green lake lies at the base of the peak, almost up to timber-line, which forms a reservoir for the waters from the melting snows of the high peaks. From this, one of the main branches of the Roches Moutonnés Creek flows down the mountain-side, forming several charming cascades on its way. The worn rocks or "sheep-backs" in the valley of the creek display most remarkable examples of the curious markings on the surface of gneiss produced by the separation of the different constituents of the rocks.

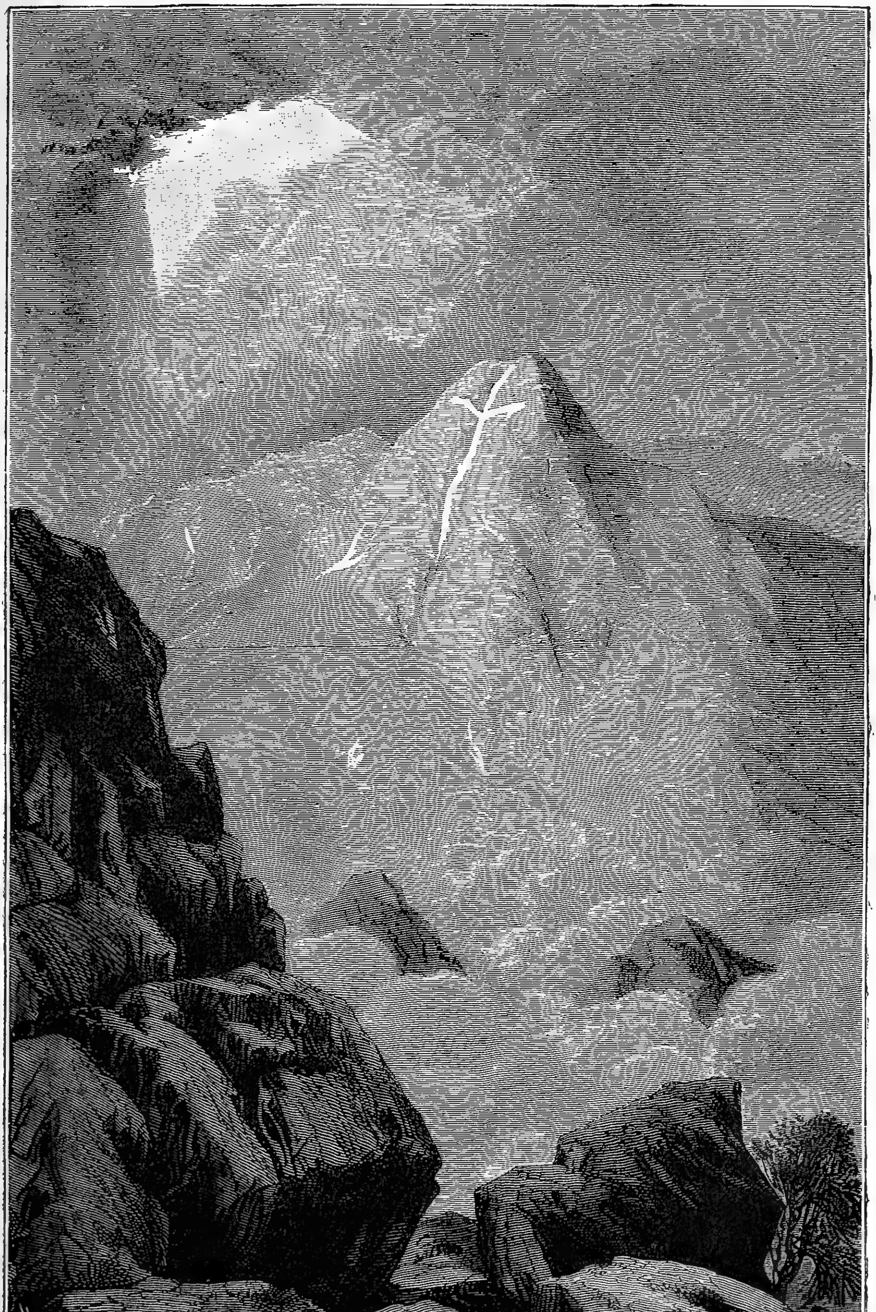
The red feldspar sometimes makes bands or seams crossing each other like mosaic work. Then there are patches of all sizes and shapes, in which the particles of mica are so fine that they appear like rounded masses inclosed in a coarse feldspathic matrix.

Many of the rocks look as if they were covered with a confused mass of hieroglyphics. These peculiar markings in the structure of gneiss are not uncommon, but they are shown on such a scale in this locality as to attract attention.

We have already described the cañon of Eagle River as monoclinal in part. It runs nearly parallel with the upheaved ridges, but as it descends passes into the sedimentary beds from the granites to the Cretaceous clays of No. 4. At first the cañon cuts deep into the granites, 1,000 to 1,500 feet, with vertical sides; soon the quartzites come in resting on the granites, and then cherty limestones of the thickness of 1,000 to 1,500 feet, which are undoubtedly a part of the same group seen in the Park range, on the west side of the South Park, and regarded as of Lower Silurian age. The channel cuts through an enormous thickness of variegated beds, not only in color but texture; a most remarkable group, with an aggregate thickness of 3,000 to 4,000 feet. That this group is of Carboniferous age, the few fossils that could be detected in different localities seemed to testify.

As we descended this stream toward the main Blue River, the high sloping ridges are seen on the left or south side, the dip well exposed in the channels of the streams that have cut deep down from the mountain-crests. Great quantities of worn bowlders and loose detritus cover these ridges, growing more abundant toward the base or near the river. On the north or right side the outcropping edges of the sandstones and indurated clays and shales are seen, the texture determining the abruptness of the sides of the cañon.

Fig. 18.



Mountain of the Holy Cross.

There are great numbers of side-cañons formed by the little streams that have their origin high up in the Blue River range.

We find here two forms of river-channels or cañons; one nearly parallel with the lines of fracture, monoclinal, as I have called them for want of a better term, and the other at right angles to the ridges and carved out of the solid mass. In the first class the drainage must have commenced in a fracture, but erosion has been the main agency in the formation of the cañon; in the latter, the channel is in most instances entirely due to erosion, the strata corresponding in position to a greater or less extent on both sides. Between the northwest end of the Sawatch range and the Blue River range there is an immense mass of sedimentary strata crushed in between the two great axes of uplift as it were, forming a sort of synclinal. The beds incline with tolerable regularity from the Sawatch toward the northeast, though the dip varies from 10° to 50° or 60°. Sometimes the dip, close up to the margin of the mountain-summits, is nearly vertical, but in a few instances great masses of strata seem to have been carried up on the underlying granite, producing extensive faults, as seen in the Park range. But the elevation of the Blue River range seems to have been somewhat peculiar, the force having acted nearly vertically, so that on the west side of the range the sandstones jut up against the sides with but a slight dip. Following up one of the branches of Eagle River, which rises high up in the west side of the range and carves a channel across the uplift, we find the inclination from Eagle River extending eastward for about six miles, where there is a sort of sag or depression and a reversed dip from the Blue River range.

From Eagle River Valley we made a side-trip to the Blue River range, ascending the highest peak, Mount Powell, by way of one of the little streams that rise on the west side. There is no name for this little stream, but it reveals in the sides of its cañon a thick group of the brick-red sandstones. The cañon is carved out of the solid mass, from the amphitheater high up on the west side of the range, down for several miles through the sandstones at right angles to the inclination of the strata. The sides of the cañon are 1,200 to 1,800 feet high on either side, and rise in abrupt steps, depending upon the texture of the different layers of sandstone. The valley varies from one-eighth to one-fourth of a mile in width, and rising up in various places in the bottom are the worn edges of the sandstones. At one place they appear above the surface completely across the valley, showing most conclusively that this gulch or cañon is entirely one of erosion.

On the west side of the Blue River range the sandstones lap on to the granite nucleus, so that the usual valley of separation is wanting; or, in other words, the ridge of sandstone lies so close to the mountain-side as to be continuous with it. As far as one can see from the summit of Mount Powell, north and south, these sedimentary beds hug the west side of the range with a very moderate dip, not usually over 10°. There are numerous streams that flow from the west side of the range and cut deep channels, which expand or contract, depending upon the texture of the rocks through which the erosive agent has wrought its way.

Everywhere there are more or less proofs of old glacial action. The moraines are common, but not on such a scale as we have already described, on either side of the Sawatch range. In the amphitheaters, as well as in the upper portion of the valleys where the granites are exposed, we find the same rounded glaciated masses which were so conspicuously shown near the Mountain of the Holy Cross.

The effects of erosion, as shown in the Blue River range, are on equally as grand a scale as in other localities previously described. Even the imagination fails to grasp the tremendous influence this agency has exerted in past times, judging from the scenery both of mountain and plain.

From the summit of Mount Powell one can follow with the eye the sharp, zigzag crest of the Blue River range, with the numerous huge amphitheaters on each side, which have been worn a long distance from the base of the mountain. Very frequently the partition-wall is broken through, forming a low bend or sag in the crest-line, and here and there a huge shaft of granite rises up 1,000 feet or more above the crest.

The Blue range, as seen from the summit, is one of the ruggedest in Colorado, composed of a mass of sharp-pointed peaks, crests, and obelisks. Great masses of snow, like glaciers, lie on the almost vertical sides perpetually, though they abruptly descend 45° or 50°.

Huge fissures may be seen in these great masses of snow and ice, that may indicate slow movements downward. At any rate, we may call them remnants of the old glaciers that once existed here in abundance and have left their traces on the surface everywhere. Numbers of little gem-like lakes are seen high up in the amphitheaters, sometimes even above timber-line, reservoirs for the water that melts from these old glacier-remnants.

A fact worthy of note here is the vast quantities of dead grasshoppers that are found on these masses of snow. The quantity may be estimated by bushels, and the bears frequent these high places in search of them for food. At certain seasons of the year the air is filled with grasshoppers, apparently flying in every direction, to a height far beyond our vision. It is probable that they become chilled in flying over these high mountain-peaks, and, dropping down on the snow, perish.

The Blue River range juts up against the south rim of the Middle Park, extending southward along the west side of the upper portion of Blue River. On the east side of Blue River, there is a long, rather high ridge, extending into the park, composed largely of Cretaceous shales with dikes of basalt in great numbers. The basalt occurs on the summit and crops out of the sides in many places.

Far in the distance to the northeast is the Front or Colorado range, with Long's Peak, and the intermediate group of high peaks. To the east, Torrey's and Gray's peaks are well shown, and to the southeast are the peaks around the Middle Park. To the south is the Sawatch range with the Holy Cross in the foreground, and west of south, Snow Mass, Sopris, and other high peaks can be distinctly seen.

The intermediate space is filled up with the sedimentary beds, of which the red beds cover by far the largest area. The Blue River range trends about north and south, extending up so as to form the northern portion of the Park range. Looking to the west we can see the great mass of sedimentary beds inclining from the west side of the Blue River range and from the east side of the Holy Cross, and its associated peaks forming about midway a curious synclinal.

The two forces have crushed the beds together. The sedimentary group here forms a belt from fifteen to twenty miles in width, expanding to a greater breadth to the west and northwest. To the northwest from Mount Powell we can look into Egeria Park, a sort of elevated plateau or meadow, a beautiful park, though small, about five miles in diameter and nearly circular in shape. North of the middle park but not very distinctly visible from Mount Powell, is the North Park. To the west, just on the verge of the horizon, is a high range called the Elk Head Mountains. Long, high ridges rising to the limit of perpetual snow may be seen far to the west, apparently composed of stratified rocks. Through these ridges the little streams have cut deep gorges as they flow westward to the Colorado River. These gorges must present most excellent sections of strata to the geologist.

Here and there we can see the whitish marls and sands of the modern lake-deposits on the upturned edges of the variegated beds. In the deep basin of the Middle Park these Pliocene or Post-pliocene deposits are quite conspicuous. The rocks which compose the great mass of the Blue range may be called granites. Much of the rock is banded and stratified, but the older portions are massive and solid, that is, the lines of bedding are wanting.

From Mount Powell we descended the west side of the mountain again, and returned to Eagle River. The evidence of the former existence of a large glacier extending up into the mountains in various directions and filling up the valley of the little stream is quite clear. The valley is oval in shape, and about four miles from the base of the mountain closes up into a narrow channel, in which are a number of morainal ridges. Above the ridges is a small lake one-fourth of a mile wide, which was undoubtedly formed by the glacier. The high ridges on both sides are covered thickly with rounded bowlders. Interstratified with the red sandstones are some thin layers of limestone, in which are numerous fossils, *Crinoids*, *Corals*, *Productus*, &c., with other forms which are unmistakably of Carboniferous age.

The dip is very slight, hardly more than 3° for several miles. The fallen timber is a great obstruction to traveling. In the autumn the surface becomes as dry as tinder, and the fires run over the country, destroying the life of the pines as they stand. The winter and spring winds prostrate them in every direction, so that they sometimes form a net-work 5 or 6 feet high for many miles.

As we descend Eagle River below the mouth of Roches Moutonnés Creek, the valley closes up for several miles, but expands out again to half a mile in width, with soft beds on both sides. High on the mountain-slopes are thick groves of poplar or quaking asp. A group of beds comes in on this stream about ten miles below the Roches Moutonnés Creek, 1,200 to 1,500 feet in thickness, which appears to be separate from the regular formations, apparently a partially fresh-water deposit, for in some thin layers of impure limestone were numerous small shells like *Planorbis*, and *Physa*, and the lower 400 feet are composed of very thinly laminated shales, while the upper portions are very gypsiferous, and might be called gypsiferous clays and marls.

This group appears very abruptly, and continues down the river for a few miles, and then disappears as if it formed a sort of basin in the variegated group. Whatever may have been the origin of this curious gypsiferous group, it seems to be local, and to lie in the Carboniferous or between the Carboniferous and the Triassic.

We traveled along the valley so rapidly that I could only examine the immediate channel of the river; and I here present these hasty observations to call attention to the group. The whole district will be studied in detail during the summer of 1874.

Above the gypsiferous group is a series of the brick-red beds, 500 feet or more, and still above a series of variegated beds 400 to 500 feet thick. In the lower portion of the gypsiferous group, in a bed of limestone, I found a species of *Productus* and a *Spirifer*, all Carboniferous forms.

Above the gypsiferous group, and just below the brick-red beds, I found, still lower down the river, in a bed of blue limestone, an *Orbicula*, plainly a Carboniferous specimen.

The evidence seems clear that all the rocks on Eagle River are of Carboniferous age. As we continue down the Eagle River to the northwest, toward its junction with the Grand, there is a very curious twist in the bed, which can hardly be described except by an illustration.

Hitherto the great mass of the strata has been inclining from the range of the Holy Cross, but here we seem to have met the force which acted from the direction of the Blue River range, by which the dip is suddenly changed by a remarkable cause from a northeast to a northwest direction, and while some portions of the group incline at an angle of not more than 20°, others stand nearly vertical, and in some instances have passed a vertical. We have here exposed in Eagle River a series of curiously-variegated beds, at least 4,000 feet in thickness, of Carboniferous age; above them 1,200 to 1,500 feet of brick-red sandstones and clays, probably Triassic, and above them 200 feet or more of Jurassic age; then overlaid by a heavy bed of quartzite, 150 feet thick, undoubtedly No. 1, or Dakota group. Above the last are the black plastic clays of No. 2, in a nearly horizontal position. Overlying the clays is a bed of dark limestone filled with fossils, as *Inoceramus*, *Ostrea congesta*, and other forms of mollusks, with abundant fish-remains, but so broken that scarcely a good specimen could be found.

At this point we left Eagle River and struck across the country north-northeast through a synclinal depression, or a sort of basin, from five to eight miles in diameter, with the quartzites of the Dakota group rising up with a gentle slope on all sides, while the high divide on the north side of Eagle River is elevated by the dikes of basalt so as to form a rim connecting the east and west sides of the basin. Eagle River, below the point where we left it, just before it joins the main stream, cuts through No. 1 and a great thickness of the brick-red beds, which are elevated so as to show a general dip east and northeast, while on the opposite side of the synclinal the dip is south and southwest.

The quartzite bed of the Dakota group gives character to the slopes as well as to the topography of this immediate region. The strata inclining to the north and northeast has been elevated by the Holy Cross range, while the almost vertical beds on the opposite side of the synclinal have been lifted to their present chaotic position by two forces; one acting from the Blue River range, and the other arising from the outflow of igneous matter in the form of dikes. We may state, in general terms, that in the Middle Park and its surroundings the complications in the positions of the strata of the various formations have been produced by igneous eruptions. The terraces along Eagle River ought to receive a passing notice. There are usually two of them. Varying from 10 feet to 50 or 100 feet above the river, usually covered with rounded bowlders, there is a good thickness of the drift on them, but the underlying strata of the original formations are everywhere exposed, showing that the valley is for the most part one of erosion.

Not unfrequently the river cuts a narrow channel across the upturned edges of the basis rocks, which, in this way, may be traced across the valley from bluff to bluff. The height of the divide overlooking Eagle River is 1,450 feet above the river-bed, and this may be taken as the aggregate thickness of the entire Cretaceous group in this basin. All the divisions appear to be represented; and what we usually regarded as No. 5 I estimated as 400 to 500 feet thick, composed of brown arenaceous shales, with irregular beds of sandstone, varying from a few feet to 100 or 150 feet. In No. 5 are a great abundance of fossils of the genera *Inoceramus*, *Baculites*, *Ammonites*, &c.

The surface of the entire country is exceedingly rugged, and the high ridges, underlaid with No. 5 or No. 1, contrast curiously by the luxuriance of vegetation with the barren, sage-covered surface of the black plastic clays of Nos. 2 and 4. The high ridges of the divide are covered with vesicular basalt, much of which is spongy, like lava. The dikes have a trend about 20° south of east, and as they are very numerous and are nearly parallel, resemble waves of the sea as they extend along the surface in more or less elevated ridges. These basaltic ridges are sometimes continuous for several miles, but they usually break up into fragments, yet still preserving about the same trend. As we travel from Eagle River to the valley of the Blue, the surface is covered to a greater or less extent with loose fragments of modern basalt, varying much in texture and color. The country reminded me very much of portions of the Yellowstone Valley in Montana. As we descend into the valley of the Blue, below the junction of the Grand, we can see that the high ridges on either side are capped with basalt, but underneath are the black clays of the Cretaceous.

A great thickness of the sedimentary beds cover the country, but they are literally riddled with dikes, and the strata are thrown into complete chaos. On the north side of the Blue River, about fifteen miles below the junction of the Grand, are several long mesa-like ridges that rise 1,000 to 2,000 feet above the river-bottom, and apparently incline from an extension of the Blue River range along the west side of Middle Park.

These mesas present a structure too complicated for our limited time, but the entire mass seems to have been lifted up nearly vertically, producing great faults, so that on the south side the variegated beds which lie beneath the Cretaceous group were tipped up at the base in a vertical position, and sometimes 15° to 20° past a vertical.

These mesas, capped with basalt, slope southwest 5° to 15°. In the sides of these mesas several beds of basalt are shown, varying from 4 to 40 feet in thickness, with a layer of volcanic tuff intervening.

To work out the complicated structure of this most interesting region would require the diligent labor of a season, and I can in this report only notice it in general terms. There are, however, most abundant illustrations of the action of the two forces, one of which, long continued and uniform, produced the anticlinals which are continually interrupted or thrown into confusion by the eruption of volcanic matter. Along the Grand and Blue Rivers, on the west of the Middle Park, are three quite important cañons, the Lower, Middle, and Upper. The Lower Cañon is formed by the passage of the Blue River at right-angles through a high ridge of feldspathic gneiss, with walls 1,200 feet high. There seem to be a number of these granite uplifts, extending with a nearly north and south trend across the park. The most western one rises about 1,200 to 1,500 feet above the bed of the river. From either side of these granite nuclei the sedimentary beds incline at various angles. The Middle Cañon is about three miles below the junction of the Grand River with the Blue, and is much the most extensive. The Lower Cañon is only about one-third of a mile in length, while the Middle Cañon is full three miles long.

The anticlinal ridge, as it might be called, is really an extension northward of the Blue River range, and forms the west rim of the Middle Park. The slopes on the east side are all gentle, and are mostly composed of the quartzites of the Dakota group. So far as I could ascertain, the quartzites rest directly on the granite nucleus and flex over the sides like a gently sloping roof. In the interval between the western and middle ridges there are several small ridges or uplifts of the granites that produced small anticlinals and synclinals. There is one about two miles above the Lower Cañon and between it and the Middle Cañon; the variegated beds form a well-marked synclinal. Scattered around among the uplifted masses are depressions or basin-like valleys that are filled with the modern lake-deposits. In the gorge of a little branch that flows into the Grand from the south side, just above the Lower Cañon, there is a bluff-exposure of these modern deposits, mostly of a deep drab or flesh color, and sometimes are 50 feet high, with three layers of sandstone each 4 to 6 feet in thickness; at another locality 200 to 300 feet in thickness of these modern deposits, with a bed of basalt near the summit.

Like the modern lake-deposits in the valley of the Yellowstone, they are very often capped with a basaltic layer. There is no doubt that during the existence of the Pliocene or Post-pliocene lakes there were repeated eruptions of basalt, and probably there were hot springs which dissolved the silica and feldspar, thus producing the fine materials which have entered largely into the composition of these deposits. Between the west ridge and the middle ridge there is an interval of about five miles.

In this interval the variegated beds seem to have thinned out much from the west toward the east, and here they rest directly on the granites. I call them variegated beds from the great variety of colors they present. Whether they be Jurassic or Triassic age, or both, I could not tell. I only know that the well-marked Cretaceous beds are immediately above them. Immediately below the Middle Cañon the Grand River flows for about three miles through what I would call a valley of depression; the river cuts down into the granite base, and at the lower portion of the little basin forms a narrow cañon with vertical sides or walls 50 feet high, while on either side granite hills rise 1,000 to 15,000 feet above.

In the basin and resting upon this granite rock, but inclining at various angles, is a considerable thickness of the variegated group. Neither on the middle ridge nor in the valley of the Blue or the Grand, east of this point, did we observe any of these red beds, and the quartzites of the Dakota group rested directly on the granites. The entire disappearance of from 4,000 to 6,000 feet of sedimentary beds within so short a distance is certainly worthy of note.

I have mentioned the parallel ridges that extend across the Middle Park in a nearly north and south direction, through which the Grand River has carved out deep cañons.

On the west side of Blue River there is one important ridge rather convex in form, with a granitic nucleus. On the west side, near the pass that leads over into the valley of the Blue River, is a singular mass of basalt, with a form so peculiar as to readily attract the attention of the traveler. It has much the shape of a huge steamboat. The materials were effused in such a manner as to form a series of thin layers, flexed upward at each end, dish-like, with vertical sides 100 feet or more. These dishes in the granite nucleus are very common. In some instances the effusion of the basalt has changed the adjacent rocks, and in many cases it has flowed out like water from a spring, producing no change, but simply covering the surface for a greater or less distance with the igneous rocks. On the high summits of the surrounding ridges caps of basalt are common, giving them a partial table-like form.

As we descended the mountain-ridge into the valley of the Blue, soon after passing the summit, we found the quartzites of the Dakota group apparently resting directly on the schists, and as we descend the gently sloping east side we here find sections of the full series of Cretaceous beds inclining not more than from 5° to 8°. As far as the eye could reach, from Mount Powell northward, the quartzites of the Dakota group laid over the east side of the ridge like the roof of a house. On the east side of the Blue there is a high Cretaceous ridge, mostly above the Dakota group, penetrated in numerous places by dikes, out of which great masses of basalt have flowed over the surface. The river itself for a distance of nearly 20 miles to its junction with the Grand flows over the black-clay shales of No. 4 and the dark-gray calcareous shales of No. 3, following a monoclinal interval.

The terraces along the Blue River are quite noticeable. There are two principal ones, but these not unfrequently break up for short distances into several smaller ones. On the east side of the Blue River, near the junction with the Grand, and on the north side of the Grand, are isolated, low hills of granitic schists, around the sides of which the Cretaceous clays are elevated at moderate angles. As we ascend Grand River even the Dakota group thins out to a considerable extent, so that in some localities it is quite probable that the entire Cretaceous group is wanting, and the lignitic strata repose on the schists. Above the junction of the Muddy the valley of the Grand reveals a good thickness of the lake-deposits. The terraces are also quite well marked, rising sometimes 80 to 100 feet above the bed of the river.

MIDDLE PARK.

The geological structure of the Middle Park has been so carefully studied by Mr. Marvine that I will pass over it very briefly. The geology is very complicated and of great interest; but in order that it may be clearly understood, it must be presented in great detail with illustrations. This Mr. Marvine was able to do. In 1869 I spent a few days in the park, and the results form one of the chapters in my annual report of that season.

The variegated beds occur in the southwest portion of the park near Frazer River, beneath the Cretaceous group, and though far less conspicuous than on the east side of the front range, are undoubtedly of Jurassic age. Near the hot springs there is a high hill, sometimes called Mount Bross, to which I directed attention in 1869. It is composed almost entirely of beds of the Lignitic group, 1,800 to 2,000 feet high above Grand River.

From this hill we obtained a great variety of fossil-leaves characteristic of the Lignitic group. From this group in the Middle Park Mr. Lesqureux has identified *Sapindus angustifolius*, *Staphylea acuminata*, *Planera longifolia*, *Rhus drymeja*, *Glyptostrobus europaeus*, *Sequoia angustifolia*, *Fraxinus prædicta*, *Ulmus tenuinervis*, *Myrica acuminata*, *Ilex sphenophylla*, *Pterocarya americana*, *Rhus Haydeni*, *Myrica latiloba*. Of the above-mentioned species *S. augustifolia* and *Planera longifolia* occur in acknowledged Tertiary strata near Elko Station, Nevada, and the former is also found in the South Park. *Ilex sphenophylla* occurs at Green River. The *Glyptostrobus europaeus* is found at Fort Union and in the arctic regions, and is regarded as a Miocene species. So far as we can judge from the fossil-plants, this great series of strata in the Middle Park must belong to the Lignitic group, and is probably of Lower Tertiary age.

On the north side of the Grand River, about the source of Troublesome and Willow Creeks, and between those two streams, the aggregate thickness of the Lignitic group cannot be less than 4,000 feet, and it is probably greater even than that. This is made up of sandstones of various texture with partings of clay, the entire mass having the dark, somber hue which characterizes the same group about the sources of the Missouri and Yellowstone Rivers.

These beds have been so thoroughly studied by Mr. Marvine that I allude to them in this connection simply to call attention to the possibility that they did not form a connection originally with the same group on the east side of the range. The differences in thickness and in lithological character of all the sedimentary groups in the Middle Park, as well as their position, indicate that a portion of the Front range was elevated above the sea, thus cutting off this portion from the east side. Although the peculiar flora of the Lignitic period is very abundant in the Middle Park series, no beds of coal have been observed as yet, and in this respect they offer a marked difference.

I have hitherto been disposed, from the original evidence shown at the northward, to regard the physical connection of this great Lignitic group on opposite sides of the mountain-ranges as proven, but there is some doubt on this point, and I now await further proof.

REPORT OF ARCH. R. MARVINE, ASSISTANT GEOLOGIST DIRECTING THE MIDDLE PARK DIVISION.

WASHINGTON, D. C., *June* 19, 1874.

SIR: I submit herewith my report on the geology of the region traversed by the Northern or Middle Park division of the United States Geological and Geographical Survey of the Territories during the working season of 1873.

The field was taken May 29 with a party proper consisting, beside myself, of Mr. G. R. Bechler, topographer; Mr. S. B. Ladd, assistant topographer; Sheppard Madeva and Robert Mitchell, packers, and George Bowline, cook; the transportation of our baggage being effected by means of a train of seven pack-mules. The methods of work were precisely the same as in the other parties. Messrs. Gardner, Holmes, and Chittenden accompanied the party during the first month of the season, when the base-line was measured, and the movements so directed that the stations forming the first expansion of the primary triangulation could be conveniently visited. When Mr. Gardner left to continue this work, and Messrs. Chittenden and Holmes to join their respective parties then entering the field, Messrs. Enos T. Luce and S. H. Nealy, general assistants, joined me, and the work was directed solely to serve the purposes of the detail topography and geology. The continental divide over into the Middle Park was permanently crossed on September 2, soon after which Messrs. Luce and Nealy returned, reducing the party to its original number. In mid-October the breaking up of the season rendered it judicious to return over the mountains before permanently closed with snow, and on the 15th of the month we turned homeward, leaving a portion of the work in the vicinity of Breckinridge incomplete. Being on the route to our work of the coming season, it can then be conveniently and speedily finished.

The area actually examined during this interval of time, so that both its topography and geology can be mapped in considerable detail, is nearly four thousand square miles, which, by material obtained from the land-surveys upon the plains, has been extended eastward to include a total area of over fifty-six hundred square miles. This area is approximately in the form of a rectangular belt sixty miles wide north and south, the eastern end resting on the western border of the great plains and including Denver City, and extending westward over the main chain of the Rocky Mountains, and across the Middle Park to the Park range bordering the latter on the west. West of the plains there are no large level areas to facilitate rapidity of work, while much of the zone of mountain country bordering the main divide on the east not only presents peculiar difficulties to rapid and at the same time accurate mapping, but it is comparatively thickly settled, and demanded much more time for its completion than equal areas elsewhere. Mr. Bechler's map of the whole region, on a scale of two miles to an inch, and in 200 feet approximate contours, is now very nearly finished.

Geologically the area surveyed divides itself into three natural districts: first, the sedimentary rocks of the plains; second, the great system of archæan metamorphic schists and granites forming the Front and Park ranges, with some minor areas; and third, the sedimentary rocks of the Middle Park.

On account of the greater length of time spent upon the eastern mountain-zone, a very great number of observations were made upon the archæan rocks composing it, and a fair insight gained of their general characters. Though the sedimentary rocks were much more rapidly passed over, yet their comparative simplicity of structure and persistence of lithological characters rendered them easier of study, and has permitted of my plotting all my observations among them on the drainage map furnished me by Mr. Bechler early in the spring, and of my completing my chapters upon them to the full extent of my observations.

I may say here that during the season the sedimentary rocks of the plains were avoided as much as possible, and preference given to the less-known archæan rocks of the adjacent mountains, with the expectation that when the autumn snows should have driven us from the latter work could still be prosecuted among the former, an expectation not realized because of the early return of the party to the East. In order to make my scattered observations among these sedimentaries more connected and useful I have thought it desirable, therefore, to utilize such other published observations upon them as I have been able to find, chiefly from your own reports, giving credit and references in their proper places.

Notwithstanding the special attention given to the archæan rocks, their far greater complexity requires that before the large number of disconnected observations made among them can be properly discussed and correct results drawn from them, they should first be carefully plotted on the finished topographical map. Since this is as yet impossible, I have been obliged to treat this subject—the most interesting one presented in the region in question—very briefly, simply giving the most general impressions received while in the field, and without a proper digest of the notes at hand.

Accompanying the report I submit also a provisional geological map, colored on a photographic copy of the drainage map of the district, as accurately as it can be done on a map expressing no topographical features except the streams, and which will serve for office use until the completion of the final map.

The report which Mr. Ladd makes to you separately on the means of communication, elevations, distribution of timber and agricultural lands, and population within the district, will greatly supplement the first chapter of my report, and completes, I believe, the record which is to appear in this annual report of the material gathered by the Middle Park division during the past season.

Besides acknowledging cordial co-operation from all members of the party, I wish also to refer to the many services volunteered by Messrs. Luce and Nealy while attached to it.

For aid in my own specialty I wish to particularly recognize the services of Mr. Holmes, Mr. Ladd, and George Bowline in the field, and of Mr. Ladd and Mr. Holmes in the office, for to them are chiefly due the sections, maps, and views accompanying this report. To Mr. Berthoud,

of Golden City, is also due much information about the coal-openings of the Territory.

Rapid preparation of a summer's observations, together with absence during publication, must atone for many errors which will inevitably occur.

Very respectfully, yours,

ARCH. R. MARVINE,

Assistant Geologist, Directing the Middle Park Division.

Dr. F. V. HAYDEN,

In Charge of the United States Geological and Geographical Survey of the Territories.

CHAPTER I.

AREA, NATURAL DIVISIONS, AND PRINCIPAL TOPOGRAPHICAL FEATURES.

The territory embraced by the survey of the Northern or Middle Park division during the summer of 1873 is included between the parallels of 39° 30′ and 40° 20′ north latitude, and the meridians of 104° 45′ and 106° 30′ west longitude. It forms, therefore, a rectangular area, which has a width north and south of about sixty miles, a length east and west of about ninety-three miles, and which contains nearly five thousand six hundred square miles. This area may be conveniently located by reference to the Union Pacific Railroad, which passes about fifty miles north of its northern border, on which side it is directly joined by a similar area of the fortieth-parallel survey.

The eastern portion of this parallelogram rests upon the western border of the great plains which extend uninterruptedly from the Mississippi and Missouri Rivers, and includes some of the most thickly settled portions of Colorado. Denver City, and many smaller towns, with their railway connections and surrounding agricultural regions, are here situated.

The middle portion of the district is traversed north and south by one of the highest portions of the main continental divide, with, on either hand of the great crest, the accompanying zone of mountain country, which contains nearly all of the more important metal-mines of the Territory.

The western portion of the area is chiefly occupied by the several depressions which together make up the Middle Park, with their separating ridges, and is limited upon the extreme west by the Park range. A strip along the southern edge of this portion was not completed by this season's work. Regarding its broadest topographical features, therefore, this rectangle may be considered as dividing itself naturally into three portions, which we may conveniently designate as the eastern portion, or the plains, the middle portion, or the mountains, and the western portion, or the park. So far as drainage alone goes, the district as a whole may be regarded as being separated by the nearly north and south crest of the main mountain-divide into two very nearly equal east and west portions, in each of which the drainage system is quite simple. The main artery upon the east is the South Platte River, which flows diagonally northward and eastward across the plains portion of the district. All the streams rising at the eastern base of the main central ridge flow in a general eastward direction, joining here and there, and within the limits of the district find their way into the South Platte.

In the western half of the district the drainage is somewhat different, though still very simple. The main divide not only passes through the center of the district, but, at the north, turns westward along its northern border, while at the south it also turns westward, trending along the southern border, thus inclosing the park on the north, east, and south sides. From all sides of this natural rim the streams flow inward to join the Grand River, which flows east and west through the middle of the system, forming its main artery. All the waters thus find their way out of this basin through the single cañon which the Grand has cut across the Park range at about its middle point, and flow on westward to join the Colorado River and the Pacific Ocean. Upon the north the North Park gives rise to the North Platte; upon the south the South Park gives rise to the South Platte, and both flowing eastward their united waters finally join the Missouri. The Middle Park is thus inclosed by a great eastward loop of the main continental divide, and it forms the easternmost point north of Mexico at which waters flowing into the Pacific take their rise.

PRINCIPAL TOPOGRAPHICAL FEATURES—MAIN DIVIDE.

The crest of the main divide crosses the northern line of the district in longitude 105° 45′ west, or at about midway of its length. From this point its trend for ten miles is southeast to near Long's Peak, where it turns directly southward, but with an undulating course, a distance of sixteen miles, to Arapahoe Peak. Along this line, the range is an exceedingly formidable one, and presents all the features of mountains composed of granitic and schistose rocks.

The eastern face of the crest presents an almost continuous line of amphitheaters and gorges rimmed with precipitous walls, which rise to a serrated crest of which many points reach an altitude of between thirteen and fourteen thousand feet above sea-level, while not a single pass exists except such as the most expert mountaineer might with difficulty ascend. Some of the higher points exist as eastern spurs somewhat detached from the main ridge; such are Long's Peak, (14,270 feet,) Mount Audubon, (13,190 feet,) and Smith's Peak, (13,090 feet,) on either side of which are the deep-cut gorges, reaching past them to the steep cliffs beyond, at the bases of which the banks of everlasting snow are constantly eating their way farther and farther into the range.

Upon the northeast side of Long's Peak, forming its very face, is a sheer, almost perpendicular, cliff, over 3,000 feet in the clear, reaching from the mountain-summit to the timber-line, the grandest wall of rock imaginable.

The western side of the main divide does not present so well-defined a ridge. Instead, it is lined by a zone of high mountains, from five to ten miles across, which falls abruptly, though not precipitously, to the great trough-like valley of the Upper Grand. It is cut by profound cañons draining into the latter. Upon the southwest, this rugged mass is sharply limited by the East Fork of the Grand, while Arapahoe Peak forms its southern apex. From Arapahoe, for twelve miles directly south to James Peak, the topography changes. The crest presents a very uniform ridge rising but little above timber-line, and for five miles near the southern portion scarcely varying 200 feet in altitude. As at the north, the eastern face of this ridge is precipitous, falling in great cliffs to a series of amphitheaters which make up the front, each with its bank of snow lying up against the base of its rocky walls. Some of the rounded spurs reaching eastward between these amphitheaters afford a means of access to the ridge. Thus, at the north end of this depressed region, and directly at the base of Arapahoe Peak, is the Caribou Pass, as yet not well opened, and unpromising; about midway of its length is the Boulder or Rollinsville Pass, (about 11,400 feet,) now reached by a road over which wagons can pass; while at its southern end, below the walls of James Peak, is the James Peak trail, a wagon-road from Central City reaching as yet only to the base of the Peak.*

The western slope from this ridge is of a very different character from the eastern slope. Though of course having many of the characteristics of a rugged mountain region, yet, as compared with the east slope, it has no precipitous front, but its massive westward spurs fall in rounded, gently-molded slopes, not separated by deep cañons, to the basin-like depression of the Frazier River. The line of separation between this region and the rugged mountain area at the north is exceedingly sharp, and is occupied by the East Fork of the Grand. Rising from the cañon of the latter on the north and east is the maze of peaks and rugged ridges, separated by profound gorges and amphitheaters, which drain into the East Fork. The south bank of the cañon, however, is cut by no important side gorge, but only by local gulches; and rising up its steep but even slope the summit ridge is found to be a comparatively smooth table or plateau, sloping westward, with gentle elevations here and there. All these massive spurs to the south have these more gentle slopes, and are remarkably similar in general section.

At James Peak, (13,283 feet,) there rises another group of rugged mountain points, among which are Mount Parry and Mount Flora. Here the divide bends more and more westward, and after making a southing of about five miles and a westing of about ten miles, it again swings southward for seven or eight miles and then southeastward for about an equal distance, taking the famous Gray and Torrey Peaks on the way, the former being 14,340 feet high, and the latter but about 5 feet lower. Though from here the drainage divide turns again westward and southward, passing into the South Park, or middle division of the survey, yet the higher ridge runs eastward as a great spur which culminates in Mount Evans, a great massive mountain, which rivals Gray and Torrey in altitude. From James around to Evans is thus a great western loop, inclosing the headwaters of Clear Creek. It represents, also, a high mountain region, not as a whole, perhaps, so rugged as the Long's Peak mass, but more extensive, spread out, and diversified in its character, yet possessing some of the grandest mountain features and most impressive scenery.

After leaving the James and Parry groups of peaks, and passing westward along the northern side of the loop, the ridge becomes less rugged, somewhat resembling that north of James Peak, while some of the separating valleys are cut to the timber-line. One of these forms Berthoud's Pass, (11,349 feet, Parry,) the summit of which is not much more than seven miles from Empire City, on the North Fork of South Clear Creek, and over which a wagon-road exists, and a narrow-gauge railway-line has actually been surveyed over to the South Forks of the Frazer River. The break next to Berthoud's Pass is called Vasquez Pass, (about 11,500 feet.)

The mountain spurs descending northward to the Frazer here pre-

* For passes and means of communication generally, with information given more in detail than here, the reader is referred to the report of Mr. S. B. Ladd.

sent the same smooth and rounded contours as those on the east side of the Frazer basin. From the northeast corner of the loop a high spur runs out, separating the Williams and Frazer drainage, and culminating in Mount Byers, (12,778 feet,) one of the most commanding points of all the Park region, at the north.

The western side of the loop is a rugged mountain ridge, with, I believe, a difficult pass, called Jones's Trail, across to the headwaters of Williams River. The descent to the main valley of the latter, along the west side of this loop, and from the Mount Byers ridge, is in great massive spurs, descending rather abruptly, but still quite evenly, and cut by deep gorges. The Gray's Peak ridge is much the same, rugged and grand, yet, on the western side, with an obvious tendency in the spurs to a general plateau-like area, though it is almost obliterated by the many cañons. Directly beside the peak, passing almost over its top, is a fair trail for animals to pass, while a few miles to the east a wagon-road is built, crossing the range at the Argentine Pass at an altitude of about 13,200 feet, and connecting Georgetown with Montezuma and the other mining towns upon the headwaters of the Blue River. Nearer Mount Evans a trail crosses the Evans spur from Georgetown over into the South Park.

Eastward from Evans the spur is continued by a long ridge-like line of hills, reaching nearly to the plains, and separating the waters which flow southward into the South Platte, and without my district, from those which flow eastward and into it. It forms, with the course of the main divide upon the west, a natural southern boundary of the district.

PRINCIPAL TOPOGRAPHICAL FEATURES OF THE EASTERN SLOPE.

The crest of the main divide as thus traced may be considered as presenting, as a whole, a flat convexity to the east, on which side its principal characteristic is abrupt slopes, usually in high precipices, surrounding profound amphitheaters. Extending eastward from these first abrupt slopes is a zone of mountain country which is narrowest at about the center of the district, where it extends about seventeen miles east from the main crest, but widening at the north and south borders of the district to nearly thirty miles. The eastern face of this zone thus presents a flat concavity to the east, the general trend of which is north and south, while the depression westward in the center is about ten miles.

This eastward border of the mountain-zone is exceedingly sharp and well defined, and all along it the mountain-spurs abruptly give way to the plains which stretch away uninterruptedly far to the east.

This mountain-zone can in nowise be regarded as made up of distinct ranges or a system of ridges, but as a unit in itself, having characteristics which hold very uniformly over nearly all its parts. From beneath the precipitous crest, from all the gorges and amphitheaters at its base, flow innumerable streams which, after emerging from these upper cañons into the smoother highlands, soon collect into a few principal water-courses, generally uniting where they are not in deep cañons. Flowing in a generally eastern course these gradually sink their channels deeper and deeper into the rocks, the different main streams uniting their cañons here and there, and finally issue from their deep-cut gorges in the mountain-front to flow out into the plains and to the Platte. Though over fourteen main branches may be considered as rising within the fastnesses of the main crest, their united waters break through the mountain-front in only seven points, while uniting still further in the plains, but four principal streams reach the Platte.

This is not including the many streams which rise in the mountains east of the crest, some of which unite with the main streams, while others break in minor cañons from the mountains; while still others rise independently in the plains, forming subordinate branches of the Platte. Of the first class—those rising at the main crest—may be enumerated, commencing at the north, The Big Thompson, North, Middle, and South Saint Vrains, Jim Creek, North, Middle, and South Boulder Creeks, North Clear Creek, Fall River, North and South Forks of South Clear Creek, Chicago Creek, and Bear River. Of the minor mountain-streams, those rising east of the crest, there are, likewise commencing at the north, the Little Thompson, Left-Hand Creek, Four-Mile Creek, Coal Creek, Ralston Creek, and Turkey Creek. Those that issue from the mountains are as follows: The Big Thompson, Little Thompson, the united Saint Vrains, the united Jim and Left-Hand Creeks, united Four-Mile and North and Middle Boulder, the South Boulder, Coal Creek, Ralston Creek, the united Clear and Chicago Creeks, Bear and Turkey Creeks; while the united Thompsons, the united Saint Vrains and Boulders, the united Ralston and Clear Creeks, and the united Bear and Turkey Creeks, or only four in all, join the Platte.

The tendency of these cross-cutting streams is to throw this eastern mountain-area into east and west ridges. These ridges, however, are seldom sharp, but massive, and rather than striking one as a system of ridges it impresses one as a system of deep-cut river-channels. Large, flat, park-like areas are numerous. In the northern two-thirds of this area, approximately parallel with and a few miles east of the first great slopes of the divide, is an irregular zone but little intersected with cañons, and these not deep, and varying in altitude from 8,500 feet to 9,000 feet. It is a park region of rolling pine-sprinkled surfaces, with the high spurs rising on the west, and the mouths of the deep gorges which extend back to the range opening out upon it. In going east, as the cañons cut deeper and deeper, the spurs perhaps not changing greatly in altitude, traveling north and south becomes almost impossible. Throughout this region, however, except Lilly Mountain, just east of Long's Peak, and Ralston Butte, between Ralston Creek and the South Boulder, there is a remarkable uniformity in the height of these ridges. Their tops are frequently quite level or gently rounded; while standing on one, the general level, which seems indicated in their tops, is very striking. South of Clear Creek, in approaching the Evans Ridge, this general summit-level is more irregular, the Squaw Chief and Bergen Park Mountain rising to exceptional heights; yet, even here, large areas are frequently undulating or level, forming beautiful park-like regions; here usually occupied as farms or for pasturage. As viewed from the plains this general evenness of the tops of the "foot-hills" is very striking. The majority of these ridges rise somewhat above 8,000 feet, while the plains along the eastern base of the mountains average not far from 5,600 or 6,000 feet. A few points along the face of the mountains rise higher than the country immediately in their rear, such as South Boulder and Golden Peaks, and Bear Creek, which stand close to the mountain edge.

But as a whole the mountain-zone lying between the main divide and the plains certainly impresses one as being, with a few exceptions, a region of very uniform or gently undulating general elevation, carved by the powers of erosion, perhaps partly glacial but mostly by streams, into a mountain area of which portions are exceedingly rugged.

PRINCIPAL TOPOGRAPHICAL FEATURES OF THE MIDDLE PARK.

We have already seen how the branches of the Grand join it from the northeast and south, like the rays of a great irregular leaf uniting with the parent stem. Along the main Grand, especially where joined by its tributaries, and following along some of the latter, are flat, open and treeless areas, which may be considered as forming the Middle Park proper. The ridges separating these tributaries are mostly well defined, some reaching altitudes of from 2,000 to 4,000 feet above the adjoining streams. These are mostly of sedimentary rocks, and quite different in character from the mountains of harder metamorphic rocks forming the main range.

The Middle Park thus differs from both the North and South Parks on either hand, which are much better defined, large, basin-like areas less broken up by local ranges. Indeed, the Middle Park is a sort of accidental middle ground between the two. The more important geological dividing line between the North and South Parks is the great fold which causes the massive spur of metamorphic rock west of the Gray Peak mass, joining it with the Park range, though cut through by the Blue. Between the Middle and North Park no such profound geological fact exists; there is no folding whatever, but the divide has been determined by the masses of hard eruptive rocks which have here found vent and protected the softer rocks below from erosion. Indeed, it is just possible that the drainage of the Middle Park once had its outlet into the North Park.

In speaking of the more special topographical features of the Middle Park region, those portions adjacent to the high eastern ridge have already been referred to. Such is the rugged, cañon-cut mountain area west of Long's Peak, separated by the East Fork of the Grand from the more gently-contoured massive spurs to the south, which swing around with the main ridge from Arapahoe, through the James Peak group to Mount Byers, inclosing on the east, south, and west sides, and partially on the north, the basin-like drainage-area of the Frazier. The latter river, after collecting the surrounding waters, escapes from this basin by a cañon carved through about six miles of the low northern portion of the surrounding granite, and enters the basin of the Grand. The main fork of the Grand, before joined by the east fork, occupies a remarkably well-defined, trough-like valley, trending directly north and south. Its headwaters rise in the deep gorges separating the main range from the high southern end of the Medicine Bow Mountains, whose northern extension forms such a symmetrical eastern border to the North Park. But where it crosses the north line of the district the V form has changed to the U form, with a comparatively flat bottom, between one or two miles broad, while the ends of the massive spurs forming its sides rise abruptly, but in rather smooth curves, on either hand.

The eastern slope of the valley retains its height and character all the way down to where joined by the East Fork, though cut by the many gorges draining the mountain area. The western slope, at the north, rises equally high and steep, though the crest being less distant it is cut by lesser cañons. Toward the south the top of the ridge becomes smoother in contour and gradually falls, finally giving way to the flattish region adjacent to the Grand. Here the latter turns westward and in a basin-like terraced area receives the waters of Willow Creek from the north and of the Frazier from the south. Passing on west it flows through two short rifts, or breaks in upturned strata, to the Hot Springs, which by their reputation and position virtually form the center of the Park. Here the stream enters a shallow cañon three or four miles long, after which, for over fifteen miles, its course is through an extensive basin, much of the region along its lower course being river-bottom land. Williams River joins it from the south, while Corral and Troublesome Creeks flow into it from the north. The Muddy from the north and the Blue from the south, however, are the two principal tributaries of the Grand and join it at nearly the same point, just before it enters the cañon through the Park range which carries it from the Park. This lowest point in the Park is about 7,180 feet above tide-water, while the Hot Springs are 7,700 feet, and Grand Lake approximately 8,150 feet above the same.

The Williams River takes its rise in the deep western cañons of the Clear Creek loop and the Mount Byers ridge. Issuing from this granite country it flows for several miles through a wide flat basin tributary to that of the Lower Grand.

The Mount Byers ridge extends from the base of that mountain as a quite straight and even-topped divide, separating the Frazier and Williams waters, and falls abruptly to the Grand at the Hot Springs. On the west side of the Williams Valley is the long, gentle, eastern slope of the symmetrical Williams River Mountains, which reach an altitude of about 11,400 feet, or nearly to the timber-line.

On the north side of the Grand the Willow, Corral, and Troublesome Creeks drain an area which, being a geological unit, has uniform topographical features. The culminating point of this mass is Park View Peak, near the northern line, 12,430 feet high, and directly overlooking the North Park. On either side of Park View Peak the divide between the two parks falls, the descent on the east to the headwaters of the Willow being about 2,620 feet to an excellent pass connecting the parks; a serrated region of not much greater height follows, and finally the abrupt rise to the Medicine-Bow Ridge. South of this line and parallel with the southern end of the latter ridge is a high, even-topped ridge, reaching to timber-line, which is quite surrounded by the eastern branches of Willow Creek. West of Park View, between the two Troublesome Creeks, the ridge is also depressed as on the east, but at the west fork it rises in a high lava-capped plateau, falling on the west to the Upper Muddy. The next point of elevation of this mass is Corral Peak and White-Face Mountain, lying south of Park View, between the Troublesome and Willow Creeks and north of the Hot Springs. These also are due to lava-caps protecting the softer horizontal sedimentary rocks below. Between all these points and extending south to the Hot Springs and across the Grand, somewhat, is a broken country chiefly made up of very numerous small spurs abutting against the streams, in all of which the tendency is to a more or less definite terrace form, the broken terraces rising in steps to the higher lands beyond. The two forks of the Troublesome leave this region, where they join, and for the rest of the course the stream is in a flat basin country like that of the Lower Williams River, tributary to the Grand. This lower basin is separated by a low hilly divide from the Lower Muddy.

The drainages of the Muddy and Blue alone remain to be referred to. Both lay at the eastern base of the Park range, and form very well defined valleys, trending in nearly the same general direction, and facing one another. The valley of the Upper Muddy is broad and shallow, presenting a strong contrast to most valleys of this country. Its general features throughout are rolling-hills upon the sides, with low terrace-forms near the streams, the latter being cut by many side-ravines. All along upon the west is the great, rolling, wave-like ridge of the Park range, thickly timbered with pine. The broad head of the valley is a gentle rise over into the North Park, the divide between the two parks here losing its character of a defined ridge. On the east rises the high table-land separating the valley from the Upper Troublesome, but this soon gives way to the low ridge separating the lower waters of the two streams. Near the head of the valley is a prominent point called the Upper Muddy Butte. Near its lower end, a similar isolated point, rising at the end of the low divide between the Muddy and Troublesome, and called the Lower Muddy Butte, narrows the valley locally before it enters the Grand. The general course of the valley may be taken as south 15° or 20° east.

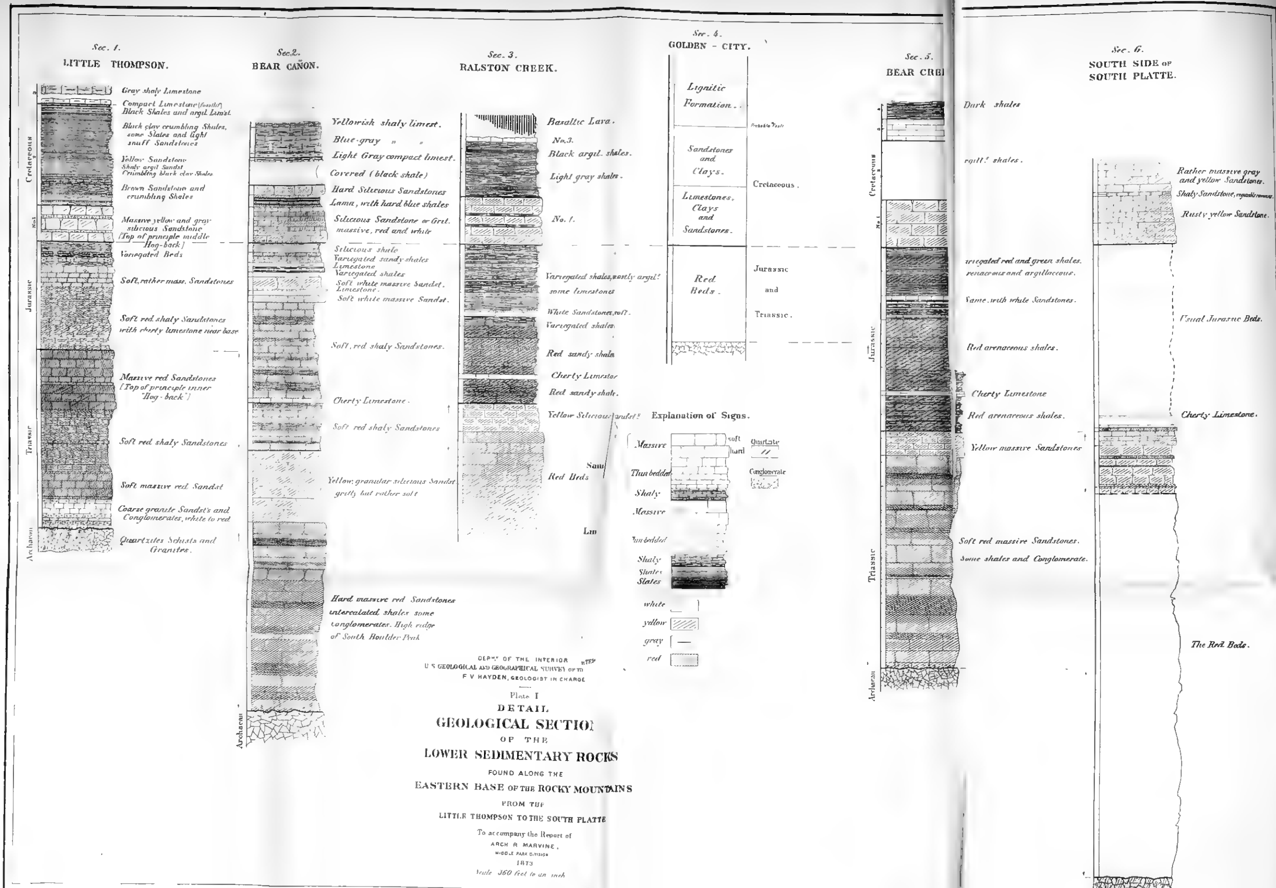
The valley of the Blue resembles that of the Muddy in the terrace features along the stream, but it is a narrower and more strongly defined valley, though by no means of the order of cañons. For the lower twenty miles the general course of the valley is north 40° west. A few miles from the mouth and on the east the Williams River Mountains commence to rise. The western face, or that sloping to the Blue, is much steeper than the slope to the Williams River. It tends to a terrace form, being of strata gently dipping east. The outline is very symmetrical, rising in long slopes and gently-undulating top to a central point, and falling again in going south, but at twenty miles from the Grand River it abruptly joins a mountain region of a different class, namely, the granitic masses west of the Gray Peak group, which line all the remaining eastern side of the Upper Blue and quite change the character of its valley. For nearly twenty miles south of the Grand the Park range on the west retains the same massive, evenly-rolling character as at the north. But suddenly it rises to one of the most rugged ridges conceivable.

The backbone of this ridge is near its western side, and trends about north 40° east, but it is made up of numerous short eastern spurs, which abruptly but pretty uniformly descend along a line nearly parallel with the main ridge. All these ridges are exceedingly sharp, and rise to a very uniform and general level; though the highest point, Mount Powell, is near the north end, and reaches an altitude of 13,285 feet.

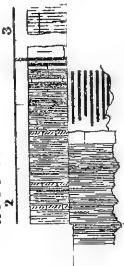
These sharp serrated ridges inclose a system of most profound gorges and amphitheaters. The main ridge is broken through by the valley of Ten-Mile Creek, but is immediately continued upon the south by a ridge running southward to the Mount Lincoln group.

GENERAL GEOLOGICAL DIVISIONS.

The three general divisions to which attention was first called—the plains, the mountains, and the park—the more salient topographical features of which have just been described, are as natural geological divisions as they are topographical ones, and will be considered in the three following chapters in the order mentioned. The one next following, Chapter II, in the sedimentary rocks east of the Front range, presents facts observed mostly along their western border, or near the mountains, together with observations gathered from other sources. Chapter III briefly gives some general results of observations among the Archæan rocks which form the mountains, and though this study was made principally upon the eastern mountain slope, yet the results appeared equally applicable to any other of the crystalline areas observed by the writer. Chapter IV deals with the general structure and distribution of the rocks of the Middle Park.


Sec. 1.
LITTLE THOMPSON.
Gray shaly Limestone
Compact Limestone
Black Shales and argil. Lim'st.
Black clay crumbling Shales, some Slates and light snuff Sandstones
Yellow Sandstone
Shaly argil Sandst
Crumbling black clay Shales
Brown Sandstone and crumbling Shales
Massive yellow and gray silicious Sandstone [Top of principle middle Hog-back]
Variegated Beds
Soft, rather mass. Sandstones
Soft red shaly Sandstones with cherty limestone near base
Massive red Sandstones [Top of principle inner Hog-back]
Soft red shaly Sandstones
Soft massive red Sandst
Coarse granite Sandst's and Conglomerates, white to red
Quartzites Schists and Granites.
Cretaceous
Jurassic
Triassic
Archaean
Sec. 2.
BEAR CAÑON.
Yellowish shaly limest.
Blue-gray " "
Light Gray compact limest.
Covered (black shale)
Hard Silicious Sandstones
Lama, with hard blue shales
Silicious Sandstone or Grit. massive, red and white
Silicious shale
Variegated sandy shales
Limestone
Variegated shales
Soft white massive Sandst.
Limestone
Soft white massive Sandst.
Soft, red shaly Sandstones.
Cherty Limestone.
Soft red shaly Sandstones
Yellow granular silicious Sandst gritty but rather soft
Hard massive red Sandstones intercalated shales some conglomerates. High ridge of South Boulder Peak
Archaean
Sec. 3.
RALSTON CREEK.
Basaltic Lava.
No. 3.
Black argil. shales.
Light gray shales.
No. 1.
Variegated shales, mostly argil.e some limestones
White Sandstones, soft.
Variegated shales
Red sandy shales
Cherty Limestone
Red sandy shale.
Yellow Silicious Sandst.
Red Beds
Sec. 4.
GOLDEN - CITY.
Lignitic Formation.
Sandstones and Clays.
Limestones, Clays and Sandstones.
Cretaceous.
Red Beds.
Jurassic and Triassic.
Explanation of Signs.
Massive
soft
hard
Quartzite
Thin bedded
Conglomerate
Shaly
Massive
Thin bedded
Shaly
Shales
Slates
white
yellow
gray
red
Sec. 5.
BEAR CREE
Dark shales
argil.e shales.
variegated red and green shales. arenaceous and argillaceous.
Same with white Sandstones.
Red arenaceous shales.
Cherty Limestone
Red arenaceous shales.
Yellow massive Sandstones
Soft red massive Sandstones.
Some shales and Conglomerate.
Cretaceous
No. 1
Jurassic
Triassic
Archaean
Sec. 6.
SOUTH SIDE OF SOUTH PLATTE.
Rather massive gray and yellow Sandstones.
Shaly Sandstone, vegetable remains.
Rusty yellow Sandstone.
Usual Jurassic Beds.
Cherty Limestone.
The Red Beds.
DEP'T OF THE INTERIOR
U. S. GEOLOGICAL AND GEOGRAPHICAL SURVEY OF TH
F. V. HAYDEN, GEOLOGIST IN CHARGE
Plate I
DETAIL
GEOLOGICAL SECTIO
OF THE
LOWER SEDIMENTARY ROCKS
FOUND ALONG THE
EASTERN BASE OF THE ROCKY MOUNTAINS
FROM THE
LITTLE THOMPSON TO THE SOUTH PLATTE
To accompany the Report of
ARCH R. MARVINE,
MIDDLE PARK DIVISION
1873
Scale 360 feet to an inch

REEK.



CHAPTER II.

THE SEDIMENTARY ROCKS EAST OF THE FRONT RANGE.

Before presenting in detail the isolated facts which together make up our knowledge of the sedimentary rocks east of the mountains, and in order that these facts may be more readily understood and their relations rendered apparent, it is desirable first to clearly understand certain general geological features which underlie the whole country. These, though familiar to most geologists, may be less so to the general reader, and I will endeavor to present them as simply as possible.

Attention has already been called to the abruptness with which the mountains rise from the plains. The two types of topography which are separated by this sharp line of demarkation are not more wholly distinct than are the two types of geology which it also separates.

The rocks of which the mountains are built, and which will be more fully treated in the following chapter, are granite, gneiss, schist, and allied rocks, which, in speaking of them as a class, it will be convenient to call *Archæan*, or metamorphic.*

These metamorphic rocks are hard and crystalline in character, and, occurring in large and comparatively irregular masses, present surface forms which are peculiar and very characteristic, so that one can seldom fail to recognize them even from a distance.

Beneath the plains, however, there is found a class of rocks which possesses characteristics exactly the opposite of those just mentioned. They are neither so hard, nor are they crystalline; and instead of occurring in large and irregular masses, they lie in broad, flat sheets or strata, resting one above another, and stretching unbroken for miles in all directions. From the Mississippi and Missouri westward to the mountains stretches this great series of rocks, composed of layers of varying thickness of sandstones, limestones, shales, slates, and clays, which remain much as they were when first laid down one after another in the bottom of the vast ocean which once existed here. Since this ocean was gradually drained off, the ceaseless action of the rains and rivers has in places removed thousands of feet of these rocks, exposing beds which were once deeply buried, and in which we can occasionally find the remains of the shell-covered beings which still earlier lived and died upon the ocean-bottom, or the skeletons of the animals and plants which peopled the surrounding shores, and were swept by the ancient rivers out into the sea to be buried with the then forming sediments. It is but natural, therefore, that the surface characteristics of the great plains and rugged mountains should differ as they do.

THE MOUNTAIN BORDER REGION.

But let us examine the line along which these two opposite classes of rocks may be supposed to join. This line, we have already seen, trends

* It has been found convenient, or rather necessary, for geologists to give definite names to certain groups of rocks. The accepted names of the more general divisions, in the order of their superposition or *age*, commencing with the oldest and proceeding to the most recent, are here given, those in small capitals occurring in the region under discussion:

1. ARCHÆAN—most ancient.
2. *Silurian.*
3. *Devonian.*
4. *Carboniferous.*
5. TRIASSIC.
6. JURASSIC.
7. CRETACEOUS.
8. TERTIARY { *Pliocene*, *Miocene*, EOCENE.
9. POST-TERTIARY and recent.

approximately north and south, passing about twenty miles west of Denver.

Along it, the sedimentary rocks of the plains, instead of remaining horizontal, with their edges thus abutting against the steep faces of the mountain-rocks, like the sands along a rocky shore, are found to be all bent or folded more or less abruptly upward, their worn edges often rising into the air and presenting their scarred faces to the mountains.

It becomes evident, therefore, that the sedimentary strata rest upon the rocks of the mountains, and that the latter, descending beneath the former, form the foundations on which they rest.

This upturning of the sedimentary rocks along the mountains is illustrated in a general way in the accompanying diagramatic sketch.

Inasmuch as sediments laid down under water cannot end abruptly, it is apparent that these beds must once have been extended much farther up on the central mountain-mass than now, as indicated by the dotted lines.

We will see later that after this folding of the rocks took place the level of the sea long stood above the present upturned edges of the sedimentary rocks, and that, as the land through ages gradually emerged from the water, the wearing action of the slowly-retreating waves and of the usual subaerial erosion gradually removed all the higher portions of the strata, working back their edges, until they are left as we now find them.

The surface of the country, as now presented to us, therefore, is due to the action of two causes: first, a folding of the rocks; second, erosion of those higher and ever-enlarging portions which slowly appeared above the gradually-retiring sea, and which may be progressing as rapidly now as the average erosion in the past.

As there is always a variety in the hardness or other characters of the different beds, some will withstand erosion far less readily than others, and, wearing away faster than their harder neighbors, leave the latter rising as ridges above the general surface. These ridges are cut through every few miles by the streams that flow down from the mountains, and while the immediate effect of these streams is to carve abrupt notches or cañons through the ridges, general surface-erosion tends to lower their adjacent ends. As seen from the east, therefore, these ridges appear to rise gradually out of the plain from either end to a nearly level center, in long gentle convex curves, and they have thus earned for themselves the unfortunate name of *Hog-backs*.

But there are other beds to claim our attention a moment than those which have been upturned. The erosion which has molded the latter into their present forms has been much longer busy in the higher mountains, and much of the material worn from them since the folding of the rocks took place has been deposited in flat beds near the mountain's base, often surrounding and quite covering the hog-back ridges.

This border region, which varies from one to ten miles in width, may, then, be briefly described as one having abrupt mountain-masses rising boldly and ruggedly upon the one hand, and rolling plains stretching far past the eastern horizon upon the other, while along it the worn edges of the harder upturned strata rise in long parallel ridges, the ends of which may fall either abruptly or in long gentle convex curves to the valleys of the cross-cutting mountain-streams, and which, rising gently from the east, fall in abrupt escarpments on the west to the trough-like valleys of softer beds between, in places all well exposed, and again so nearly covered with the accumulation of more recent material in horizontal beds that the higher ridges barely peep above the surface. In exceptional cases, harder beds may rise in ridges of abnormal height, or all may be leveled flat; the rocky fold may be more gentle or more abrupt, or complex; or the presence of volcanic products may add new features to the scene. Still the normal structure of the region remains the same.

This region furnishes, then, the key to a knowledge of the rocks which underlie the plains, and, by selecting favorable localities for exposures, we may, in passing from the mountains eastward, pass in succession across the edges of the beds from the lowest to the uppermost. It would thus be found that a thickness of probably over 7,000 feet of sedimentary beds has partaken of the folding. These beds would seem to divide themselves naturally into four groups, which, so far as the present burden of proof goes, are referable to the following geological formations, commencing with the oldest: Triassic, Jurassic, Cretaceous, and Eocene(?). The upper part of this series, from the Middle Cretaceous up, being of comparatively softer beds, has been generally eroded back so far from the mountains, and to such a level and grass-covered surface, that exposures are few and scattered, requiring for study more time than could be given to them during the last summer. They have received special study from others, however, so that some general results can be given in the sequel. For the present we will confine our attention to the lower portions of these beds, the Triassic, Jurassic, and part of the Cretaceous.

In describing these beds it will be found convenient to regard, first, their more detailed structural features, as lithological characters, age, &c.; and, second, their more general structural features, or the manner of their folding. To illustrate the first class of facts Plate I has been prepared; and for the second, Plate II, (see end of chapter,) though in dealing with either class it will occasionally be found desirable to refer to both plates at once.

On Plate I are gathered sections taken at six points along the zone of hog-backs, namely, commencing at the northern one, at Little Thompson Creek, Bear Cañon, Ralston Creek, Golden City, (Clear Creek,) Bear Creek, and at the South Platte. The thicknesses of the beds were estimated, and are, therefore, only approximate, but checks of various kinds were used to prevent any gross errors, and when the same series were observed by different persons the results were generally very concordant. The beds whose thicknesses were thus obtained have their limiting lines carried through to the vertical line forming the left-hand border of each section, upon which, also, spaces of 100 feet each are indicated, while beds expressing general characters of the series, but not so exactly placed, are carried through only to the line next to the left edge of the section. The several sections are placed with the base of "No. 1 Cretaceous" upon the same horizontal line.

Throughout the series, what first strikes the observer is the marked absence of limestones, and the great predominance of sandstones. Limestones exist, it is true, and, considering their relative thinness, are very persistent, forming good horizons to refer other beds to, but they are wholly subordinate to the arenaceous element.

THE TRIAS.

General characters.—Resting directly upon the smoothed, though often irregular, surface of the Archæan rocks, and forming the lowest member of the exposed stratified formations, is a series of sandstones which varies in thickness from over 1,600 or 2,000 feet to possibly as little as 400 feet, and in which red is so striking and predominant a color that they are commonly known by the name of the "Red Beds." Though shaly strata are frequent, and the whole series may be quite soft, yet the general thickness, or massiveness, of the strata forms another prominent and characteristic feature.

Most of these sandstones are of a normal red-sandstone type, varying from coarse grits and moderately coarse sandstones, with fine examples of cross-bedding, to quite fine-grained and shaly layers. The latter occasionally may make up a considerable thickness, but though occurring frequently they are generally so intercalated with the heavier beds, that, as said before, a sort of massiveness characterizes the group. Though conglomerates may occur anywhere in the series, they are mostly confined to near the base, where they are often plainly derived from the subjacent rock. It is in these lower parts, indeed, that the beds are so directly made up of the material of older rocks near by that a very little metamorphism has in some instances made it difficult to distinguish small masses of sandstone from the underlying granites. Dark red is the prevalent color, though light-red, yellow, and cream-colored beds are frequent, and may, in places, quite predominate over the red. This is more noticeable near the top, while the conglomerates and beds directly composed of granitoid materials are also generally gray or light in color. Sometimes, also, a peculiar character is shown by sharply defined, often perfectly circular yellow or white spots up to three-quarters of an inch in diameter scattered upon the deep-red background, as if drops of water in falling on the stone had worked the color from it. This would not necessarily be characteristic of this formation, though I did not see it elsewhere.

Although the surface of the Archæan rocks below is more or less smoothed, it is often irregular, and occasional bosses of granite, &c., project into the sandstone, as in the accompanying instances, (fig. 2,) observed by Mr. Gardner, near Turkey Creek.

Near the Big and Little Thompson's and Saint Vrain's Creeks, exposures indicate a general shelving off or abutting of the edges of the lower strata against the Archæan rocks, or "overlap," a point of interest to which attention will be called later.

Had opportunity offered, this feature would probably have been found all along the base of the mountains.

Local characters.—Toward the north end of the district the shaly character is more marked than elsewhere. At the Little Thompson (see Plate I, section 1) the series has a total thickness of about 750 feet, and is composed of soft granite sandstones and conglomerates below, white to red, with coarse soft red sandstones above, followed by two or three hundred feet of shaly sandstone, the whole capped by massive red sandstones about 250 feet thick, but generally breaking into from two to three prominent layers, with thin shaly strata between. Farther north, the lower beds become much shalier than here, while southward the shales grow heavier bedded. In this northern region, the fact that the more massive beds are confined to the upper part of the series, combined with a gentle eastern dip, causes the surface features to differ somewhat from those farther south. The long, gentle eastern slopes of the massive beds are denuded by erosion, often for several miles to the east of the softer series of rocks which would lie above them, (and yet to be described,) and the lower series, thus occurring alone over considerable areas, has a sort of geographical individuality given to it. It is this feature, a result of the more massive character of these beds as compared with those above, and this alone, which

Fig. 1.

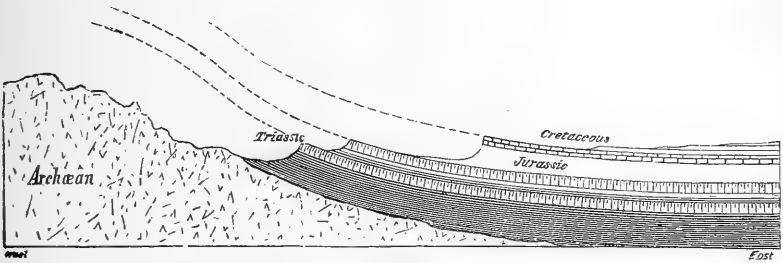
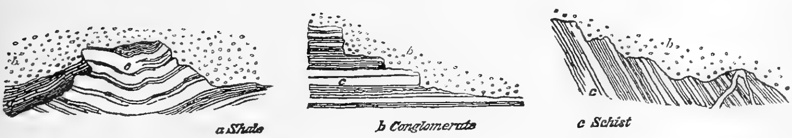


Diagram showing the relations of the Sedimentary rocks of the plains to the Archæan rocks of the mountains.

Fig. 2.



Example of irregular Junction between the Archæan schists and Jurassic conglomerates and shales, near Turkey Creek.—J. T. Gardner.

Fig. 3.

To illustrate the shelving off or overlays of the Triassic Sandstone on the Archæan, at Dry Creek, between the Big and Little Thompson Creeks.

makes it convenient to place the plane of separation between these two lower series just at this horizon, there being no fossils known in the beds to afford any paleontological grounds for a separation at any particular plane.

Gentle folding near the north has in places left the red beds forming several ridges, but between the Saint Vrain and Left-Hand Creeks they run into one, and the whole series occurs as a simple upturned ridge dipping away from the mountains at an angle of about 35°, and as a simple fold it continues on southward, only varying much in dip, being in places even turned slightly past the vertical. The general characters, as given at the Little Thompson, also slowly change in approaching Left-Hand Creek. The series thickens slightly; the top is a thickening band of yellow; the shales have diminished in amount, and the lower part has less conglomerate and yellow, while the general softness is such that the ridges formed are not prominent. These lithological features remain much the same to Bowlder City. Here a sudden change in the hardness of the red beds occurs; they become massive nearly throughout, and all the lower 800 feet is of a deep dark red. The hardness is so increased in these lower beds that they rise in a high ragged ridge reaching over 2,000 feet above the plains, and even considerably above the granite buttresses against which they rest. This ridge of hard sandstone reaches south far enough to be cut by both Bear Cañon and the South Bowlder, the cañon of the latter being quite profound, while between the two cañons the ridge attains its highest point in Bowlder Peak, one of the stations of the primary triangulation. The latter is, in reality, on a second or inner ridge of sandstone, which has been faulted down from the outer one, as will be shown more in detail later. (See Plate II, section 11.) These cañons give excellent sections of these lower rocks, but this exceptional hardness at this point does not make them typical. In places, however, the origin of the lower sediments is well shown, being often composed of a rather coarse aggregate of quartz and feldspar, with frequent pebbles of adjacent quartzitic and granite rocks.

Lying over this lower 800 feet of red beds, which thus attain an altitude higher than any other sedimentary rocks east of the Front range, are about 300 feet of free, clean, gritty, siliceous sandstone, very light yellow in color, inclined to massive in bedding, but cleaving with a fine plane surface. They do not reach very far up on the higher ridge of their harder underlying red companions.

Near Coal Creek the red beds have again become softer, and are eroded away till barely exposed. At Ralston Creek they again rise at a low angle to a considerable height, but only to again fall to a valley trough a few miles north of Golden City, where they begin to thin out in a remarkable manner, and at that city scarcely reach a thickness of 400 feet. Their relations, however, are here not wholly clear, as they are quite soft and have been eroded nearly away, the valley trough in which they should outcrop being well sod-covered. They dip from between 40° and 50° near the granites, which form the very abruptly rising western border of the valley, but near their top are thrown somewhat beyond the vertical. Section 4, plate I, is scaled from a section given me by Mr. Berthoud, of Golden City.

South of Golden City the red beds again rapidly thicken, and continue to thicken all the way southward to where the South Platte debouches from the mountains, the southern limit of the district, where they attain a thickness of over 1,600 feet. Throughout this southern region, though still massive in general character, they are yet quite soft, and though often forming a number of minor ridges, the latter nowhere rise in prominently continuous hog-backs, while, on the contrary, they may be quite eroded away into a broad valley, with the Archæan rocks forming its western side, the beds yet to be described forming their bounding hog-backs in the east. They often rise, however, for considerable distances up long gentle slopes of the mountain rocks, which places them in a favorable position to be eroded into the peculiar and grotesque forms which characterize the Garden of the Gods, which, however, is in a very different geological horizon, though somewhat similarly circumstanced. The curious groups of worn rocks and monuments thus formed sometimes have their tops worn off horizontally, as if by the surface action of the old retiring sea, while the same sub-aqueous erosion has in places smoothly leveled off considerable areas of the upturned rocks, as is best shown a few miles north of the South Platte. (See Plate II, section 17.)

THE JURASSIC.

General characters.—The series of strata lying next above the red beds form a group of rocks in which the thin-bedded and shaly element decidedly predominates. The outcropping edges of these beds have therefore generally been more eroded away than the harder beds above and below, so that they generally appear in valleys; and being soil covered, they are not usually well exposed.

The arenaceous element still predominates, though argillaceous material is often present to a very large extent, while beds of impure limestone occur—one of which appears very persistent—and gypsum is frequent in thin layers, and sometimes occurs in workable quantities and of good quality. As before, red is the prevailing color, though a series of marked variegated colors occur, and weathering frequently produces an ashen-gray tint upon the surface. A brief detail-description of sections taken at several points will best convey an idea of the lithological characters of the series, proceeding in each case from above downward.

Section of Jurassic beds near the Bear's Church, Big Thompson Creek.—Dr. F. V. Hayden, Third Annual Report, 1869, *reprint, p.* 125.

No.	Nature of strata.	Thickness in feet.
	Top.	
7	Loose drab-yellow sand, *débris* of underlying beds, one limestone 2 feet thick.	
6	Limestone, quite pure, blue, semi-crystalline	8
5	Variegated clays	200
4	Ashen clay, with six-tenths feet of blue cherty limestone, clay partings	25
3	Blueish limestone	4
2	Fine bluish-brown sandstone	2
1	Massive reddish-gray, rather fine sandstone	20
	Base.	

Section of Jurassic beds exposed near Saint Vrain's Creek.—William H. Holmes.

No.	Nature of strata.	Thickness in feet.
	Top.	
14	Argillaceous sandy shales, variegated and irregular, crumbling	20
13	Hard, blue, beautiful limestone, solid	4
12	Argillaceous and sandy shales, same as No. 15	30
11	Fine-grained, calcareous quartzite, with seams of crumbling gypsiferous shales	20
10	Limestone	2
9	Shaly	5
8	Red sandstone	4
7	Shales, with seams of quartzite	12
6	Shales and sandstones	20
5	Soft yellow massive sandstone	30
4	Soft red massive sandstones	60
3	Red shaly sandstones	200
2	Cherty limestone	*or*
1	Red shaly sandstones	300
	Base.	
	Total	400–500

Section of Jurassic beds exposed in Bear Cañon.—William H. Holmes.

No.	Nature of strata.	Thickness in feet.
	Top.	
11	Light gray, fine, siliceous shale, almost quartzite	40
10	Sandstones, shaly, variegated, (white, snuff, orange,) containing a shaly limestone	42
9	Limestone, hard, gray; conchoidal fracture, with beds of variegated argillaceous, arenaceous, and calcareous shales	40
8	Covered	20
7	Soft massive sandstone, white, with hard siliceous seams	50
6	Limestone, hard, with conchoidal fracture	6
5	Covered	20
4	Soft white massive sandstone, with soft greenish concretions	30
3	Soft, red, thin-bedded, and shaly sandstones	400
2	Siliceous limestone, porous	20
1	Soft, red, thin-bedded, and shaly sandstones	200
	Bottom.	
	Total, (about)	870

At remaining points, though taken in less detail, the sections still show the general features of the series:

Section of Jurassic beds exposed near Ralston Creek.—William H. Holmes.

No.	Nature of strata.	Thickness in feet.
	Top.	
6	Variegated shales, mostly argillaceous, with thin beds of limestones and sandstones	270
5	White sandstones	30
4	Variegated shales, mostly argillaceous	40
3	Thin red sandstones and arenaceous shales	200
2	Cherty limestone	20
1	Red sandy shales	100
	Bottom.	
	Total, (about)	660

Section of Jurassic beds exposed near Bear Creek.—William H. Holmes.

No.	Nature of strata.	Thickness in feet.
	Top.	
5	Variegated red and green arenaceous, some argillaceous shales, with loose brick-red sandstones and gypsum	200
4	Like No. 5 above, with white or rusty yellow sandstones	100
3	Red arenaceous shales, and purple-red sandstones	300
2	Cherty limestone, bluish	20
1	Red arenaceous shales, like No. 3	150
	Base.	
	Total, (about)	770

Near the South Platte the general characters remain much the same as near Bear Creek; the white sandstones, which in the section (Plate I) are placed near the base of the Jurassic, should more probably be included in the lower formation as the equivalents of the yellow sandstones at the top of the Trias. The South Platte section was made by Mr. J. T. Gardner.

The cherty limestone, near the base of this group, seems to be a very persistent bed, and being rather hard, often forms a minor hog-back ridge. It varies slightly in character. At Bear Cañon it is porous, with the silica apparently disseminated through the bed. A rude attempt here at making lime from it has failed. At Ralston Creek, however, the silica seems more concentrated in the numerous nodules of pink chert, which are sprinkled thickly through the bed, the matrix being compact and hard. A large kiln here in active operation seems to be making a very excellent quality of lime.

Between Ralston and near Golden City, and again at several points further south, more or less rude lime-kilns have been built for the purpose of making lime from this bed, the product usually seeming to be very white, though I know nothing definite of its adhering qualities. Near Bear Creek a small mill was erected for the purpose of grinding the gypsum which occurs in the Jurassic beds near by, and which Dr. Hayden, in his third annual report, for 1869, p. 136, describes as follows: "The gypsum is amorphous, but very white and pure, and would make the finest of casts and moldings. Some of the layers are susceptible of a high polish, like the California marbles, only they are of a more uniform white color.

It is possible that in this group also belongs the "silica in a state of fine division," or an "aggregation of very fine grains of quartz" which has been opened at Golden City.

THE CRETACEOUS No. 1.

Next above the last group of strata comes a series of sandstones, which, though only from one to two hundred feet thick, form a more convenient horizon for reference than any group in the sedimentary series. Though this is partially due to its well-defined and pretty-constant lithological characters, it is chiefly due to the fact that its hardness is so constantly and so considerably greater than the beds either above or below, that it forms a more persistent hog-back ridge than any other group. Except when cut by the streams, this horizon can be traced, almost without losing it for a moment, from the Big Thompson to the South Platte, unless it be somewhat obscured near Golden City. Between the cross-cutting streams for all this distance and beyond, it rises in its long characteristic ridge, capping the soft Jurassic beds below, and whether the dip be high or low its top usually reaches to about the same general level. These sandstones are usually clean, gritty, even-grained and siliceous in texture, varying from a siliceous conglomerate, on the one hand, to a hard quartzite on the other, and only occasionally becoming soft. Their color is usually light yellow or light gray, or even white, varying to rusty yellow, and only occasionally red in the softer portions. These are the hard and massive portions which characterize the group, and which are separated by thin shaly layers which may be quite argillaceous or even carbonaceous in character, with many broken remains of fossil plants.

Section of Cretaceous No. 1 at Bear Cañon.

No.	Nature of strata.	Thickness in feet.
3	Hard siliceous sandstone	40
2	Same as 3, with hard blue siliceous shales	50
1	Siliceous sandstone, gray to flesh-red above, white below; even-grained, particles rather free, gritty; few feet of siliceous conglomerate at base; obscure vegetable impressions near top	150
	Total, (about)	240

Dr. Peale has allowed me to use the following section made by him near the South Platte:

Section of Cretaceous No. 1 near the South Platte River.—Dr. A. C. Peale.

No.	Nature of strata.	Thickness in feet.
4	Gray and yellow sandstone, rather massive	70
3	Shaly sandstone, carbonaceous, Proteoides, &c	12
2	Fine-grained white sandstone	3
1	Rusty-yellow sandstone, rather massive	300
	Total, (about)	385

"Near the summit of the sandstone-ridge No. 1, on Turkey Creek, there is an asphaltum spring which has been wrought for oil. A considerable thickness of the sandstone seems to be thoroughly saturated with the pitch or bitumen, and between the layers of the sandstones are accumulations of tar. This spring is located on the east side and near the summit of the 'hog-back.'"*

CRETACEOUS No. 2.

In this group we have a series of shaly beds which may be either highly argillaceous or quite arenaceous in character, there being associated with them in either case a few thin brown sandstones, the

* Hayden, Third Annual Report, 1869, reprint, p. 136.

total thickness varying from about 200 to 400 feet in thickness. The following sections will best illustrate these beds:

Section of Cretaceous No. 2 at Little Thompson Creek.

No.	Nature of strata.	Thickness in feet.
5	Dark, thinly laminated crumbling shales, some slates 1 to 3 feet thick, with interlaminated beds 6 to 18 inches thick, of fine compact drab argillaceous limestones	50
4	Black, finely crumbling, argillaceous shales, some slates, and few light-snuff-colored sandstones cleaving in slabs	165
3	Light-yellow and snuff-colored siliceous sandstone	5
2	Black, crumbling shales, with broken and jointed argillaceous sandstones	60
1	Fine black, crumbling shales, with brown sandstones 1 to 3 feet thick	120
	Total, (about)	400

Section of Cretaceous No. 2 at Bear Cañon.

No.	Nature of strata.	Thickness in feet.
3	Light, calcareous shales	12
2	Argillaceous limestone	5
1	Covered (pit sunk for coal) black argillaceous shale (?)	100
	Total, (about)	120

It will be observed that between the Big Thompson and Bear Cañon a decided change has taken place, not only in thickness, but also in character. At Ralston Creek the argillaceous element again predominates, there being light-gray shales below, and very black argillaceous shales near the upper part of the series. At Bear Creek these beds are also mostly argillaceous in character, and are about 250 feet thick. Between Bear and Turkey Creeks small amounts of brown iron-ore in concretions have been obtained in the shales of No. 2. Here, also, upon the outcropping edges of No. 2 are some small lakes impregnated with carbonate and sulphate of soda to the extent of 33 per cent. They are described by Dr. Hayden in his report for 1869, page 137. The analysis of the salt from the evaporated water, by Persifor Frazer, jr., was as follows:* "A white, efflorescent salt, falling to powder on exposure to the air, and containing—

Sulphate of soda	63.87
Sulphate of lime	9.70
Chloride of sodium, sulphate of magnesia, &c	4.55
Water of crystallization of the efflorescence	21.88"

CRETACEOUS No. 3.

Cretaceous No. 3 forms, like No. 1, another excellent horizon for reference. Though forming a ridge not nearly so well marked nor so per-

* Hayden's Report, 1870, p. 187.

sistent as No. 1, yet, when it does appear above more recent accumulations, the fact that it is of a decidedly calcareous character and that it usually contains numerous fossils renders it easily recognized. A complete section of No. 3 was not obtained at any point, though the lower beds were observed at a few places.

Section of the lower beds at Cretaceous No. 3, at Bear Cañon.

No.	Nature of strata.	Thickness in feet.
	River terrace; horizontal; recent.	
	Dip 25° *east.*	
3	Limestone, thin shaly, argillaceous, slate-color weathering white-gray; near base beds are 2 to 5 inches thick; argillaceous and arenaceous above, growing more calcareous below; seams of gypsum, odor of petroleum, some fossils	45
2	Covered	40
1	Like 3, but more calcareous; near top some beds of massive compact limestone, 3 feet thick, light-gray; fossils quite numerous, Inoceramus	20

Section of the lower beds of Cretaceous No. 3, at Little Thompson Creek.

No.	Nature of strata.	Thickness in feet.
	Terrace of very coarse gravel and bowlders; horizontal; recent.	
	Dip 50° *east.*	
4	Yellow shaly limestone, impure, weathering white or light-gray	20
3	Blue-gray shaly limestone, impure	100
2	Dark-gray shaly and thin-bedded limestone	10
1	Light-gray compact limestone, beds one to 2 feet thick, some shaly; fossiliferous	20

A rude kiln had been erected on the lower bed here for burning lime, making, as I was told, a good quality though not very white. The thin-bedded, impure, calcareous, and fossiliferous character seems generally to characterize the beds. The odor of petroleum is also often quite marked, but not so much so as west of the mountains. At Bear Creek, No. 3 was about 90 feet thick, but no section was made.

CRETACEOUS NO. 4 AND NO. 5.

Unfortunately opportunity did not offer to study in detail the dark shales of No. 4, and rusty yellow and gray arenaceous rocks of No. 5. The former were observed to be about 300 feet thick near Bear Creek, but no detail-section was made. At several points characteristic fossils were obtained from the beds, which are quite well exposed and fossiliferous near Ralston Creek; but, as before remarked, the softer character of these upper beds has caused them to be rather poorly exposed, and the mountain work left not sufficient time for their proper study.

Before turning to the consideration of the overlying beds it will be well, now that their lithological characters have been described, to examine the reasons for separating the preceding beds into the divisions indicated, viz, the *Triassic*, *Jurassic*, and *Cretaceous*, Nos. 1, 2, 3, 4, and 5.

In 1869 Dr. Hayden passed along the base of the mountains, and in his report for that year described these beds at the many points at which he touched them. Having traced them from regions where they were typically developed he easily assigned them to their proper horizons, and my classification is but a reflex of his. The reasons for his classification he also gives, but at scattered points through the report. I hope I may be pardoned, therefore, if I undertake to throw the evidence which bears on the age of these particular beds in Colorado into a little more definite form.

The Cretaceous age of the groups numbered 1, 2, 3, 4, and 5 cannot be questioned.

From Nos. 3 and 4 especially the characteristic *Inocerimi*, *Ostreæ*, *baculites*, *scaphites*, *ammonites*, &c., determine their Cretaceous age conclusively. The western Cretaceous was first satisfactorily studied by Dr. F. V. Hayden and Mr. F. B. Meek, in the Upper Missouri country, and afterward by the former in the Black Hills, and five well-marked divisions were there clearly made out, having well-defined Jurassic below and Tertiary above.

These divisions, with their lithological and paleontological characters, were first given in the proceedings of the Academy of Natural Sciences of Philadelphia, May, 1857, and subsequently reproduced in tabular form in Dr. Hayden's first annual report, 1867, reprint, page 49. They may be expressed briefly as follows:

General section of the Cretaceous rocks of Nebraska.

No. 5. *Fox Hill beds.*—Gray, ferruginous, and yellow sandstones, and arenaceous clays.

No. 4. *Fort Pierre groups.*—Dark-gray and bluish plastic clays.

No. 3. *Niobrara division.*—Lead-gray calcareous marls, and massive layers of chalky limestone.

No. 2. *Fort Benton group.*—Dark-gray or black laminated clays, sometimes with limestones near top and sandstones near base.

No. 1. *Dakota group.*—Yellowish, reddish, and occasionally white sandstones, with, at places, some clayey beds and dicotylodenous leaves.

The general resemblance between these five divisions and the corresponding ones in Colorado, but for the great distance separating the two localities, would naturally suggest their direct co-relation and identity.

Dr. Hayden has, however, directly traced them, except some easily-passed gaps, across the intervening region, thus establishing their identity.

In his third annual report, 1869, page 121, he says:

Quite marked changes occur in the sediments of these divisions in different parts of the West, but by following them continuously, in every direction, from their typical appearance on the Upper Missouri, the changes are so gradual that I have never lost sight of them for a mile, unless concealed by more recent deposits.

Again, page 114, in speaking of the Cretaceous in Colorado, he says:

At various localities all along the margin of the mountain ranges these divisions of the cretaceous are far less distinctly separated, and vary more or less in their structure and composition, and yet in tracing them carefully and continuously from the Missouri River they always retain enough of their typical character, so that I have never been at a loss to detect their presence at once, although after leaving the Missouri River we do not find any well-defined lines of separation, either lithologically or paleontologically.

In Colorado the want of fossils in No. 1 has made its position the most uncertain of any of the five; but Dr. Peale's discovery in these beds of the fragments of leaves in his section near the South Platte seems to fix this horizon with quite a degree of certainty.

Professor Lesquereux, in writing to Dr. Peale in relation to these leaves, says that these are fragments of a *Proteoides*, very near *Proteoides acuta*, (Heer,) if not a small form of the same. As yet no leaf of this genus has been recognized in our American measures higher than the Dakota group, or No. 1. These sandstones, then, probably lie at the base of the Cretaceous.

In the so-called Jurassic and Triassic, I believe that not a single fossil has rewarded this summer's search. In the Upper Missouri, not only does well-defined Jurassic underlie No. 1, so that we might expect to find it beneath No. 1 in Colorado, but Dr. Hayden has traced it also directly to Lake Como, near the Union Pacific Railroad, where it contains well-defined Jurassic fossils.

In tracing it further south along the base of the mountains the fossils disappear; but in a section exposed on the Box Elder Creek, north of the Big Thompson, Dr. Hayden found some beds which he described (report, 1869, p. 119) as "undoubtedly the usual Jurassic beds, with all the lithological characters as seen near Lake Como," and containing a species of ostrea and fragments of *Pentacrinus asteriscus*, a characteristic Jurassic fossil. These beds are the same that occur near and above the cherty limestone in the sections which I have described as Jurassic, and seem to settle the correctness of their assumed age as decisively as possible without the direct finding of fossils in the very region under discussion.

THE TRIASSIC BEDS.

The correctness of the assumption of this age for the red beds depends only upon their position in relation to other beds of known age, for nowhere that I know of have fossils ever been found in these beds.

Somewhat north of my district, and between the Cache a la Poudre and Cheyenne, there appears between the red beds and the Archæan rocks, outcrops of Carboniferous rocks, so that the red beds here lie between Carboniferous and Jurassic rocks. West of the Middle Park, where all the upper beds retain their characters as east of the mountains, the development of the Carboniferous beneath the red beds is far more marked, and consists principally of a second series of red beds of deeper purple hue than those referred to the Triassic.

Leaves gathered from the upper measures of these by Dr. Peale are referred by Professor Lesquereux to the Permian. Unless the red beds, then, are referred to the Triassic, there will be an unoccupied gap between the Permian and Jurassic ages; nor would we know to which of these ages the beds in question could be more properly referred. Until fossils are found, therefore, to definitely settle their age, it seems most reasonable to refer them to the Triassic.

I have already spoken of the indefiniteness of the line between the Triassic and Jurassic, and have suggested the convenience of placing this arbitrary line above the more massive portions of the red beds, and above the massive sandstones which usually cap them, and not far below the cherty limestone.

THE LIGNITIC FORMATION.*

We turn now to the consideration of the group of rocks which lies directly superimposed upon the Cretaceous beds, and which, economically considered, is of more importance than any of the preceding formations. This is the formation that contains in its lower portions the lignites of Eastern Colorado. To what epoch of geological time this group of rocks should be referred, whether it should be considered as an upward extension of the preceding cretaceous, or the commencement of a more recent epoch, is a matter about which there is still diversity of opinion. Its fossil flora is very abundant, fifty-six species of vegetable remains having been found at Golden City alone. Yet Professor Lesquereux, the eminent authority in fossil botany, says that throughout the group not a single leaf has as yet been found identical with a Cretaceous species;† and, further, that "no member of the American lignitic, as far as this formation is known by its vegetable remains, can be referred to the Cretaceous."‡ He concludes, from his extended observations, "that the great lignitic group must be considered as a whole and well-characterized formation, limited at its base by the fucoidal sandstone; at its top by the conglomerate beds. That, independent from the Cretaceous under it, and from the Miocene over it, our lignitic formations represent the American Eocene."§

There seem to be indications near the base of the group, however, of Cretaceous fossils. Lesquereux, himself, calls attention to the fact that Dr. Hayden and Dr. John L. LeConte have each found a badly-preserved Inoceramus low down in the series. Both of these localities, however, have since been carefully but unsuccessfully searched for fossils; while the similar occurrences which have thus far from time to time been reported from various localities have, upon investigation, been shown to be the result either of inaccurate observation, or that the facts observed were wrongly interpreted, or their bearing overestimated, or else that they occurred at points where geological complications of the rocks made all observation more or less uncertain, as, for instance, at Golden City. Indeed, none of these observations so far recorded can be considered as furnishing evidence in the case, and should be thrown out. Only the occurrence of Cretaceous fossils bearing the clearest and most undoubted relations to the adjoining beds, and that at more than one or two exceptional localities, can, under the circumstances, be accepted as defining the age of this great overlying formation. Even if further observations were to show that these occurrences were other than exceptional, or, perhaps, accidental, they would not necessarily prove more than that these lower beds only were of Cretaceous age, or, as considered by Hayden, beds of transition between the Cretaceous and the Eocene; though, in view of Lesquereux's idea of the definiteness of the formation as a whole, if the lower beds are proved to be Cretaceous the rest of the series also could hardly, with consistency, be considered otherwise.

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* So many facts have already been collected from this formation by observers of repute that, in any attempt to give as complete an idea as possible of the geology within my specified area, it becomes necessary to draw upon these facts to a very great extent, especially as the writer's opportunities for observation in these better-known upper beds were quite limited. The endeavor will be made to make the material obtained from each authority supplement that from the others. The principal sources of information have been the reports of James T. Hodge, Professors Lesquereux, F. V. Hayden, and John L. LeConte, while much practical information has been personally given by Mr. E. L. Berthoud, of Golden City, Colorado.

† Hayden's Report for 1872, p. 343.

‡ Ibid, p. 419.

§ Ibid, p. 350.

So much for the general character and extent of the testimony thus far presented from the marine life found in or near the base of these beds.

Terrestrial vertebrate remains, however, occur under neither so equivocal nor restricted circumstances, but such as have been found range higher in the formation, and are considered as of decided Cretaceous types, and, judging from them alone, the formation would be considered as Cretaceous.*

It must be supposed, then, that either a Cretaceous fauna extended forward into the Eocene period, and existed contemporaneously with an Eocene flora, or else that a flora, wonderfully prophetic of Eocene times, anticipated its age, and flourished in the Cretaceous period to the exclusion of all Cretaceous plant-forms. Which of these views is correct is still the undecided point. Though the latter might seem the more probable view, if judged by the rapidity of faunal changes as compared with floral changes in the more immediate past, yet not only the great amount, but the remarkable unanimity of the evidence of fossil botany, as interpreted by Lesquereux, would indicate the former. Newberry's interpretation of the facts from fossil botany, however, again leans toward the latter view. In either case the fact remains that here the physical and other conditions were such that one of the great kingdoms of life, in its progress of development, either lost or gained upon the other, thus destroying relations and associations which existed between them in those regions from which were derived the first ideas of the life boundaries of geological time, causing here apparent anomalies.

Much of the confusion and discrepancy has, in my opinion, arisen from regarding different horizons as one and the same thing. It must be distinctly understood that this group as it exists east of the mountains in Colorado is very different from and must not be confounded with the horizon in which much of the Utah and New Mexican lignite occurs, and which belongs undoubtedly to the Lower Cretaceous; and, further, that the extended explorations of Hayden and others would seem to prove almost conclusively that the Colorado lignitic group is the direct southern stratigraphical equivalent of the Fort Union group of the Upper Missouri,† which is considered generally to be no older than the Eocene, while Newberry asserts it to be Miocene.‡ When all the facts are known they may develop some new ideas as to geological transitions.

But only the consideration of large areas of country, as Hayden, Lesquereux, Meek, Cope, Leidy, Marsh, and others have already done, will solve the problem. Here we have to do only with the aspects of the formation, whatever may be its age, as it occurs within our district, and for the present we will speak of the formation as the lignitic.§

The nature of the rocky fold found along the mountain front, and of the subsequent erosion, has been such that in passing eastward over

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* See Cope, Trans. Amer. Philos. So. 1869, pp. 40, 98, 243; also Bulletin No. 1 of the U. S. Geol. and Geog. Surv. of the Terr., 1874, p. 10, and Bulletin No. 2, p. 7.

† Equivalence founded on similar fossil vertebrates has recently been suggested by Cope. (See Bulletin No. 2 of the U. S. Geol. and Geog. Surv. of the Terr., p. 7.)

‡ Hayden's annual report, 1870, pp. 95, 96.

§ The most complete *résumé* of the evidence bearing upon the age of the lignite formation has probably been given by Professor Lesquereux in Hayden's last report, 1872, pp. 339–350. See also Newberry, in Amer. Jour. Science, April, 1874, (III, vol. vii., p. 90,) and Lesquereux, Ibid., June, 1874, (III, vol. vii, No. 42, p. 546.) See also Cope, Bulletin No. 2 of U. S. Geol. and Geog. Surv. of the Territories; Meek in Hayden's report, 1872, p. 461, &c.

the upturned edges of the strata all the lower formations are found dipping eastward at an angle seldom above 60°, and generally much less, until, upon reaching the Upper Cretaceous and lower lignite beds, they are found—at least all through the middle of the district—to be tipped up nearly vertical, or even pushed over beyond the vertical, so that they appear to dip at a high angle toward the mountains.

Immediately there follows an abrupt bend, which at once throws all the remainder of the lignitic series into nearly its natural horizontal position, and thus it stretches eastward as the formation directly underlying and forming the plains. All through the plain portion of the district these nearly horizontal beds have been eroded by the streams into a rolling country, the irregularities of which are really quite considerable, the hills frequently rising several hundred feet above the numerous intersecting streams, and, though generally gently molded in long, rounded slopes, still abrupt and irregular bluffs, formed of the edges of sandstone strata, and of considerable height, occasionally occur. Trees occur only along the streams—such as the cottonwood and willow—the hills being clothed in a sort of grassy vegetation of very uniform yellow-green color, so that, standing upon an elevation, all the surrounding hills are thrown against their neighbors with but little sense of relief, and all appears quite level, notwithstanding the decided unevenness of the surface. Along the South Platte River, near and below Denver, the strata dips very gently from either side toward the river, forming a flat synclinal of the valley. To the east, as the surface gradually rises, pines in scattered groups begin to occupy the country, the precursors of the tract known as the pineries.

The rocks comprising the lignitic formation, which directly underlies this country, are principally sandstones and clays. As compared with the older formations, these generally present a much newer or less consolidated appearance. The sandstones are usually of somber colors; dull reddish-brown and yellow, and rusty gray, perhaps, prevailing. They vary from the conglomerates to quite fine sandstones, and are usually friable, and but seldom compact and firm enough for building purposes. Some few clean, gritty, white siliceous sands occur.

The clays which predominate in the formation are of the nature of fire-clays. They are of various colors, most often perhaps light-gray, generally rather soft, and when very fine and unctuous to the touch are commonly called "soapstones." At Golden City excellent fire-brick, pottery, &c., are made from some of the lower clays. The transitions between sands and clays are sometimes gradual, giving zones of mixed material; soapstones becoming gritty, and sands argillaceous. No limestones occur, and argillaceous shale and slate only in very subordinate quantities.

Fossil leaves, and fragments of wood, &c., are very numerous in some horizons, usually near the coal. They are mostly of deciduous trees, many of which are closely allied to species common in our Southern States and the tropics, the flora of which this ancient vegetation must have somewhat resembled, while no true coal-measure (Carboniferous) plants, such as ferns, &c., have been found. The remains of trunks of trees of enormous size are sometimes met with.

The following sections are given as illustrating the general characters of the series: The first, which shows the strata as they occur at Golden City, is from a section made by Mr. E. L. Berthoud, the positions of the outcrops being given on Plate II, section 13. It probably shows a greater portion of the full thickness of the lignitic than exposed elsewhere, for which we have to thank the protective action of the cap of hard lava, which has preserved the lower beds from erosion. The section is from the artesian boring for water at Denver City. The first part is constructed from samples from the well, given me, with descriptions, by Mr. Brooks, the engineer superintending the boring, the lower part being furnished by Mr. Brooks directly, his section being indicated by quotation marks.* The sections illustrating the character of the strata associated with the coal will be given later.

Section of the lignitic strata at Golden City, Colorado Territory, from a cross-section made by E. L. Berthoud, civil engineer.

No.		Nature of strata.	Thickness in feet.
		Doleritic lava, thickness averaging 125 feet:	
14	Nearly horizontal.	Conglomerate and dark sandstone, with layers of buff clay containing fossil leaves and plants	25
13	Nearly horizontal.	Yellow, gray, and rusty sandstones and conglomerates	135
12	Nearly horizontal.	Red, yellow, and gray clays, with streaks of coal, fossil caries, sedges, and grasses	45
11	Nearly horizontal.	Yellow, gray, and white sandstones and conglomerates, with beds of buff and yellow clay, with fossil leaves	130
10	Nearly horizontal.	Rusty sandstones, with obscure casts of stems and leaves	30
9	Nearly horizontal.	Conglomerates and clays, probably	900 or 1,000
		Green clays and marls, with septaria:	
8	Nearly vertical.	Dark conglomerate	70
7	Nearly vertical.	Clays and marls	260
6	Nearly vertical.	Fire and potter's clay, with rusty red sandstone	150
5	Nearly vertical.	Clays and marls	250
4	Nearly vertical.	Bog-ore bed, with fossil bones and plants	60
3	Nearly vertical.	Sandstone and fire-clays	260
2	Nearly vertical.	Coal-measures, (five seams or veins of coal)	350
1	Nearly vertical.	Sandstones and clays, probably	400 or 500
		Total thicknesss of lignitic, from	3,060 to 3,360

Section of artesian well near Denver City, by Eli Brooks, engineer.

No.	Nature of strata.	Thickness in feet.
1	Surface-soil, probably indurated clay decomposed in place by atmospheric agencies	20
2	Light-gray clay; some sand	55
3	Fine black sand	20
4	Irregular black sand	5
5	Light siliceous sand and clay	16
6	Light-gray unctuous clay	16
7	Fine black sand	68
8	Light sandy clay	8
9	Sand, rather coarse, with clay	8
10	Light-gray clay, mingled with some sand	35
11	Fine, clean, gray, siliceous sand; water	5
12	Clay, mingled with sand	84
13	Gray, indurated, unctuous clay, (soapstone)	160
14	Coarse, dirty, irregular sand, with clay below	30
15	Fine, clean, gray siliceous sand; some mica flakes; coarser siliceous sand near base; water rising high in the well	10
16	"Soapstone"	10
17	"Sandrock"	40
18	"Soapstone"	30
19	"Sandrock"	90
20	"Soapstone"	85
	Depth of well February 8, 1874	795

THE COAL SERIES.

At many points scattered through the formation streaks or indications of coal occur. The only points at which their development has reached financial or commercial success, however, seem to be confined to the lower horizons of the series as exposed near the mountains. These horizons would also be found underlying the plains east of their natural outcrops, and could be reached by artesian borings. How deep these borings would have to be, however, to penetrate to the coal horizon beneath the plains, sufficient examination has not yet been made to determine with any degree of certainty; and even if reached, it is by no means certain, though quite probable, that coal would be found to exist in the same workable quantities as nearer the mountains.

CHARACTERS AND APPLICATIONS OF THE LIGNITIC COALS.

Chemical characters.—The name lignite would imply that these coals were allied to the brown coals of Europe, a relation indicated by the large percentage of water, usually above 12 per cent., which they contain. At the same time this amount of water is small as compared with that of most foreign lignites, while, instead of having a fibrous or woody structure, they are compact, and generally have a very black color and high shining luster, thus more resembling some bituminous coals. The percentage of ash for lignites is also low, varying from 2 to 6 per cent., while sulphur seldom reaches 1 per cent., and is often nominally absent. The "volatile products" evolved from coal below a dull red-heat usually vary from 25 to 37 per cent., while the amount of "fixed carbon" generally lies between 45 and 60 per cent., these two components representing approximately the calorific or heat-producing power of these coals. The above characters would seem to indicate that these coals are superior to those foreign coals from which the term lignite has been derived. Since, on the other hand, they differ in some respects from bituminous coals, and since their extensive occurrence in the West requires some convenient term which will express to a certain extent their character, I have seen fit to use the term lignite coal or lignitic coal.

It has been necessary to thus separate these coals as above into the four principal ingredients—water, ash, volatile products, and fixed carbon—because nearly all the analyses of them that I have been able to find thus separate them. While such proximate analyses, as will be pointed out shortly, do not give sufficient data for estimating closely the actual calorific value of these coals, and would therefore be misleading in comparing them with bituminous and other coals, they yet serve, to a certain extent, to compare these lignites among themselves; indeed, they form the only data for such comparisons at the present time.

With this end in view, I have gathered together in the following table all the trustworthy proximate analyses that I have been able to find. They are arranged geographically, commencing in New Mexico and proceeding northward along the eastern base of the mountains through Colorado to the line of the Union Pacific Railroad in Southern Wyoming, thence westward along this line to Utah, then proceeding northward along the Pacific coast, and ending finally with a few localities near our northern boundary. For better comparison, the localities within my district are printed in small capitals, and are included in the group between the two heavy lines. All the analyses give the percentages of the components as calculated upon the coal as taken from the mine—that is, including the moisture—except those with the reference "*g*" attached, in which the percentages are calculated on the dried coal; that is, after the moisture has been expelled. They consequently give too high percentages of volatile products, fixed carbon, and ash, as compared with the other analyses; and in them, therefore, the percentages of these ingredients should be diminished proportionally to the amount of water present in each.

A few words in connection with the heat-producing power of coals. The amount of heat developed in the burning of coal is simply the result or outward expression of the chemical union of the oxygen of the air with those substances in the coal for which it has a chemical attraction or affinity. These are principally the carbon and the hydrogen. The products of the union of oxygen with these simple elements are the compound substances carbonic acid and water. The amounts of these produced in combustion represent directly the amount of heat which has been produced as the result of their formation. Having once been formed, chemical action ceases and no further heat arises. If substances are present in the original coal that are now combustible, or already united with oxygen, that is, already burned, they deteriorate the coal accordingly. The ash and moisture present in coals are such substances; they both act as simple impurities, as slate or clay would act, diminishing the relative percentages of the combustible ingredients, and hence the heat-producing power of the whole. But the moisture acts further; to convert it into steam requires a considerable amount of the heat produced by the other substances, and which would otherwise be available.

The amount of moisture in the same coal may be a very variable quantity; so that in analyses the moisture is often first driven off and its amount determined, and the remaining ingredients calculated as percentages of the *dried* coal, as has been observed in those marked "*g*" in the table.

Practically, however, the moisture goes into the furnace with the coal, there to absorb a large amount of heat and diminish the metallurgical value of the coal as a fuel. Analyses which ignore it, therefore, give misleading results.

Are there no other ingredients present which would further deteriorate the coal? In the table above the "volatile products" are considered as combustible. Ultimate analyses, however, show them to be composed of carbon, hydrogen, oxygen, and a small quantity of nitrogen. The latter is simply inert, an impurity, and too small in amount to be of importance. But the oxygen is already united with the remaining two, and to just this extent they must be considered as already burned, and so far unavailable as heat-producers.

This oxygen is usually considered as being combined with the hydrogen to form water. From the "volatile products," then, there should be taken away as non-calorific the oxygen, and so much of the hydrogen as with it will form water, leaving only the remaining hydrogen and all the carbon as available for producing heat. This "combined water" in the "volatile products" acts just as the uncombined water, or "moisture," in diminishing the efficiency of the fuel. To arrive at its amount, ultimate analyses only will serve the purpose. To illustrate these points, Mr. Rossiter W. Raymond, United States commissioner of mining statistics, has recently* collected a number of ultimate analyses of lignites, (none, however, I am sorry to say, of coals in my district,) some of which I reproduce here, with two additional ones, following him in the lessons he draws from them. I have also added columns 15 and 16, which are explained later:

* See Engineering and Mining Journal, May 27, 1873, Silliman's Journal, September, 1873, p. 220, and Report of the Commissioner of Mining Statistics for 1872,

TABLE A.—*Proximate analyses of Western lignitic coals.*

	Locality.	Specific gravity.	Water.	Volatile matter.	Fixed carbon.	Ash.	Litharge reduced by 1 of coal.	Carbon corresponding to volatile matter.	Total carbon.	Approximate units of heat in 1 pound of coal.	Color of ash, &c.	Analyst.	References.
1	Vermejo Cañon, N. Mex.	1.36	3.27	23.73	59.72	13.28	22.80			5418*	Brownish-gray	George J. Brush	(a)
2	Raton Mountains, N. Mex.	1.31	0.90	23.50	55.40	20.20					Gray; sulphur = 0.9 %	C. Leo Mees	(b)
3	Fifteen miles north of Trinidad, N. Mex.	1.26	1.15	37.05	57.60	4.20					Gray; sulphur = 0.85 %	do	(b)
4	Cañon City, Colo.	1.29	5.40	36.40	54.70	3.50					Yellow; sulphur = 0.78 %	do	(b)
5	Cañon City, Colo.	1.28	4.50	34.20	56.80	4.50					Ochre-yellow	Prof. E. T. Cox	(c)
6	Colorado Springs, Colo.	1.27	12.90	39.10	46.00	2.00					Fawn; sulphur = 0.58 %	C. Leo Mees	(b)
7	GOLDEN CITY, 56 feet below surface, Colo.	1.32	13.43	37.15	45.57	3.85					Gray	James T. Hodge	(d)
8	GOLDEN CITY, north end, 100 ft. level, Colo.	1.35	13.67	34.75	47.58	4.00						do	(d)
9	GOLDEN CITY, north end, 100 ft. level, Colo.		13.10			3.70						do	(d)
10	GOLDEN CITY, south end, 100 ft. level, Colo.		12.70			4.10						do	(d)
11	MURPHY MINE, Ralston Creek, Colo	1.34	13.83	35.88	44.44	5.85					Orange	do	(d)
12	MURPHY MINE, Ralston Creek, Colo		13.70			5.80						do	(d)
13	MURPHY MINE, Ralston Creek, Colo		13.90			4.30						do	(d)
14	MURPHY MINE, Ralston Creek, Colo	1.39	11.70	29.07	55.31	3.92	20.49			4870*	Ochre-yellow, luster waxy	George J. Brush	(a)
15	COAL CREEK, Colo.	1.29	20.00	19.30	58.70	2.00					Reddish and light-gray	Dr. John Torrey	(e)
16	MARSHALL MINE, Colo.	1.40	12.00	26.00	59.20	2.80					do	do	(e)
17	MARSHALL MINE, Colo.	1.33	12.00	33.08	49.72	5.20					Gray; light, bulky	James T. Hodge	(d)
18	BAKER MINE, Colo.	1.32	15.00	30.50	50.65	3.85					Olive-brown; coal, hard, tough	do	(d)
19	ERIE (BRIGGS) MINE, Colo	1.27	14.80	34.50	47.30	3.40					Orange	do	(d)
20	Near Coopers Station, Wyo		9.28	39.12	47.04	4.56	22.20			5276*	Yellow-brown; sulphur = 1.38 %	Dr. F. A. Genth	(f)
21	Carbon, Union Pacific Railroad, Wyo	1.31	8.10	34.70	51.65	5.55					Gray; sulphur = 0.91 %	C. Leo Mees	(b)
22	Carbon, Union Pacific Railroad, Wyo	1.30	6.10	38.80	49.30	5.80					do	do	(b)
23	Carbon, Union Pacific Railroad, Wyo	1.33	6.80	35.48	49.72	8.00					Light-gray, nearly white	James T. Hodge	(d)
24	Carbon, Union Pacific Railroad, Wyo	1.37	11.60	27.68	51.67	6.17					Light-gray; sulphur = 2.88 %	J. P. Corson	(h)
25	Separation, Union Pacific Railroad, Wyo	1.34		48.00	50.57	1.43	20.62	10.08	60.65	4900	Deep-red	W. Ashburner	(g)
26	Black Butte, Union, Pacific Railroad, Wyo	1.31		46.00	50.78	3.22	19.99	8.02	58.80	4751	Fuses into globules	do	(g)
27	Hallville, upper bed, Wyo	1.45		46.00	50.60	3.40	19.43	6.55	57.15	4618	White	do	(g)
28	Hallville, upper bed, Wyo	1.32	12.12	29.75	54.37	3.76					Gray, smoke-whitish	James T. Hodge	(d)
29	Hallville, lower bed, Wyo	1.45		48.00	48.02	3.98	18.45	6.26	54.28	4386	White	W. Ashburner	(g)
30	Hallville, lower bed, Wyo	1.32	13.26	29.46	52.41	4.87					Yellowish-gray	James T. Hodge	(d)
31	Point of Rocks, Wyo		8.54	30.60	52.34	8.52	21.80			5181*	White; sulphur = 0.04 %	Dr. F. A. Genth	(f)
32	Point of Rocks, Wyo	1.34		50.00	46.50	3.50	19.64	11.27	57.77	4668	White	W. Ashburner	(g)
33	Van Dyks, Wyo	1.28		46.00	52.67	1.33	23.35	16.01	68.68	5549	Brick-red	do	(g)
34	Van Dyks, Wyo	1.27	8.12	36.65	53.23	2.00					Light-gray, coking	James T. Hodge	(d)
35	Rock Springs, Wyo	1.29	7.00	36.81	54.46	1.73					do	do	(d)
36	Rock Springs, Wyo	1.23	6.25	31.75	52.45	9.55					White; sulphur=0.94%	C. Leo Mees	(b)

37	Rock Springs, Wyo	1.35		46.00	44.98	9.02	22.41	20.93	65.91	5325	White	W. Ashburner	(g)
38*	Evanston, Wyo	1.33		40.00	52.75	7.25	20.75	8.27	61.02	4930	...do	...do	(g)
39	Evanston, (1,) Wyo	1.34	8.07	43.06	47.34	9.60	23.70	22.36	69.70	5632	Gray	O. D. Allen	(g)
40	Evanston, (2,) Wyo	1.35	8.10	42.70	47.67	9.67	23.70	22.03	69.70	5632	...do	...do	(g)
41	Evanston, Wyo	1.30	8.58	35.22	49.90	6.30						James T. Hodge	(d)
42	Christmans, Coalville, Utah	1.32	10.66	38.23	48.00	3.11						...do	(d)
43	Christmans, upper tunnel, Utah	1.32	9.56	48.09	48.14	3.77	23.80	21.86	70.00	5656	Gray	O. D. Allen	(g)
44	Christmans, lower tunnel, Utah	1.32	10.33	49.28	47.83	2.89	24.00	22.76	70.59	5704	Yellowish-white	...do	(g)
45	Christmans, lower tunnel, Utah	1.32	9.83	47.46	48.91	3.69	23.70	20.79	69.70	5630	...do	...do	(g)
46	Robinsons, Utah	1.32	9.42	48.21	48.27	3.32	25.20	25.65	74.12	5989	Light-gray	...do	(g)
47	Johnsons, Utah	1.29	9.89	47.34	49.35	3.31	23.80	20.65	70.00	5656	...do	...do	(g)
48	Wasatch, lower tunnel, Utah	1.31	8.38	47.06	49.68	2.26	29.90	26.49	76.17	6154	Nearly white	...do	(g)
49	Wasatch, upper tunnel, Utah	1.30		47.80	49.75	2.22	25.30	24.66	74.41	6012	...do	...do	(g)
50	Wasatch, Utah	1.32		50.00	46.73	3.27	20.79	14.42	61.15	4941	Reddish-white	W. Ashburner	(g)
51	Spragues, Utah	1.44		54.00	42.53	3.47	20.46	17.64	60.17	4862	White	...do	(g)
52	Spragues, (1,) Utah	1.32	1.68	47.27	48.78	3.95	23.50	20.44	69.12	5585	Light-reddish gray	O. D. Allen	(g)
53	Spragues, (2,) Utah	1.33	8.62	47.16	49.03	4.01	23.20	19.20	68.23	5513	Light-reddish gray; sulp'r=2.40%	...do	(g)
54	Weber River, Utah		9.45	26.21	58.32	3.64						George Baxter	(k)
55	Monte Diablo, Cal		3.28	47.05	44.90	4.71						W. P. Blake	(d)
56	Monte Diablo, Cal		20.53	35.62	36.35	7.50						J. D. Whitney	(i)
57	Monte Diablo, Cal		14.13	37.38	44.55	3.94						...do	(i)
58	Monte Diablo, Cal		13.84	40.27	44.92	0.97						...do	(i)
59	Monte Diablo, Cal		14.69	33.89	46.84	4.68						...do	(i)
60	Monte Diablo, Cal		13.47	40.36	40.65	5.52						...do	(i)
61	Coos Bay, Oreg		20.09	32.59	41.98	5.34						...do	(i)
62	Coos Bay, Oreg		50.27		46.54	3.19						J. S. Newberry	(j)
63	Bellingham Bay, Wash		8.39	33.26	45.69	12.66						J. D. Whitney	(i)
64	Bellingham Bay, Wash		50.22		47.63	2.15						J. S. Newberry	(j)
65	Nanaimo, Vancouver Island		2.98	32.16	46.31	18.55						J. D. Whitney	(i)
66	Nanaimo, Vancouver Island		44.30		51.81	3.19						J. S. Newberry	(j)
67	Chestnut River, near Bozeman, Mont		3.00	41.50	43.50	12.00						A. C. Peale	(l)
68	Chestnut River, near Bozeman, Mont		7.00	34.50	50.50	8.00						...do	(l)
69	One mile south of northern boundary, near 106°, Mont.		12.05	35.12	64.18	6.65					Light-gray	G. M. Dawson	(m)
70	Souris Valley, near 49th parallel, Brit'h Col.		15.11	32.76	47.57	4.56					Yellowish-white, light	...do	(m)
71	Souris Valley, near 49th parallel, Brit'h Col.		12.07	32.74	45.44	2.75					Reddish-white	...do	(m)

* Approximate: One part of pure carbon being taken as reducing 34 parts of litharge, (Berthier's method,) usually giving results within one-ninth smaller than obtained by calculation from ultimate analysis.

(a) Notes on the Geology, &c., from the Smoky Hill River, Kansas, to the Rio Grande, by Dr. John L. LeConte, p. 58.

(b) The Lignitic Formation and Fossil Flora, by Prof. Leo Lesquereux; Hayden's Report, 1872, p. 370.

(c) Engineers and Mining Journal, August 20, 1872, and Raymond's Report on Mines and Mining West of the Rocky Mountains, for 1872, p. 304.

(d) The Tertiary Coals of the West, by James T. Hodge, in Hayden's Report, 1870, p. 321.

(e) Dr. F. V. Hayden in Silliman's Journal, March, 1868, and Final Report of Nebraska, 1872, p. 62, (also in *a* above.)

(f) Quoted by Persifor Frazier, jr., in Hayden's Report, 1870, p. 185.

(g) Exploration of the Fortieth Parallel, Clarence King in charge; vol. 3 Mining Industry, p. 473.

(h) Hayden's Report, 1867–'68–'69, reprint, p. 197.

(i) Geology of California, Prof. J. D. Whitney, vol. 1, p. 30; quoted in *a* above, and "Mineral Resources of the West," 1868, J. R. Browne, p. 229.

(j) Report on the Geology, &c., of Northern California and Oregon, War Department, Washington, D. C., 1857, by John S. Newberry, pp. 64–67.

(k) Alaska and its Resources, W. H. Dall, Boston, 1870, p. 472, and Macfarlane's Coal Regions of America, New York, 1873, p. 577.

(l) Hayden's Report, 1872, p. 114.

(m) Geological Report of Progress for 1873, British North American Boundary Commission, by George M. Dawson, Montreal; also, Canadian Naturalist, April, 1874, p. 250.

TABLE B.—*Ultimate analyses of Western lignitic coals, adopted from R. W. Raymond.*

Locality.	Uncombined water.	Carbon.		Hydrogen.		Oxygen.	Nitrogen.	Ash.	Sulphur.	Combined water.	Calorific power I.	Calorific power II	Calorific power III.	Calorific power IV.	Calorific power as compared with that of pure carbon.	Analyst.
		Probably fixed.	Probably combined with hydrogen.	Probably combined with carbon.	Combined with oxygen to form water.											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Cañon City, Col	5.18	50.36	17.22	5.74	1.68	13.42	....	5.77	0.63	15.10	7439	7845	7330	6961	86%	Dr. T. M. Drown.
Carbon Station, Wyo	11.56	59.41	5.58	1.86	1.90	15.20	1.74	1.68	1.07	17.10	5892	6662	5738	5618	69%	H. S. Monro.
Carbon Station, Wyo	8.06	59.63	9.51	3.17	1.19	9.54	1.25	6.62	1.03	10.73	6679	7264	6578	6374	79%	H. S. Monro.
Weber Cañon, Utah	9.41	57.64	7.20	2.40	1.94	15.52	1.29	3.00	1.60	17.46	6056	6685	5912	5757	76%	H. S. Monro.
Echo Cañon, Utah	9.17	62.25	7.59	2.53	1.37	10.99	1.93	3.40	0.77	12.36	6515	7172	6400	6237	77%	H. S. Monro.
Coos Bay, Oreg	13.28	54.29	1.95	0.65	2.73	21.82	0.42	4.05	0.81	24.55	4768	5498	4565	4523	56%	H. S. Monro.
Monte Diablo, Cal	8.94	50.36	9.36	3.12	1.96	15.69	1.01	5.64	3.92	17.65	5900	6472	5757	5526	68%	H. S. Monro.
La Roche Percée*	13.92	52.63	3.87	1.29	2.36	18.91	0.80	5.62	0.60	21.27	5009	....	4821	4738	59%	C. Tookey.
Fort Edmonton†	14.50	46.26	4.34	1.44	1.80	14.41	0.90	15.93	0.42	16.21	4585	....	4420	4327	53%	C. Tookey.

* Souri River, British America; latitude 49° 7′ north, longitude 115 west; Tertiary.(?)

† Right bank of the Saskatchewan; latitude 53° 33′ north, longitude 113° 20′ west; Lower Cretaceous.(?) (See Hector's Report on Geology of Country between Lake Superior and the Pacific; Quarterly Journal Geological Society, London, vol. xvii, Part I, pp. 409 and 421; Percy's Metallurgy, vol. 1, Fuel, p. 87.)

The moisture, or uncombined water-ash and sulphur, in the above table appear in the same manner as in the preceding table. The carbon appears greater in amount because, besides the "fixed carbon," it includes the carbon before contained in the "volatile products."

The amount of oxygen included in these volatile products now becomes apparent. If combined with the associated hydrogen to form water, it has thus already rendered one-eighth of its weight of hydrogen unavailable as a heat-producer. The resultant combined water (equal to the oxygen plus one-eighth of its own weight of hydrogen) is given in column 11, and this acts precisely as the moisture does in absorbing heat. Mr. Raymond, in speaking of the first three columns of calorific powers, which he gives, says:

In each of these the amounts are expressed in centigrade heat units, and therefore indicate directly the pounds of water which could theoretically be raised from zero to the boiling-point by the combustion of one hundred pounds of fuel. The first column is obtained in the following manner: The amount of combined water is found by adding to the oxygen one-eighth its weight in hydrogen; the remaining hydrogen is multiplied by 34,462, the number of heat-units evolved in the combustion of hydrogen; and the amount of carbon is in like manner multiplied by 8,080, the calorific modulus for carbon. The sum of these two products is the number of units generated by the complete combustion of one unit of the fuel, containing the given proportions of carbon and available hydrogen. The heat units due the combustion of the sulphur are disregarded, in view of the small amount of sulphur, its low calorific capacity, (about 2,240 units,) and the circumstance that it exists partly in the form of pyrites, the decomposition of which still further diminishes the amount of heat from this source, and partly as sulphuric acid, causing a net loss.

The second class of calorific powers is obtained by a similar calculation on the supposition that the moisture is absent. The third column gives the closest approximation to the available heat, and is obtained by deducting from the figures in the first the amount of heat-units required to vaporize the moisture and combined water. This is 537 units of heat for each unit of water.

In reality, the results in column 14 (calorific power III) should be still further reduced.

We have seen that the full amount of hydrogen given in the analysis cannot be realized as a heat-producer, as part of it already exists in the form of water. Is the remaining hydrogen to be regarded as in a condition to give out all its great heat energy? It is, in fact, combined with some of the carbon present, probably mostly in the form of marsh-gas, (composed of one part by weight of hydrogen to three of carbon,) and though the two ingredients are both combustible, yet they have to be separated from one another in uniting with oxygen in the process of burning. As the union of elements to form compounds produces heat, so the separation of compounds in their elements absorbs heat, and each unit of marsh-gas thus decomposed absorbs about 1,612 units of heat. In other words, when a unit of marsh-gas is burned it produces but 13,063 units of heat instead of the 14,675 units which would be produced if it were first separated into its components and these then burned, as is implied in the preceding calculation of calorific power III.

In estimating the calorific power of the fuel from this last point of view, the amount of hydrogen rendered unavailable as a heat-producer in the form of water remains the same as before. (Columns 6 and 11.) The remaining hydrogen, (column 5,) if its combination with carbon is considered to be in the proportion to form marsh-gas, which is approximately true, must take up three times its weight of carbon (column 4) to form this gas, and the sum (column 4 plus column 5) multiplied by 13,063—its calorific modulus—will give the heat produced in its combustion. The remaining carbon only, then, gives out heat in proportion of 8,080 units to one of carbon, and the two products together give the total amount of heat produced, from which, as before, the heat absorbed by the vaporization of the water must be subtracted to obtain the actual available heat produced by the combustion of a unit of this coal. The results are given in column 15. (Calorific power IV.) They may also be obtained by subtracting from calorific power III 64.5 units of heat for each per cent. of hydrogen present in the analyses over and above that required to form water with the oxygen present. Column 14 gives the relation between the heat-producing power of these coals as compared with that of pure carbon, (8080.)

It shows that many of them may be considered as having three-fourths of the calorific power of that substance as represented by perfectly purified charcoal. These numbers, of course, can never be fully realized in actual practice, but neither can the full calorific power of pure carbon; they still serve, however, for purposes of comparison, and they show that the inherent or potential capabilities of these coals are far greater than they are usually supposed to be.

So much for the quantity of heat that these coals are capable of producing, if completely and perfectly burned. The temperature produced by this combustion, and which is the chief consideration in the application of fuel to practical purposes, is another matter. This temperature depends on the rapidity or intensity of the combustion in a given space, and the amount and specific heats of the gases produced by it, and may be as seriously affected by the physical behavior of the fuel as by its chemical composition. That the latter is favorable to the production of high heats is shown above; but before being able to judge of the best mode of application of these coals, their physical characters and behavior must be first examined.

PHYSICAL CHARACTERS OF THE LIGNITIC COALS OF THE PLAINS.

The lignitic coals of Colorado occur varying from mere streaks of carbonaceous matter to beds 16 feet in thickness. "For the most part they are remarkably free from impurities, it being not rare to see a face of 8 or even 10 feet of clean coal of brilliant luster, perfectly sound and solid in the mine, without a particle of slate or any visible foreign matter that would injure it. Iron pyrites, however, may generally be detected in small flakes and thin disks, but very rarely in sufficient quantity to be injurious. Mineral resin is a common ingredient." *

Their specific gravity is seldom below 1.3, sometimes 1.4. With one or two exceptions, in which the color is a dull black, they all possess a high shining luster, and cleave readily into cubical blocks. When well protected they may remain a long time unchanged, but on exposure to the atmosphere they disintegrate very rapidly. "This tendency to crumble is the cause of great waste at the mines—all the greater that these tertiary coals can scarcely ever be made to melt and agglutinate into a firm coke. With rare exceptions, when submitted to the coking process they retain their form or crumble into a dry powder." "The coal kindles and burns freely, making a bright fire with a yellow blaze and comparatively little smoke; the odor of this is not so strong or disagreeable as that of the bituminous coals, and somewhat resembles the smell of burning peat. The smoke is not always dark and thick, but is sometimes of a light-gray color. The ashes are remarkably light and bulky." †

* Hodge on the Tertiary coals of the West, (Hayden's Report for 1870, p. 319.)
† Ibid., pp. 319–320.

APPLICATIONS.

These coals have been found to serve well for all domestic purposes, either for cooking or warming, and are now largely used both for stationary boilers and locomotives. Their freedom from sulphur, in rendering them less injurious in burning out grate-bars, &c., would recommend them for these purposes; though with some of these coals a frequent use of the exhaust in increasing the draught is necessary to insure a sufficiently rapid combustion. According to Hodge, the engineers find that the more crumbling varieties sift through the grate-bars, requiring closer screens at the top of the smoke-stacks. "They endeavor to obtain the coal as freshly mined as possible, on account of its sounder condition. Clinkers sometimes form sufficiently to be troublesome when the coals are obtained from those mines that contain seams of slate."

These coals are at present also used for the following purposes, for information about which I am indebted to Mr. Berthoud: At the two smelting works at Golden City the best lignitic coal is used in roasting ores, either in close furnaces, or in step-furnaces used in desulphurizing pyritous ores. It is also used at Golden for baking the bricks, &c., there made from the clays of the lignitic series. For gas-making in Colorado the lignitic coals are alone used, while a five-feet bed at Golden City, Cañon City coal, and Trinidad coal are all used in blacksmith-work.

And here we seem to stand on the limits of the usefulness of these coals. Notwithstanding the high potential calorific power which we have seen that they possess, it remains for some reason unavailable. For all those processes in the arts in which high temperatures are required, the lignitic coals—as compared with anthracite and bituminous coals—have so far proved seriously defective. Indeed, they hardly compare with some of the coals with which they are allied in both physical and chemical features, as, for instance, the "block-coal" of Indiana, which, though not equaling in calorific power some of these western coals, as Raymond has shown, yet is successfully used in smelting iron. With these coals, however, even for common blacksmithing purposes, it has required much experience before they have become to be permanently used for welding, and, while they are used at Golden City for roasting the ores, for smelting them (mostly galena, and siliceous ores of gold, silver, copper, lead, and zinc) a large proportion of Pittsburgh coke is used. One or two experiments in reverberatory furnaces and several trials in blast furnaces have all proved unsuccessful. In the former the common fire-box and horizontal grate was used, and in no case was strong artificial draught or pressure employed. What might be accomplished with the many recent appliances in the way of improved grates, fire-boxes, and high pressures remains yet to be seen, but, so far as tried, they have failed as producers of high temperatures.

The cause of all these failures appears to be due simply to the physical behavior of the coal when heated—in giving off their large percentage of moisture they crumble into small pieces. On the furnace-grate this produces a layer not readily penetrated by sufficient air to support a rapid combustion and consequent high temperature, and the frequent stirrings necessary to avoid this difficulty introduces another in the loss of heat incident upon the constant opening of the furnance-doors. In the blast furnace the tendency to crumble is augmented by the superincumbent weight, so preventing the access of air that the furnace nearly chills without reaching a smelting temperature. They might still be made available for this purpose to a small extent by mixing them with charcoal. In Austria somewhat similar coals have been used to the extent of one-eighth or one-fourth of the amount of charcoal used.*

The usual process employed to make coals of low calorific power useful, by driving off the moisture, and concentrating, as it were, the combustible material, is the process of *coking*; but this, as we have already seen, fails with these coals. I believe that no coal so far found in my district has been successfully coked. They either crumble to powder in the process, or make such a friable product that it pulverizes in handling or in the furnace. Further south Trinidad coal makes a fair coke, and Cañon City coal a poorer one.

A process has been patented for coking the lignites, but I am informed it makes a crumbling, inferior article, unfit for smelting iron, though applicable for light forging.

To obviate the great loss arising from the easy crumbling of these coals—and the process would improve their behavior in the furnace as well—Professor Lesquereux has suggested the mixing of the coal slack accumulating at the mines with some agglutinizing material and compressing the mixture into coherent blocks; and for the Western Wyoming and Utah coals he suggests the use of the bitumen stored in the black shales of the Green River group of rocks near by. Were this to give sufficient coherence to the mass, it is certainly an admirable suggestion. Many of the substances used for such purposes, as clay, &c., being non-combustible, only subtract from that calorific power in which the lignites are originally somewhat defective, while the bitumen would naturally assist in their combustion. The enormous accumulations of slack about Eastern and European coal-mines have already led to many experiments to render them commercially available. When some of these processes are perfected, their application to western coal-slack may some day form an important industry.

But any process which can employ directly or which requires a fuel of friable character is the one best adapted to these coals. Heat-producing appliances have naturally been designed for the use of coherent fuels, and hence these crumbling lignites have failed when used in their stead. Processes, however, have comparatively recently been introduced which attain the very highest metallurgical results, and which are yet assisted by the friability rather than by the compactness of the fuel; and, so far as this character is a factor in the operation, these coals would be admirably fitted for such processes.

Such processes may be considered as divided into two classes; namely, those using gaseous fuel, and those using pulverized fuel. The type of the former is the now well-known Siemen's process, with the regenerative furnace. Here the coal, or any carbonaceous matter, is first burned in a small, close furnace, called the "Producer," in which the object is to produce, not a high temperature, but a combustible gas. For this purpose the fineness of the coal rather aids the process, for the carbonic acid, formed by the first contact of the air with the lower layer of burning coal on the grate, is then all the more certain, in passing up through the fine mass of incandescent fuel above, to become carbonic oxide, the gas employed in the final operation in the main furnace. This process has so far probably been more generally successfully used for the production of the very highest metallurgical temperatures than almost any other; and as not only lignites, but peat, wood, and even sawdust have been successfully used, and all but the latter for the greatest heats, there

* Tunner's Leob., Jahrb., VI, 186.

is no doubt but that the lignites of Colorado could be employed in any process embodying this principle. The "plant," however, is expensive, and has so far only been economically used, so far as I know, in large iron operations, the ore necessary for which is still wanting in the far West. The principle of producing and using the gases from these coals, however, could still be applied when such high temperatures as require the use of the "regenerators" are not desired.

A successful type of a pulverized fuel process is that of Messrs. Whepey & Storer. In strong contrast with the expensive plant of the Siemen's process, the essential piece of apparatus here is a machine differing but little from a fan-blower. The coal, first screened to the size of coarse gravel, is automatically fed into a cylinder varying from 12 to 30 inches in diameter, in which a paddle-wheel revolves at the rate of from 1,500 to 3,000 times per minute. Caught in the rapid revolutions of this paddle—the particles abrading one another in the swift air-currents—the coal is rapidly pulvérized to the finest dust, and, with the accompanying air, is forced in a constant stream through a short pipe a few inches in diameter into the previously slightly heated fire-place beneath the boiler, or into the combustion-chamber of the furnace, as is the air from an ordinary fan-blower, every minute particle of coal floated upon and surrounded by the very air which is to burn it, while the supply of either coal-dust or air can be instantly regulated and varied in amount until so proportioned to one another as to produce the most perfect combustion. Indeed, the conditions for combustion here seem almost perfect, so that, notwithstanding the apparent inadequacy of the means employed, the highest metallurgical heats may be obtained and used on a large scale. It is easily applicable to common boilers, or most heating appliances, and generally requires but slight change in the original apparatus.

Aside from the portability and ease of application of the apparatus, important considerations in the West,) the process appears to be so particularly adapted to these friable coals, especially in view of the difficulties surrounding their application in other ways, that it seems as if it were in this direction that the lignitic coals of the West could be best rescued from the metallurgical difficulties which now surround them. It is certainly a process which is aided by that very character of these coals which renders them unfit for use by the usual methods.*

DISTRIBUTION AND DEVELOPMENTS OF THE LIGNITIC COAL.

On the accompanying map (figure 4) will be found indicated nearly all the points at which openings have been made on coal deposits within my district, the positions of which with respect to the sections, with but few exceptions, have been very kindly furnished me by Mr. E. L. Berthoud of Golden City. These openings are indicated by prominent black squares, the names of the mines, or their owners, being in most cases attached to them; while the outcrop of the coal horizon, as inferred from these openings, is given in the strong black line to better emphasize its position.

Over most of this region this outcrop is hidden from view by the superincumbent horizontal terrace-beds or detrital material. Along the western edge of the maps are the abrupt ends of the massive mountain-

* For a clear and simple statement of the chemical principles which underlie the combustion of fuel, and of the practical considerations affecting the carrying out of these principles, and realizing the full value of the fuel, the reader is referred to James Macfarlane's Coal Regions of America, New York, D. Appleton & Co., 1873, pp. 626–638.

spurs of the Archæan rocks. Then comes the zone of outcropping edges of the Triassic, Jurassic, and Cretaceous beds, approximately shown by the lining; the first two by oblique lines downward to the right, the last by horizontal lines. To the east, so far as I know, all is of the Lignitic formation.

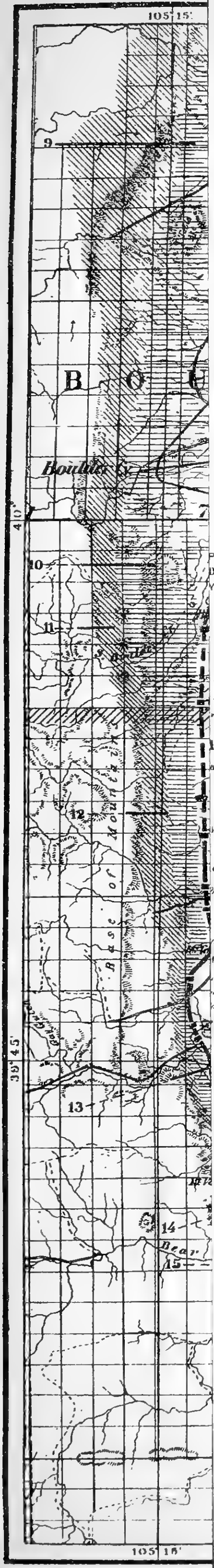
Sections illustrating the relations between these beds at several points (indicated by numbers on the map) are given on Plate II. The basis of this map is compiled from the United States land survey, the townships and sections being therefore authoritative. The limits of the counties are shown by the oblique lining downward to the left, while all the railroads at present in operation are also given. It will be seen that, as before stated, the main coal-measures, so far as known and opened, lie chiefly near the mountain-base. From near Bowlder City southward through Golden City to where the South Platte debouches from the mountains is almost a continuous line of openings, among which are the Marshall and Murphy mines, probably as well known as any coal-mines in Colorado. Though at the north the beds dip gently to the east, throughout nearly all the remainder of this line they stand nearly vertical, and in places are thrown over beyond the vertical. To the north, along the zone of hog-backs, this horizon would probably be found lying a little above the Cretaceous beds, and it has, I understand, been opened near both of the Thompson Creeks, but so far the demand in this northern region has not required an active search for coal. Instead of to the north, the main openings have been developed to the northeast of Bowlder City, reaching to Platteville near old Fort Saint Vrain. Of these, the Erie and Baker mines are the most prominent. Whether belonging to the same or to a higher horizon in the lignitic group than the former coal-openings, is not yet ascertained with certainty.

The best known coal-openings, then, may be considered as arranging themselves along a line running from Platteville southwestward to near Bowlder City, and then turning southward along the base of the mountains to the South Platte. It is near the middle of this zone that the best and thickest development of the coal seems to occur. Besides these openings, excepting a few poor indications of coal at scattered places, the only others that I have heard of lie from fifteen to seventeen miles east of Denver City, and near the Box Elder station on the Kansas Pacific Railroad.

In describing what is known of the occurrence of coal at the various points indicated, I will speak first of this eastern group, and then, commencing at the north, follow southward along the line of openings before spoken of to the South Platte. The information is gathered mostly from the reports of Hodge, Hayden, and Lesquereux, supplemented by much material given me by Mr. Berthoud. It is to be understood that in speaking of "mines," such extensive openings as characterize the eastern coal regions are by no means intended. As yet the demand for coal has been but small, and in nearly all cases the mining has been crude in method and small in extent, though the time is at hand when both its improvement and enlargement will be very great.

THE VARIOUS COAL-OPENINGS.

East of Denver, in township 4 south, and probably between ranges 65 and 66 west, a shaft has been sunk for some depth in a high bank on the south side of Sand Creek, but is now abandoned. The coal also



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D GEOGRAPHICAL SURVEY OF THE TERRITORIES
YDEN, GEOLOGIST IN CHARGE.

Plate IV.

MAP
OF THE
RAIL ROADS, SECTIONS &c.
TERN BASE OF THE MOUNTAINS
R DENVER CITY.

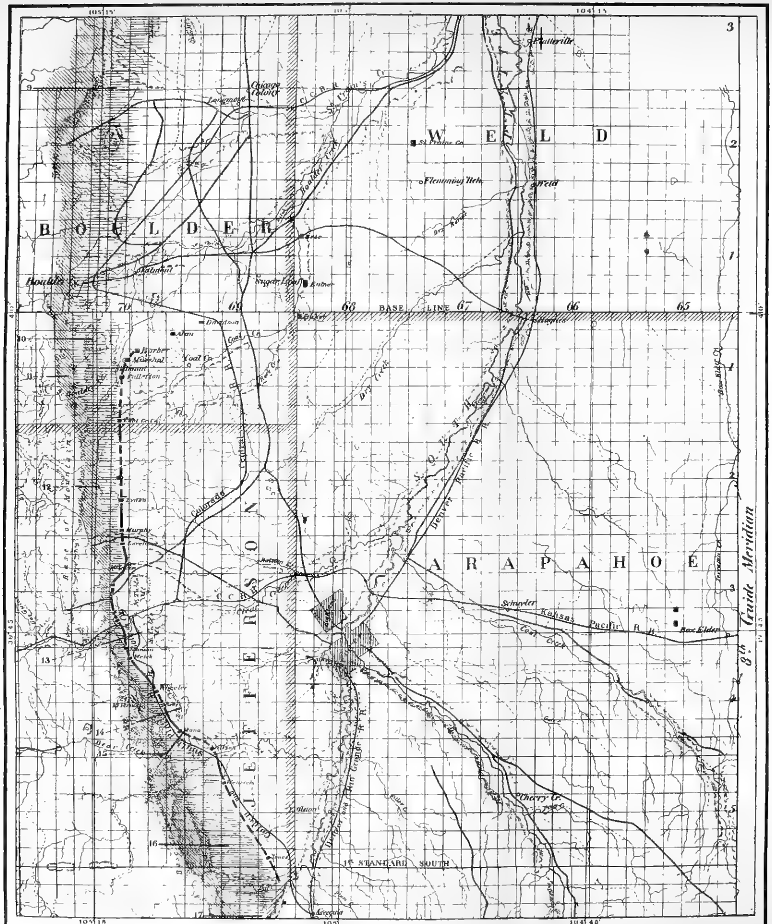
accompany the Report of
ARCH. R. MARVINE,
MIDDLE PARK DIVISION
1873.

Scale 6 miles to an inch.

LEDGEND:

c Archaean rocks along the West Border.
p of Triassic and Jurassic beds . . .
Cretaceous beds . . . .
. *Coal horizon, so far as known*
s and Mines . . . .
the Formation upon the East.

ap is compiled from the notes of the U.S. Land Survey
e coal openings, with respect to the Section lines, etc.
a furnished by Mr. E. L. Berthoud, of Golden City.
ections 9 to 17 of Plate II are indicate near the
west side of the map.



DEPT OF THE INTERIOR
U. S. GEOLOGICAL AND GEOGRAPHICAL SURVEY OF THE TERRITORIES
F. V. HAYDEN GEOLOGIST IN CHARGE

Plate IV.

MAP OF THE COAL OPENINGS, RAIL ROADS, SECTIONS &c. ALONG THE EASTERN BASE OF THE MOUNTAINS NEAR DENVER CITY.

To accompany the Report of
ARCH. R. MARVINE,
MIDDLE PARK DIVISION
1873

Scale 6 miles to an inch

LEGEND

Metamorphic Archaean rocks along the West Border
Line of outcrop of Triassic and Jurassic beds
Cretaceous beds
Coal horizon as far as known
Coal openings and Mines
Lignitic Formation upon the East

The basis of the map is compiled from the notes of the U. S. Land Survey. The positions of the coal openings with respect to the Section lines, etc. are from data furnished by Mr. E. L. Berthoud, of Golden City. The positions of sections 9 to 17 of Plate II are indicated near the west side of the map.

outcrops on the bank, and there appears as of a very poor quality. Fossil-leaves are abundant.

It was near here that the first discoveries of coal were made in Colorado, and the stream at this point is often known as Coal Creek, though called Sand Creek farther down. The latter name should be retained, to prevent confusion between this and the better known Coal Creek on the west side of the Platte.

About four miles to the north, near Box Elder on the Kansas Pacific road, in range 65 west, township 3 south, section 28, (?) and probably in the same horizon as the last, are two shafts which reach coal, and on which work has been done now and then for some years. It is probably in one of these three shafts that the following section was made by Mr. E. B. Mally, (quoted by Lesquereux in Hayden's report for 1872, p. 327,) and which serves to give an idea of the strata near here:

Section of strata in shaft fourteen miles east of Denver.—E. B. Mally.

No.	Nature of strata.	Thickness. Feet.	in.
	Top.		
1	Slaty clay	16	0
2	Sand	18	0
3	Yellow clay	5	0
4	Light-blue soapstone	6	0
5	Brown soapstone	2	0
6	Soapstone and clay	13	0
7	Drab soapstone	14	0
8	Dark-brown soapstone	2	0
9	Black slate, with veins of coal	5	6
10	Coal, wet and smutty	4	0
11	Coal, better	3	0
12	Black-clay parting		4
13	Coal	1	0
14	Soapstone, blue, brown, and black	24	7
15	Hard sand-rock	1	4
16	Spotted sand-rock	12	0
17	Very hard sand-rock	5	0
18	Soft sandy clay	9	6
	Bottom.		
	Total	142	3

The work was abandoned on account of the poor quality of the coal. Professor Lesquereux thinks that the section indicates the horizon of the bed as being at the top of the great lignitic or fucoidal sandstone under the series of beds of clay and soapstone, as at the Raton Mountains.

Platteville, range 66 west, township 3 north, sections 17, 18, 19, 20; coal in small veins, now owned by the Saint Vrain Coal Company.

McKissack, range 67 west, township 2 north, sections 18, 19; coal in bed or beds some 10 feet thick, now coking, crumbling, and with but little sulphur, as usual.

Erie mine, range 68 west, township 1 north, sections 7 and 8, called also the Briggs mine. This opening, which is one of the larger ones, is on the west side of a hill facing Coal Creek, the opening being down the gentle slope of the bed east-northeast into the hill.

In 1870 the main adit had been driven 500 feet, with galleries on either side, no provision being required on account of water. The coal is glistening black, breaking in rectangular blocks, and occurs in an upper bed of $8\frac{1}{4}$ to $8\frac{3}{4}$ feet thick, and a lower one of 3 to $3\frac{1}{2}$ feet, separated by a slate parting of $1\frac{1}{4}$ feet. The property is owned by the Kansas Pacific Road, and it is connected by railroad with Hughes, on the Denver Pacific. In 1872 the amount frequently taken out daily was 200 tons. For analysis see Table A, No. 19.

In passing up the eastern banks of Coal Creek from the Erie mine, we first pass the Eulner coal-bank, and in about four miles reach the Baker or Douglass coal-bed, range 67 west, township 1 south, section 6.

The Erie coal horizon has meanwhile risen higher and higher on the hills, and at the Baker mine appears some 200 feet above the outcrops then worked. The bed is $4\frac{1}{2}$ or 5 feet thick, dipping at a low angle eastward into the hill, and produces a "coal very different in appearance from that of the other mines. A part is a dull jet-black, hard and brittle, breaking in cuboidal fragments, and streaks of this cannel-like character are seen in the more brilliant varieties that are also found. Iron pyrites in extremely thin disks, and resin also, are noticed in this coal. Two or three other small beds appear in the bank of the creek, and in the slates or shales over them are courses of kidney ore." (Hodge. See analysis 18, table A.)

Davidson's opening, range 69 west, township 1 south, section 6. This coal, which was found in 1869 near the summit of the high ground lying about six miles west of the Baker mine, is about $3\frac{1}{2}$ feet thick, and probably lies far above the main coal-horizon.

Alan opening, range 70 west, township 1 south, section 12, northeast corner of the northwest corner.

Barber opening, range 70 west, township 1 south, section 15, northeast corner of the southeast corner.

Marshall mine, range 70 west, township 1 south, section 16, northeast corner of southeast corner, on the east side of the valley of the South Bowlder Creek, about five miles southeast of Bowlder City, and twenty-two or twenty-three miles north-northwest of Denver. This mine was among the earliest worked in Colorado. It was in operation in 1863, has been worked with no material interruption since, and stands among the best mines of the Territory. Eleven seams of coal are said to be recognized here, amounting in all to a thickness of 63 feet in a thickness of beds of 500 or 600 feet. Several of these have been opened and worked, the principal one of which is the lowest in the formation. This bed is nearly horizontal, dipping easterly but 8°, and having an east and west vertical cleavage. It is worked to a thickness of from 10 to 12 feet, through the whole of which the coal is remarkably free from slate and other impurities. It contains very little pyrites in thin disks, and some resin in small particles. In the mine the freshly-exposed face presents a beautifully brilliant appearance, and the coal is so found that a cubic block of it, said to weigh over three tons, was taken out for exhibition at the fair at Denver. In 1870, according to Hodge, the two parallel headings or levels by which this bed is worked had penetrated to a distance of 600 feet, being driven in from the north side of the hill, and rising a little up the slope of the bed. From there rooms are worked on either side, but chiefly up the slope. In the other direction, the bed passes under a meadow where the coal will have to be worked and drained by means of vertical shafts. This bed was then mined for $1.25 per ton, besides cost of props and keeping the track, &c., in good condition. In 1869 the average amount mined per day was 50 tons; in

1872, but 25 tons. The coal is used very generally by blacksmiths, who have overcome the difficulty they formerly experienced in not being able to get up a welding-heat with it.

A bed 7 feet in thickness, and lying somewhat above the main bed, was formerly mined through a shaft 50 feet deep, while, lying still above, a three-foot bed, capped with fire-clay, was followed for 60 or 70 feet down its gentle eastern slope into the hill. Still higher, a bed known as the Dabney bed is said to be 9 feet thick, and, when worked, furnished coal of a superior quality, especially for blacksmiths' use. Several other beds have also been opened to a small extent.

I append a section of the neighboring beds made by Dr. Hayden in 1867 and 1869:

Section of the lignitic beds at the Marshall mine, Colorado.—Dr. F. V. Hayden, 1869.

48. Drab clay with iron ore along the top of the ridge.
47. Sandstone.
46. Drab clay and iron ore.
45. Coal, (No. 11,) no development.
44. Drab clay.
43. Sandstone, 15 to 20 feet.
42. Drab clay and iron ore.
41. Coal, (No. 10,) no development.
40. Yellowish-drab clay, 4 feet.
39. Sandstone, 20 feet.
38. Drab clay full of the finest quality of iron ore, 15 feet.
37. Thin layer of sandstone.
36. Coal, (No. 9,) nearly vertical where it has been worked, 12 feet.
35. Arenaceous clay, 2 feet.
34. Drab clay, 3 feet.
33. Sandstone, 5 feet; then a heavy seam of iron ore; then 3 feet of drab clay; then 5 feet sandstone.
32. Coal, (No. 8,) 4 feet.
31. Drab clay.
30. Sandstone, 25 to 40 feet.
29. Drab clay, 6 feet.
28. Coal, (No. 7,) 6 feet.
27. Drab clay, 5 feet.

Dip, 37°:
26. Sandstone with a seam of clay, 12 to 18 inches, intercalated, 25 feet.
25. Drab clay, 4 feet.
24. Coal, (No. 6,) in two seams, $4\frac{1}{2}$ feet.
23. Drab clay, 3 to 4 feet.

22. Yellowish, fine-grained sandstone in thin, loose layers, with plants, 5 to 10 feet.

Dip, 8° (15 feet):
21. Drab clay, excellent iron-ore.
20. Coal, (No. 5,) 7 feet.
19. Drab clay.

18. Sandstone, dip 11°. This sandstone has a reddish tinge, and is less massive than 14.

20 feet, obscure:
17. Drab clay.
16. Coal, (No. 4.)
15. Drab clay.

14. Sandstone, massive, 60 feet.
13. Drab clay.

12. Sandstone.
11. Drab clay.
10. Coal, (No. 3.)
9. Drab clay.
8. Sandstone, 25 feet.
7. Drab clay.
6. Coal, (No. 2,) 8 feet.
5. Drab clay.
4. Sandstone, about 25 feet.
3. Drab, fire-clay, 4 feet.
2. Coal, (No. 1,) 11 to 14 feet.
1. Sandstone.

"In bed No. 22 there are three layers of sandstone, which contain a great variety of impressions of leaves. Below coal-bed No. 6 there is a bed of drab clay, 7 feet thick, with a coal-seam at the outcrop, 3 feet thick; but the coal appears to give out or pass into clay as the bank is entered, so that there are 10 feet of clay above coal-bed No. 6. Much of the iron-ore is full of the impressions of leaves in fragments, stems, grass, &c. The ore is mostly concretionary, but sometimes it is so continuous as to give the idea of a permanent bed. Above coal-bed 5 there is a seam of iron, with oyster-shells, apparently *Ostrea subtrigonalis*."

Professor Lesquereux estimates, allowing for wastage, &c., that 90,000,000 tons of lignitic coal are probably obtainable from beneath twenty-five square miles of the Bowlder Valley region. In arriving at this amount, he considers the total thickness of coal obtained over this area as being only 9 feet. For analysis see Table A, Nos. 16, 17.

Fullerton bank; range 70 west, township 1 south, section 21.

Coal Creek openings: range 70 west, township 1 south, section 33. These are about three miles south of the Marshall and Fullerton mines, and are separated from them by a plateau twelve to fifteen hundred feet high. They were first opened in 1860, when a drift of 150 feet was driven. The bed opened probably corresponds with the sixth coal-bed, or bed No. 23, of the Marshall-mine section, and was here 7 feet thick. Six other beds have also been found, all dipping eastward at an angle of about 43°, but steepening in dips to 68° north of the stream. Underneath the third bed is a layer of excellent fire-clay, 6 or 7 feet thick, having in it nodules of iron-ore containing impressions of leaves of deciduous trees. The bed that was opened had but little clay on either side between it and the usually inclosing sandstones, while above the upper sandstone is another bed of coal and more fire-clay. "Above the coal the clay is very irregular, sometimes thinning out entirely, so that the sandstone comes directly upon it." All the beds of coal are so badly crushed together that they are rendered somewhat obscure.

From Coal Creek the sandstone ledge above the coal can be easily traced south about four and one-half miles over a broad and highly elevated plateau to the Leiden mine; range 70 west, township 2 south, section 28.

The bed here appears on the western side of a sandstone ridge, and is bent over slightly beyond the vertical, and appears dipping at a high angle toward the mountains. The owner in September, 1870, lost his life by entering the mine when the air was foul in consequence of its having been left unworked for some time.

Following on still south about a mile, we come to the Murphy mine: range 70 west, township 2 south, section 33, on Ralston Creek; about five miles north of Golden City, and but twelve or thirteen miles from Denver, with which it will shortly be directly connected by railway. This mine ranks with the Marshall, Erie, and Golden mines in importance, and the same number of seams of coal are claimed to have been found here as at Marshall's, namely, eleven, but here all standing nearly vertical. Of these the lowest, or westernmost, was first opened in the south bank of Ralston Creek to a distance of about 30 feet, and found to be 9 feet thick of good coal. The bed next above, however, or about 25 feet to the east, being more conveniently situated and thicker, was worked in preference. A shaft was sunk in this bed on the north side of the stream to a depth of 60 feet, and levels run either way, since when the shaft has been farther sunk to a total depth of 112 feet. Where worked, the course of the vein is south 23° east, magnetic dip vertical, and thickness varying from 14 to 18 feet, averaging 16 feet, of brilliantly lustrous-cleaving coal, without parting of any kind, and free from slates. For analyses see Nos. 11 to 14 in Table A.

In 1870 mining cost $1.50 per ton, coal run out by the miners, who found their own powder, lights, and tools, the owner getting the timber from the mountains; coal was then $4 per ton at the mine. Eighteen thousand tons of coal had been taken out up to 1872. For the greater part of 1873, thirty-two tons per day were extracted, the working capacity being probably one hundred tons per day. On the west side of the bed 4 feet of fire-clay are found suitable for pottery and fire-bricks, and a similar bed 8 to 10 feet thick is found on the east side. Above and below these the usual yellow sandstones occur. Limonite, or bog-iron ore, is found near by to some extent.

Loveland mine: range 70 west, township 3 south, section 4, near south line; strike north and south; magnetic dip 70° or 80° west; vein 9 feet thick; no parting.

Golden City Mines.—In going south from the Loveland bank, the course of the coal formation is irregular, bending in westward behind North Table Mountain, and not showing well upon the surface. Here the Mineral Land Company owns the veins. The first opening is on section 16, township 3 south, range 70 west, where a 2-foot vein has been found. The line of the vertical beds is but poorly indicated by the streaks of coal-smut or blossom. In one instance, about two miles north of Clear Creek, these were followed to a depth of 70 feet through fire-clay before they led to solid coal, which was there found to be 10 feet thick. Passing to the south bank of Clear Creek, we come to the Golden City mines proper. These were first discovered in 1861-'62, and have been worked continuously since 1865.

Several small and nearly vertical beds quite near together were first found in the steep bank of Clear Creek, about half a mile below where it issues from its mountain cañon. The place was unfavorable for working, and the extension of one of the beds southward was opened on the summit of the ridge about a quarter of a mile from the creek. The bed here was found to be 10 to 14 feet thick, and a shaft 100 feet deep was sunk in it, levels being driven north and south from the bottom, and also at a depth of 56 feet. The course of the vein is south 53° east, with dip varying from 72° to 65° southwest. The bed proved to be quite irregular in thickness, sometimes pinching to a few inches in thickness, and then winding to 8 or 10 feet. Dr. Hodge considers its average thickness as being about 5 feet. He says also that the appearance of the coal itself, which is of a dull black, without the bright luster common to the coals from the other mines, has operated unfavorably on its reputation in the Denver market, though no inferiority of quality is indicated by the analyses. (See Table A, analyses 7 to 10.) It is obtained, too, in pieces of very irregular shape, quite unlike the handsome rectangular blocks of the other coals. Like them, however, it is almost entirely free from slate and iron pyrites. Resin occurs in it in scattered particles and bunches more abundantly than in the coals of the other mines. In 1872 the vein was worked from three openings, and up to that time about 8,000 tons of coal had been mined, the average amount being about thirty tons per day.

A cross-cut from the bottom of the mine driven 70 feet east, gave the following section, the east or upper end being at the top of the section:

No.	Nature of strata.	Thickness, in feet.
	East end, highest, geologically:	
15	Sandstone	6
14	Coal	2
13	Clay	8
12	Coal	2
11	Clay	2
10	Sandstone	3
9	Clay	4
8	Black slate	3
7	Clay	8
6	Sandstone	7
5	Clay	3
4	Sandstone	12
3	Coal	2
2	Sandstone	4
1	Clay, (west end, lowest, geologically)	4
	Main coal bed, total	70

The eastern sandstone (No. 15) is probably the extension below of a heavy ledge of sandstone, that forms the crust of the ridge. The clay is all fire-clay, of pretty uniform and excellent quality, very similar in appearance to that of the true coal-measures. It is used for the manufacture of fire-brick in an extensive manufactory at the base of the hill. Dr. Hayden observed near by the following outcrop of the lower lignite beds:

East, highest.
Rusty yellow sandstone.
Fire-clay, with one or two unimportant seams of coal, 10 to 15 feet.
Coal, 8 feet.
Fire-clay.
Rusty yellow soft sandstone.
West, lowest.

The clay is used for fire-brick and potter's ware. In the upper bed of sandstone impressions of leaves of deciduous trees are found, among them a *Platanus*. In the southern extension of the Golden City beds we pass several openings, one of which is a shaft 70 feet deep, showing the nearly vertical bed to be 5 to 11, and even 14, feet thick of good coal.

Johnson mine: range 70 west, township 4 south, section 3, shows a bed of coal 7 to 9 feet thick, which is mined from a shaft 90 feet deep.

Welch and Loveland mine: range 70 west, township 4 south, section 3, about a quarter of a mile only south of the Johnson bank; course, south 50° east to south 48° east; dip, 71° southwest. A drift having a course of north 34° east furnished Mr. Berthoud with the following section:

No.	Nature of strata.	Thickness, in feet.
	Top, (northeast.)	
12	Coal, No. 5	5
11	Sandstone and clay	16
10	Coal, No. 4	1
9	Sandstones	6½
8	Fire-clay	3
7	Coal, No. 3	3
6	Sandstones	6½
5	Fire-clay	4
4	Coal, No. 2	2
3	Fire-clay	5
2	Coal, No. 1	3
1	Shale and sandstone	5

Coal No. 5 is mined by a shaft 15 feet in perpendicular depth at the end of the drift.

Wheeler mine; range 70 west, township 4 south, section 14. The bed has a course of south 45° east, magnetic, and dip of 74°; is 7 feet thick, and has been worked to a depth of 40 feet, furnishing coal not of very good quality.

Rowe mine; range 70 west, township 4 south, section 23. The course of the bed is here south 48° east, and dip nearly vertical where mined, though it is 70° east near by. The coal is 4 to 6 feet thick, and is the lowest of several coal-beds near by. Dr. Hayden gives the following section: Top, arenaceous clay, 3½ feet; coal, 4 feet; clay, 3½ feet; coal, 4 feet; clay, 5 feet, base. The coal is reached by passing 141 feet through sandstone. Its ash is white, like pine-wood ashes, and small in quantity. Up to 1868, 250 tons of coal had been taken out, but in 1872 the mine was idle for want of good communication.

Mann opening; range 70 west, township 4 south, section 24.

Wilson mine; range 69 west, township 4 south, sections 31 and 32; course, south 50° east, magnetic; not mined now.

Gilpin (or Wenrich) mine; range 69 west, township 5 south, section 9.

Jones mine; range 69 west, township 5 south, section 35.

A little farther south coal was opened near the Platte in 1866. It occurred in two beds, in all about 5 feet thick, separated by about 2 feet of clay, and not of very good quality. On the opposite (south) side of the Platte, in the continuation of the same line of outcrops, coal has also been opened, and a considerable quantity used in Denver.

Iron.—Iron concretions occur here and there scattered through the clays and shales of the lignitic formation at certain points, usually in the coal horizons, and may be so continuous as to give the idea of a permanent bed. By the weathering away of the inclosing rock, as the degradation of the surface by erosion goes on, these concretions sometimes accumulate in sufficient quantities to appear as solid ledges of ore. In the South Boulder Valley these accumulations cover quite large areas. These nodular masses are of limonite, more commonly known as brown hematite, or brown iron-ore, and probably originally existed in the beds in which they occurred as clay, iron, stone. They vary from an ounce to a ton or more in weight, and on breaking them open they are often found to have a regular concentric structure, like the layers of an agate, the layers perhaps varying in color from brown to yellow, while many of the nodules are full of impressions of leaves in fragments, stems, grasses, &c. From the vicinity of the Marshall mines, on South Boulder

Creek, Mr. Marshall has gathered and taken out more than 500 tons of this ore. In smelting it in a small blast-furnace, with pure charcoal from the mountains, the following mixture was used: Ore, 200 pounds; limestone, 20 pounds; charcoal, 13 to 15 pounds. Smelted in this way, 4,400 pounds of ore produced one ton of a very excellent quality of gray pig-iron.

POST-LIGNITIC FORMATIONS.

In the lignitic we have the uppermost of those sedimentary formations which participated in the folding and upturning of the rocks along the mountain front, while it is also the last extended formation with which we have to deal east of the mountains. The remnants of but one group of sedimentary rocks is here found which is more recent than the lignitic, and that is quite subordinate both in extent and importance. Opportunity was not had to study it particularly, but the impressions received from what was seen of it will be briefly stated. These beds usually consist of gravels, often exceedingly coarse, which are derived principally from the archæan rocks of the mountains, and consist mostly of hard quartzite, schist, and granite *débris*. They always lie nearly or quite horizontal, apparently entirely undisturbed, frequently nearly cover the upturned edges of the older folded strata, occasionally almost lapping over them on to the metamorphic rocks of the mountain spurs, and stretch eastward into the plains in well-marked terraces. Their thickest development is naturally nearest the mountains from which they were derived, though they probably nowhere reach a thickness of 500 feet, perhaps not half that amount. The main cross-valleys nearly always cut through them to the lignitic or cretaceous beds beneath, though the latter are generally concealed by *débris* or alluvium of the streams. They seldom completely cover the highest portions of those ridges capped by Cretaceous No. 1, and, at the north, where the zone of hog-backs is wide and these ridges lie some distance from the mountains, the gravels are forced out eastward equally far. From the gently-sloping tops of No. 1 or No. 3 they here extend eastward for several miles as low terraces, as near the Thompson and Saint Vrain Creeks. Near the latter some yellow marl occurs above the gravels, the latter being cemented largely with oxide of iron. The benches or terraces here seldom reach an altitude of more than 200 or 300 feet above the streams, often break off quite abruptly at their ends, with occasional outlying "table-mountains," lower terraces showing here and there, while the main terrace is in places separated from the hog-back ridges at the west by a small north and south valley. Between Left-Hand and Boulder Creeks a large area has been removed, leaving a shallow, fertile valley. In proceeding southward the lower folded beds, assuming a steeper eastern dip, occupy a much narrower zone than at the north, and the terraces, likewise, lie close up under the mountain-spurs and reach greater altitudes. They have, perhaps, a typical development between the North and South Boulder Creeks. It is here that the Triassic sandstones rise to their greatest height in the formidable ridge cut midway by Bear Cañon. Passing from the sandstones over hardly more than 2,000 feet of outcropping Jurassic and lower Cretaceous beds, we pass directly from No. 3 upon the high gravel terrace. Boulders of the red sandstone, over 10 feet in diameter, may here be seen, and the mass throughout is of exceedingly coarse material, in which sandstone boulders predominate. For a quarter of a mile outward the inclination of the surface is about 5°, gradually becoming flatter, until, in less than a mile, the abrupt slope is reached which descends to the valley of the South Boulder, lying some 800 feet below. Opposite rise the high flat-topped hills, composed mostly of the nearly horizontal lignitic strata, with the Marshall and other mines upon their sides, but capped with the same gravel deposits.

South of the Boulder Creeks to Coal Creek the long sweeps of high gravel terraces are quite continuous, and reach quite up to the higher slopes. Then they again diminish in altitude. From North Table Mountain, near Golden City, they may be seen at the north extending in two or three terraces from the higher hog-backs far eastward to near the junction of Clear Creek with the South Platte, a few miles below Denver. Near this point several prominent outlyers occur, rising a few hundred feet above the river, and capped with from a few to 50 or 60 feet of siliceous gravel. Even to the east of the Platte a few remnants are found still retaining their cap of archæan *débris*, chroniclers not only of the former wide extent of the bed, but of the great amount of erosion which has taken place since it was deposited. Over a great deal of this region patches of *débris* from this bed may be found, the remains after the weathering away of the soft subjacent strata. Farther south, from near Bear Creek to the Platte, the terraces are again lower, and much like those at the far north.

It is here hardly necessary to refer to the latest of all the geological formations, and that progressing at the present time, the alluvium which has accumulated in places along all the larger streams of the plains. In places spreading out in considerable areas, it forms, both on account of natural fertility and ease of irrigation, (which has here to be resorted to,) some of the best agricultural lands in the Territory. Otherwise it is of no special interest, being apparently like most local river alluviums.

THE ERUPTIVE ROCKS OF THE PLAINS.

The eruptive rocks east of the mountains are exceedingly limited in extent, and would barely attract any attention but for the fact that they occur in the midst of thickly-settled regions. The only points at which they are known are at Valmont, situated at the junction of the North and South Boulder Creeks, and near Golden City. At the latter place are the two well-known table-mountains which form such conspicuous objects in the foreground of the high range when viewed from the east. The accompanying sketch (Fig. 5) by Mr. Holmes gives their appearance as viewed from Bear Creek Station, a high point on the very border of the mountains overlooking the plains, and about six miles south of Golden City. The characteristic appearance of the plains to the eastward is also well given. The table-mountains are separated from the granite mountains by a valley about a mile in width, in which Golden is situated, and stand one on either side of the gorge through which Clear Creek flows after debouching from the mountains. The railroad now passes through this gorge and on up the cañon of Clear Creek to the mining regions. These two hills, which are irregular in shape, with diameters but little over a mile in any direction, are formed below of the horizontal strata of the lignitic group, capped by layers of basaltic lava. The northern table stands the highest, reaching some 900 feet above Clear Creek, and 700 or 800 above the surrounding valley. The tops of both are nearly in the same plane, which dips gently to the south and east at an angle of about two or three degrees. The source of this lava is from beneath North Table Mountain, on the summit of which, and near the northwest corner, the remnants of a group of small volcanic cones may still be seen; weather-beaten, and nearly worn away, they still suffice to show from whence the lava came. From near this point the lava flowed toward the then lowest portions of the country, and, in virtue of its hardness, formed a protective cap to the softer beds beneath, which could withstand erosion better than the surrounding unprotected hills. The latter have, therefore, wasted away the faster, and the former valley has become the mountain. The thin edges of the lava-sheets have also been gradually worked backward, and broken away, and the limits of the tables are constantly becoming more and more circumscribed.

The more compact varieties of the lava vary from brown to black in color, and from a very compact to a fine-grained texture, being rather dull in luster, (basalt.) In this as a matrix there may or may not be porphyretically imbedded numerous black and well-formed crystals of augite, giving a doleritic character to the basalt, while yellow decomposing spots of an undetermined mineral, probably olivine, are often present. These varieties are columnar in structure. Very vesicular or scoriaceous lava also occurs, as well as amygdaloidal material. At one point the latter had a light gray or purplish base, granular, with imbedded augite crystals, the numerous irregular cavities being filled with zeolitic minerals. *Chabazite*, *leucite*, *natrotile*, and others are said to occur.

Near the north end of the north mountain the edges of several of the harder lava-flows show well as lines of cliffs or palisades running along the hill-side, separated by the slopes of softer rock between. A section was here observed as follows:

	Feet.
Cliff at top.—Dark columnar doleritic basalt	40
Slope.—Scoriaceous basalt and amygdaloidal dolerite	30
Palisade.—Columnar basalt	60
Slope.—*Debris* of scoria and volcanic sand	100
Palisade.—Columnar basalt	30
Slope.—Covered to base.	

These lava-flows are not widely continuous, some extending much farther than others. The northern end of South Table Mountain rises about 600 feet above Clear Creek, the volcanic products reaching an average thickness of about 125 feet. Immediately below the lava the lignitic beds at several points yield many fossil-leaves. Besides the two tables, and extending from near them in a line trending a little west of north to the bend of Ralston Creek, near the Murphy mine, are four rounded buttes topped with the same lava; whether an extension of the dike through which the lava has been erupted, or remnants of a lava stream from the North Table, was not ascertained, though it is apparently the latter.

Green Mountain, or Mount Hendricks, is a bulky hill situated a few miles south of South Table Mountain, and, like it, isolated from the main range by the zone of hog-backs. Below it also is made up of lignitic strata, while above occur large bowlder-beds of rolled volcanic rocks, showing, in its northeast side, that it is apparently an extension of the same lava that caps the South Table Mountain.

Valmont.—The only remaining instance of the occurrence of volcanic rock east of the mountains is the dike at Valmont. This dike was examined by Dr. Hayden, and a description and illustration will be found in his report. Being within my district, however, I will mention it briefly, the facts being gathered from the notes of Dr. Hayden and Mr. Holmes.

The dike is vertical, and appears as a wall-like ridge rising abruptly

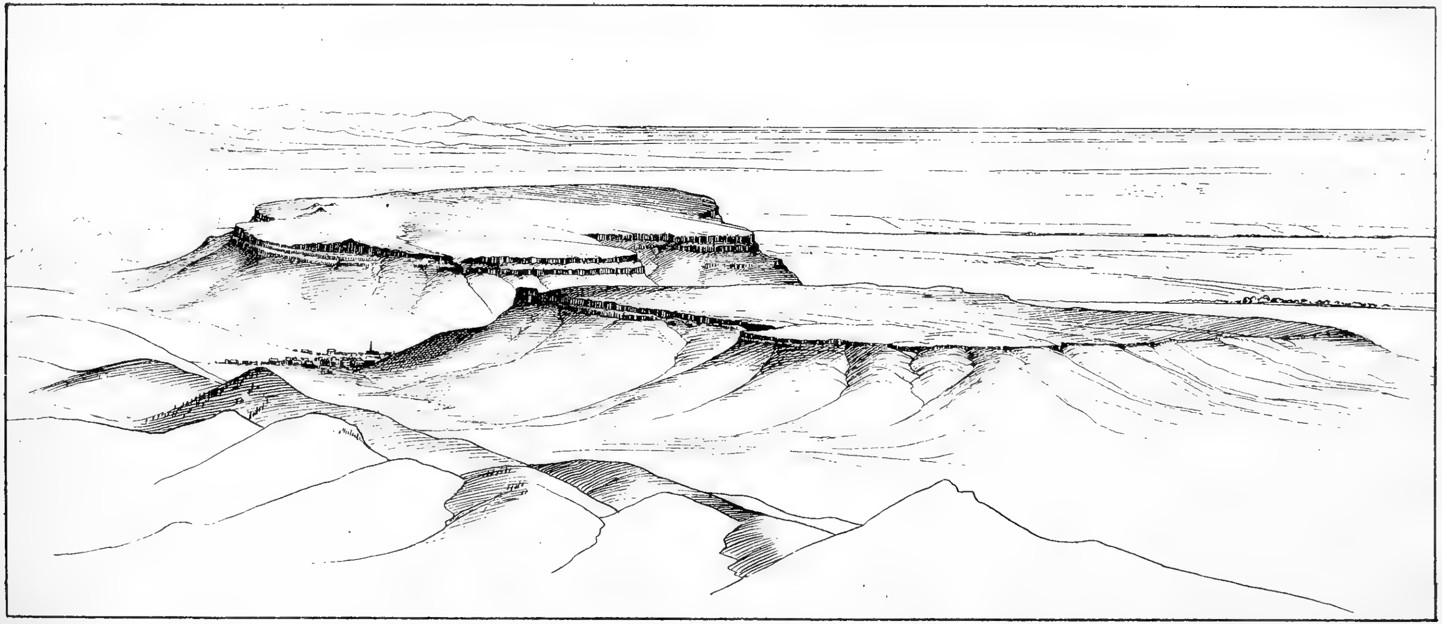


Fig. 5: Golden City and the Table Mountains, viewed from a point six miles south. Wm. H. HOLMES.

just east of the junction of the North and South Boulder Creeks, to a height of 275 or 300 feet. From this point the trend is very nearly northeast, and for a mile the points of the ridge all reach a height of over 200 feet. In another mile it falls to the plain and disappears. On the south side of the dike abuts a remnant of a gravel terrace. In a direction nearly west of the west end of the main dike, and near Boulder City, a small outcrop again shows itself above the plains. This wall of rock weathers in very square blocks. A specimen shows the lava to be a doleritic basalt composed of a very hard crystalline base, much more crystalline than the golden lava, of handsome dark gray color, in which a greenish transparent feldspar seems to predominate, and containing, porphyritically imbedded, numerous crystals of black augite. North of Valmont some miles, a conical hill would seem to indicate the presence of another small dike.

There is no reason why lava did not flow through the vertical crevice or fracture which here broke across the sedimentary rocks, eventually giving form to the dike which we now see, and pour out over the then higher surface of the country in sheets, as at the Table Mountains of Golden City. Destroy the flat tops of the latter, as erosion is certain to do in time, and beneath them, at least of the North Table, a *fac simile* of the Valmont dike would probably be found. Indeed, above and near Valmont the old lava flows, which poured through the dike and flowed over the surface of the country, were first probably formed into table-mountains and then gradually worn away until erosion has entirely removed all evidences of them save the lava which remains as a dike in the crevice through which the earlier lava flowed.

GENERAL STRUCTURAL FEATURES OF THE MOUNTAIN-BORDER REGION.

It has been quite impossible in giving, in the preceding pages, the more special features of each formation, not to refer more or less to the manner in which the whole series of sedimentary rocks has been folded at different points along the face of the range. These general structural features, however, have so many points of interest attached to them that they deserve to be considered separately.

On Plate II are gathered seventeen geological sections across this zone of folded strata. They trend as nearly as possible at right angles to the outcropping beds, or approximately east and west, extend from the archæan rocks on the west across the more prominently exposed ledges of sedimentary rocks, and are arranged one below the other in their natural order from north to south, No. 1 being farthest north, No. 17 farthest south. The map upon the plate covers the northern portion of this zone, and shows the positions of the first nine sections. The characteristic topography of the region is given in contours, approximately 200 feet apart vertically, and the geology is indicated as far as possible without the aid of colors and without obscuring the topography. Since the outcrops of Cretaceous No. 1 and the border of the archæan rocks here give the key to the general structure, they are indicated more prominently than the other formation. The positions of the remaining sections, from 10 to 17 inclusive, are given on the map, showing the distribution of coal, &c. (Fig. 4.) Sections 1 to 9 are drawn on a scale of three-quarters of a mile, or 3,520 feet to one inch; sections 10 to 14 on a scale of 800 feet to one inch; sections 15 to 17 on a scale of 1,600 to one inch; the vertical scale in all cases being as nearly as possible the same as the horizontal. Sections 3 to 9 are arranged exactly north and south of one another as they actually occur, while 1 and 2 are offset a few inches to the left. The latter, to be represented in their true relative position with respect to the others, therefore, should be considered moved about $5\frac{3}{4}$ inches (representing 4.3 miles) to the right, as indicated by the points at which each section is intersected by the meridian of 105° 15′ west longitude.

These sections are the result of rapid field-work, and can by no means claim to be free from local errors, though they express truthfully all the main features of the region.

Thicknesses have in all cases been estimated or obtained by pacing, and many local points not well fixed by the topographer's notes have been filled in by the eye.

In traveling from the north along the zone of hog-backs lying at the base of the mountains southward, the traveler finds the mountain-slope directly west of him falling lower and lower until it becomes an insignificant ridge, and finally dies away in the plains.

Passing around the southern end of the diminishing ridge the main mountain-slope is found lying several miles to the west, and separated from the ridge by a bay-like valley extending northward behind it. There are here several such offsets or jogs in the mountain-border, caused by its component ridges being arranged *en échelon*, north and south of each other. The trend of these spurs is somewhat west of north, while their echelon arrangement is such that a line touching their southern ends trends east of north and west of south, with a flat concavity presented to the east. As is so often the case in the West, these peculiar topographical features are but the surface expression of a similar and equally important geologic cause. These ridges, and the included valleys, indicate that here the folding of the rocks have also taken place *en échelon*. The ridges are uplifted or anticlinal folds, the valleys depressed or synclinal folds, both dying away southward into the flatness of the plains, though the west side of the westernmost synclinal is always preserved in the normal uplift along the main mountain-base. With such a structure, and since the sedimentary rocks have been to a very great extent eroded from the summit of the ridges and worn down to a pretty uniform level, it is necessary that the outcropping strata should be found bending around the southern ends of the spurs, their strike first swinging westward, that of the lower beds bending on still farther to the northwest to form the eastern side of shallowing synclinal basins, which finally terminate to the north, the reverse, in all respects, to the anticlinal ends, while the uppermost beds, those farther out, do not necessarily bend around into the synclinals, but after turning somewhat westward, again resume their southern course with the others.*

The most interesting feature of these folds, next to their general echelon arrangement, is the fact that in the anticlinals the western side of the fold is always more abrupt than the eastern side, and may become a fault, the downthrow being upon the western side. That is to say, the tendency of the forces forming the folds seems to have been to lift up the eastern side relatively to, and push it over against, the western side; and the expression of this tendency has been either an abrupt downward bend of the west side, or a direct downward faulting of the west side, or by both combined. And along the same fold these three forms of arriving at the same result are interchangeable. Indeed, the type of these anticlinals *en échelon* may be expressed thus: From the rather

* These echelon ridges and folds were first observed, so far as I know, by Dr. Hayden in 1869, and partially described in his report for that year.

Fig. 4.

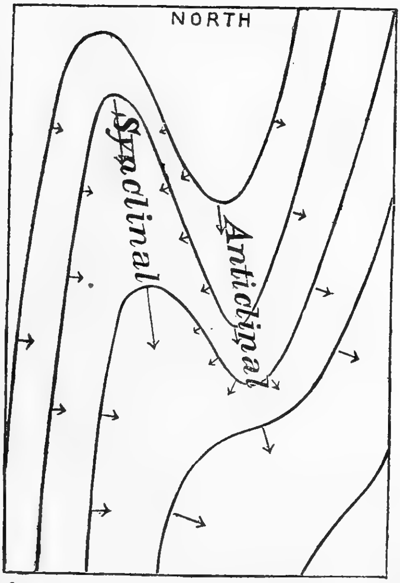


Diagram showing the course of the outcrop of Beds around the northern end of an Echelon Fold.

abrupt southern point of one the ridges of outcropping rock soon bend on the one side east of north, on the other to the west of north, inclosing between them the higher ridge of archæan rock. The eastern side, however, dips gently eastward, frequently not over 20°, seldom reaching 40°, while upon the west the same ridge often stands nearly or quite vertical, and, following it northward, the drag downward soon becomes quite sufficient to fault the bed also, while, farther on, the increasing fault may not upturn the beds upon its west side at all. Farther north, after passing beyond the limits of the sedimentary rocks, the fault becomes far more difficult to trace in the more structureless archæan rocks.

The echelon folds and faults that occur within my district are shown by the first nine sections of Plate II and the accompanying map. The anticlinals are designated by the letters *a*, *b*, *c*, *d*, *e*, the same fold always having the same letter attached. Folds *a* and *c* are the two principal ones.

Circling around the southern end of the high schist ridge *a*, section 1,* and dipping away from it to the east, south, and west, are the edges of the Triassic red-beds which once mantled over it, but which erosion has removed and worn downward, leaving but two prominent ridges now projecting above the surface. Two or three miles to the east rises the abrupt west face of the hog-back ridge formed of the variegated Jurassic shales, capped by the hard sandstones of Cretaceous No. 1, all dipping gently to the east. The latter sandstones are here formed of two main layers, separated by about 100 feet of softer shales and sandstones.

This double ridge trends from here nearly southwest to where the Big Thompson and Dry Creeks join, when, turning very abruptly, it assumes a northwest direction. At the point of turning the southward dip of the lower sandstone of No. 1 is 20°, that of the upper being 50°. The outer beds likewise swing around, but in curves of much larger radius, though they are much obscured by the soil and the gravel terraces. In its northwest course the double ridge stands vertical like two parallel stone walls, for about two miles, when it quite abruptly disappears, covered either by the thick soil present or faulted below the surface. (See sections 1 and 2.)

Along the west side of the valley the same beds again outcrop in their normal position upon the face of the granite ridge *b*, dipping east at a gentle angle, and, with a nearly southward strike, they may be followed nearly to the Little Thompson. When crossing Dry Creek No. 1 has an east dip of 20°, that of the overlying beds of No. 2 and No. 3 increasing to 35° and 50° within a mile to the east.

Before reaching the Little Thompson, however, No. 1 again steepens in dip, and the strike suddenly swings from south to west and northwest, inclosing a low anticlinal hill (*b*, section 5) of Jurassic beds, on the southwest side of which it appears standing nearly vertical.

Following it north it shortly disappears, and, as the Cretaceous shales now lie upon the west, both a fault and fold probably exist. (Section 5.) Still farther north, at *b*, section 4, a ridge of quartzite makes its appearance, indicating a decided increase of the fault. (Section 4.)†

Again to the north the fault seems to be replaced by a simple fold, as in section 3, *b*. To the north of Dry Creek the high schist ridge *b*, sec-

* The details of this northern fold have been kindly furnished me by Mr. Holmes and Dr. Hayden.

† Though the structure at this point was at the time understood to be as given in section 4, and though the quartzite is lithologically the same as neighboring archæan quartzites, this ridge may still be a metamorphosed fragment of the somewhat similar Cretaceous No. 1 broken down into the present position.

tion 2, rises in a long spur, the red-beds mantling round its southern end with a very low dip, while upon its western side small areas of the red-beds still remain, and, preserving an eastern dip, indicate a fault separating them from the main ridge.

Returning southward we find west of the ridge *b* the same series again reclining at a gentle angle upon the next echelon ridge to the west, *c*. The hill *c*, section 4, is a very commanding point, rising some 2,000 feet above the adjacent creeks.

Its uniform eastern slope descends to the long ridge of red-beds which runs uninterruptedly from Dry Creek to the Little Thompson, and dips eastward at an angle not far from 10°. Ending as a ridge at the Little Thompson, the next ridge of red-beds to the south is found between the Little Thompson and Saint Vrain's Creeks, but offset some three miles to the west with respect to the former ridge.

In the Lower Little Thompson the ridge *b* does not exist as an anticlinal at all, though its effect may be seen in the flatter dip of the beds. Proceeding up the stream an excellent section of the rocks may be obtained from Cretaceous No. 3 downward to the Metamorphic rocks, the gravel terraces concealing all east of No. 3. (Section 6.)

In passing through the ridge formed by No. 1, it is here seen to flatten and swing around westward to the south, on through the red-beds, which show a like tendency, when, at their base, a rugged outcrop of archæan quartzite presents itself, on which the red-beds rests, and on the west side of which their lower members are dragged abruptly downward, followed by a space of contorted strata which is fairly represented in section 6. The quartzite is the southern extremity of the long southeast spur of the ridge *c*. Continuing southward from this point, and after passing some of the contorted beds, No. 1 is found on either side gradually closing to the south, with a flat east dip and steep west dip, *c*, section 7. The trio sides join farther on, the bed becoming continuous, but again the area covered by No. 1 is broken open, and a small crescent-shape patch of the underlying Jurassic is exposed on the summit of the hill *c*, section 8, lying midway between the Little Thompson and Saint Vrain's Creeks. The steeper dip at this isolated point is upon the east. This is the last known indication southward of fold *c*. Taking it up again at the Little Thompson, section 6, and following it northward, we find upon the east side of the schist ridge, *c*, the long sandstone ridge before spoken of dipping gently east, while the red-beds upon the west side of the sharp ridge, instead of being upturned upon it and dipping west, are faulted sharply downward, abutting directly against it. As the northern end of the valley rises, and erosion having removed the beds at higher levels, the lower sedimentary rocks are found forming a bay-like area southwest of the high hill *c*, section 4, faulted against the schists at the east, and lying upon the schists on the west and north, (section 5.)

Passing north around the steep west base of the high hill *c*, an isolated sandstone area of similar structure is found in Rattlesnake Park, (section 3.) It would here seem as if the fault bent from a northwest to a northeast course. Returning to the sandstone bay, west of ridge *c*, its lower red-beds are found mantling around the south end of the lower schist ridge *d*, lying west of hill *c*, with a south dip of about 40°, when, turning southward, they form the high, western, most hog-back ridge between the Little Thompson and North Saint Vrain's. East of this ridge the same beds are folded into the rolling anticlinal *d*, section 7, which a few miles south is only apparent by the flatness of No. 1 on the south side of the Saint Vrain's, (sections 8 and 9, *d*.) The high prominent butte just west of the junction of the two Saint Vrain Creeks is a southward continuation of the ridge of red-beds to the north, and, at its western base, its lower beds are found faulted downward about 300 feet, showing about 50 feet of granite at the base of the hill, section 8. This forms the minor echelon fault *e*. Upon the south side of the river cañon it may be seen as an exceedingly gentle fold, and on still farther, where the red-beds lie at a very low angle reaching far up upon the gentle mountain slope, it is still barely indicated, (section 9.) From here southward the pronounced multiple character of the fold ceases with the dying away of the fold *e*, though the influence of the various flexures may still be felt here and there in the plains in slight changes of dips. The gentle plications found at the Baker and Marshall mines may be the southern continuation of some of the folds at the north.

From a few miles south of Saint Vrain Creek the flatness of the dip gives the outcropping beds a wide zone of exposure upon the surface, the lower measures reaching farther west upon the long mountain-slope than at any other point. The dip, however, rapidly steepens in going south, causing the zone of outcrops to contract within narrow limits, which is accomplished by the approach toward the mountains of the outer lines of ridges. At Left-Hand Creek they are gathered within quite a narrow space, the lower beds dipping eastward at an angle of 20° or 30°.

From here southward to South Platte, this one line of upthrow is perfectly continuous, and, though peculiar in its character, being something more than a mere simple upward fold, it is nowhere prominently offset *en échelon* by another fold at the north, though the tendency is exhibited at a few points, as at Bear Cañon and Golden City. The general direction of this line is at first south, gradually swinging to about south 20° east, or about parallel with the echelon folds, of which, in reality, it may be considered as a very long one. Taken as a whole, the general course of the line of outcropping hog-backs along the mountain front, as indicated by a line drawn tangent to the southern ends of the echelon folds at the north, and following the more connected line of outcrops at the south, presents a great cresent or arch-like form, with its flat concavity to the east; the span north and south being sixty miles, the ver-sine, or depression westward, at the middle, being about ten miles. The southern portion of the fold yet remains to be examined.

North from Boulder City the lower red-beds appear in a low ridge, the western portions of which are thrown over a few degrees beyond the vertical, as in section 12, to be described later, the remaining beds being pretty effectually obscured by the gravel terraces. They probably quite abruptly assume a very gentle eastern dip, however.

At Bear Cañon, as frequently noticed before, from beneath the high gravel terraces the full series, from Cretaceous No. 3 downward, are all fully exposed, dipping very regularly 50° to 55° eastward. But beyond the high ridge of hard Triassic sandstone, and the granite behind it, a second and higher ridge appears. It is of the same sandstone, a fault separating the two, the down-throw being on the west side, as shown in section 10. The western ridge probably never stood so high above its present position as to be in the same plane with the eastern sandstone as it now stands, being subsequently faulted down into its present position, but both were probably simultaneously tilted from the horizontal into their present positions by the one operation.

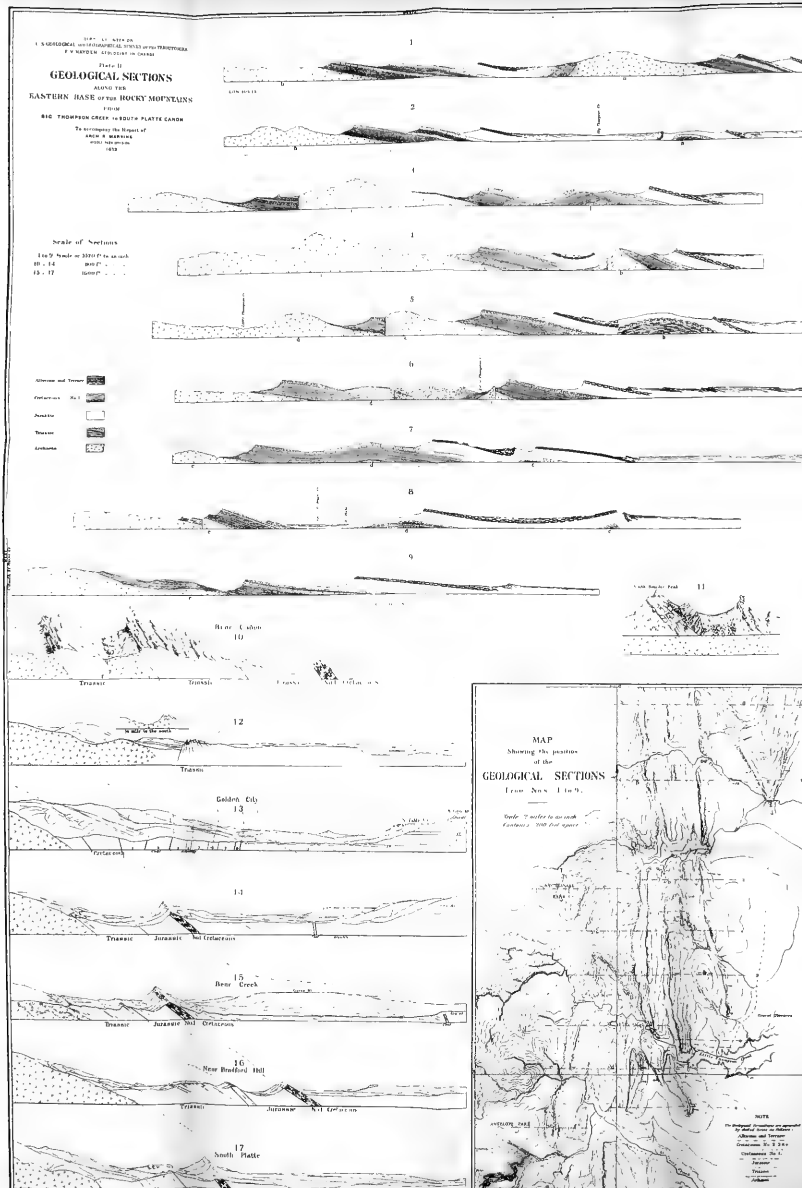
Scarcely a mile south of this section, in South Boulder Peak, a portion of the western ridge has been caught in the faulting and bent abruptly upward, forming a sharp synclinal, as shown in section 11. Though much metamorphism and obliteration of bedding has here naturally taken place, yet there is enough structure remaining to show that the legs of the V make an angle of only about 70° degrees with one another. The erosion of the surrounding rock has left the south end of this V-shaped mass almost as if perched upon a pedestal of granite. The main ridge, however, continues on past the deep cut of the South Boulder almost to Coal Creek, but gradually disappearing beneath the soil.

Abreast of Bear Cañon, about three miles to the east, the outer series of rocks, as the lignitic with the coal horizons, all have a gentle eastern dip, but in coming southward of Coal Creek they approach the mountains and assume a nearly vertical position. Just south of Coal Creek Cañon section 12 occurs, (Plate II, as usual, and Fig. 4,) in which some of the red-beds lean beyond the vertical, and appear as an eastern wall to the little valley inclosed between them and the hills of schist and granite upon the west. To the east they rapidly flatten, while within a half mile to the south the same beds, rising in a higher ridge upon the archæan rocks near Ralston Creek, again show a flat dip. Within exceedingly short distances, then, great changes of dip may occur, and from them, with but slight changes of exposure, unconformability might be inferred. Yet all are perfectly conformable; the sudden change really indicating only a very abrupt flexure in the main fold, as indicated by the dotted lines. To the east the formation again steepens, the coal horizons being found nearly vertical, while still east the higher beds again quite suddenly assume a flatter position, indicating just such another abrupt flexure as occurs here nearer the mountains, but not necessarily any more of an unconformability than here.

A few miles north of Golden City (see Fig. 4) a very remarkable contraction of the whole series commences, all the outer ridges bending rapidly westward to form a sort of loop or bay in the rear of the Table Mountains, and near the narrowest point of which Golden City is situated. There has been some differing opinions expressed about the structure of this region, and a section here is one of the most important of the series. In absence of a complete or personal examination, a section drawn by permission from one made by Mr. E. L. Berthoud, is presented, (No. 13.) Its general correctness may be assumed not only on account of the opportunities and ability of Mr. Berthoud, but from the evidence afforded by the adjoining sections, between which and that at Golden there are many points in common.

The close proximity of the vertical coal-beds to the horizontal beds of Table Mountain has been taken as indicating unconformability between the two, though in reality it no more follows from this fact than would unconformability in the Triassic from the similar phenomenon presented near Coal Creek. Indeed, the change of dip here is hardly as abrupt as at the latter point. An abrupt fold, as indicated in the other sections along the front of the range, with erosion removing those portions which by fracture, &c., are most likely to be removed, would naturally leave this portion of the section as it now appears, the lignitic being continuous and conformable throughout.

One of the most interesting features presented in the Golden section is the apparent thinness of the usual lower beds of the series. This may be caused by an actual thinning of the original deposits at this point, or by a fault which has pushed the higher portion of the series westward over the upturned edges of the lower portion, thus concealing much of the latter. That the former is not impossible follows from the conditions naturally attending the laying down of new formations upon the newly-prepared, and hence uneven, surfaces of older rocks, and



F V HAYDEN GEOLOGIST IN CHARGE
Plate II
GEOLOGICAL SECTIONS
ALONG THE
EASTERN BASE OF THE ROCKY MOUNTAINS
FROM
BIG THOMPSON CREEK to SOUTH PLATTE CANON
To accompany the Report of
ARCH R MARVINE
Scale of Sections
Bear Cañon
10
11
Triassic
12
Golden City
13
Cretaceous
14
Jurassic
No 1 Cretaceous
15
Bear Creek
16
Near Bradford Hill
17
South Platte
MAP
Showing the position
of the
GEOLOGICAL SECTIONS
from Nos 1 to 9.
ANTELOPE PARK
NOTE
Alluvium and Terrace
Cretaceous No 1.
Jurassic
Triassic

becomes quite probable when one recollects the shelving or overlapping which these strata present, or the similar meaning phenomenon of the appearance of the Carboniferous beds from below the Triassic at the north, as well as the great variations of thickness which occur just to the south. At the same time, some of the facts at hand indicate that a peculiar fault, depending on the nature of the sharp fold, and possibly connected with the lava near by, may have caused the present appearance. Enough is not yet known to decide with certainty which of these explanations is the true one, but it is hoped that a few hours' work during the coming season may clear up this interesting dynamical problem.

A few miles farther south of Golden the formation again widens, though not so rapidly as north of the town, and near Mount Vernon it again presents nearly the same section, (No. 14.) The lower dip of the lower beds growing steeper in passing over them eastward till the coal is reached standing nearly vertical, with the flat beds just beyond, in Green Mountain, gives the usual type of section hereabouts. Nearly the same order is preserved at Bear Creek, section 15. East of Cretaceous No. 1 nearly all is here covered, but a few exposures show the upper Cretaceous very nearly level. This space is followed by an outcrop of the coal horizon, standing nearly vertical, and surrounded by a gravel terrace. Beyond, the Lignitic beds again flatten. South, still the same general features appear. The lower sandstones at first occupy a widening zone, owing not only to a lessening dip, but also to an actual thickening of the beds. Near Bradford Hill, section 16, they extend quite a distance upon the schists, having a low dip at the west, (15°,) increasing eastward, (to 40°,) and flattening again in No. 1 Cretaceous, (30°.) As the coal-measures farther out probably steepen, we have again the common type of fold, a larger fold which seems to carry upon it two minor ones, the upper and western one with a rather large radius, the lower and eastern one more abrupt, often setting the beds beyond the vertical; the larger and main fold, as a whole, being concave upward; the minor folds upon it being convex upward. A large area of apparently subaqueous erosion is an interesting feature here. At the South Platte, section 17, the fold seems to be in a simple curve, the dip of the lower red-beds being nearly 70°; of No. 1, about 50°.

The abrupt fold which is so constantly present along the outer part of the main upthrow in all the southern half of the district, is probably due to the crumpling which would naturally take place in the upper members of a thick series of rock when folded in a rather sharp curve whose concavity is upward. South from the Platte the mountain fold passes on into the next district. While plication may occur in the plains, it must be to an exceedingly small extent, and wholly subordinate to the more profound fold found along the mountain border, the main features of which have just been given. The detail and careful examination of this fold would be rendered quite easy on account of the many cross-cutting streams, and the lessons in dynamical geology to be gathered from it can be of scarcely less interest than the results from the careful study of the historical geology of the region.

Leaving the plains, the subject next in order is the geology of the mountains.

CHAPTER III.

THE METAMORPHIC CRYSTALLINE ROCKS OF THE MOUNTAINS.

As was dwelt upon at length in the last chapter, the nearly flat sedimentary rocks which underlie the plains have an exceedingly well defined and continuous western border, along which their edges are found folded more or less abruply upward, thus forming the zone of uniclinal ridges or hog-backs which lie at the eastern base of the mountains. Along this well-defined line the occurrence of these rather simply composed and structured rocks abruptly ceases, and westward for many miles no sandstones, slates, or shales, or other comparatively little-changed and normal sedimentary rocks are to be found. An entirely different class of rocks take their place. First rising either abruptly or in great massive slopes for one to two thousand feet from beneath the lowest of the Triassic sandstones, they form the first great eastern slope of the main range. This slope is not an unbroken north and south line, for all the streams from the range beyond cut great cañon-gashes through it, emerging from which they break across the zone of upturned sedimentary ridges and thence out on to the plains. Moreover, between these greater cañons, the faces of the more continuous slopes are still cut and broken by almost an infinite number of lesser ravines and gulches which drain down the slope to the first longitudinal valley back to the inner sandstone-ridge, and thence north or south to the adjacent greater cross-cutting streams. Rising in this manner to a pretty general uniform level with higher mountain masses here and there, all cut by the cañons into a rugged mountain country, this region extends west for fifteen to thirty miles to the last abrupt rise to the great main crest of the front range, which, in this portion of its course, constitutes the main continental divide, separating the waters of the Pacific from those of the Atlantic, and the topographical characteristics of which were described in Chapter I. The whole of this portion of the great front range, down its less abrupt western slope to the comparatively small and lower-lying sedimentary area of the Middle Park, with nearly all of the elevated country lying south of the park and separating it from the South Park, and forming the connecting link between the Front and Park ranges, and all of the latter bordering the Middle-Park drainage area on the west, together with the southern extremity of the Medicine-Bow range, which penetrates into the park at its northeast corner, and, finally, a few low, small, and isolated areas in the park itself; all this great area, which includes all the grander mountain country, is composed of crystalline rocks, schists, gneisses, and granites.

Disregarding some comparatively small, and, in this connection, wholly unimportant occurrences of undoubted ancient eruptive rocks, (porphyries, &c.,) as well as some minor granite areas of uncertain eruptive nature, the series as a whole must be regarded as a great system of ancient sedimentary rocks which have undergone, in greater part, the most profound metamorphism, the result of which, over large areas, has reached that last term of metamorphism, viz, *structureless granite.* Though, in the region under consideration, the Triassic red sandstones form the oldest recognized sedimentary rocks which rest upon this underlying series of crystalline rocks, and thus indicate that they are only at least of Pre-Triassic age, yet further south and west the Potsdam sandstone covers it in large and well-recognized areas, thus demonstrating it to be at least of Pre-Silurian or Archæan age, a conclusion also rendered almost necessary on the independent ground of the extent, uniformity, and completeness of the metamorphism which has affected the mass. For it is no case of local metamorphism, nor one of supposed dependence upon adjacent masses of eruptive rock, nor of the accidental presence of mineral waters. The metamorphism is regular, or normal, affecting a great system of bedded rocks of unknown thickness and indefinite extent. Throughout the district examined, this character of the metamorphism was unmistakable. Disappearing beneath the rocks of the plains it becomes impossible to tell how far the series and its characters may continue in that direction. Where appearing through the sedimentaries of the Middle Park and from beneath them along their western border in the park range, their clearly metamorphic nature is still present. Again covered with the sedimentaries, yet many hundreds of miles to the south and west, where the cañons chiseled by the Colorado and its tributaries have penetrated the upper rocks, and on beyond past the limits of the Colorado plateau, in the regions of Arizona, Nevada, and Utah that have been stripped of the sedimentaries, rocks similar in character occur, indicating that the substratum of the whole country is what is left of ancient and highly metamorphosed series of rock formations. No special facts bearing on the equivalency of the metamorphic series, as exposed in the front range of Colorado, to any of the divisions of the Archæan rocks at the East, were observed.

The prevalence of siliceous and granitic types recalls the descriptions of Laurentian areas. But the presence of granites may only mean extent of metamorphism and not necessarily a greater age. There may, indeed, be the representatives of two or more groups of the Archæan present, but a strong impression was received that there was but one great conformable series of rocks, and that its characters might be quite peculiar to the series and region in question. It will be impossible here to go into any detailed lithological study of the series. Though, notwithstanding the extended and rapid character of the exploration, much material was gathered bearing on the subject, yet sufficient time for its elaboration and study has not yet elapsed, and more complete results must be postponed for a final report. A few general results, however, can be offered. Considering the extent and antiquity, the formation and the probable mutations of its history, its lithological characters, as a whole, seem to be remarkably simple and uniform. From quartzite through siliceous and mica schists to very simple varieties of gneisses and granites, in which the mica is wholly subordinate, and the feldspar mostly a tabular and twined orthoclase, with possibly one or two triclinic feldspars present, and the list of rocks seems complete. Aside from an apparent tendency at several points to the formation of iron garnets, hardly any other accessory minerals were observed, while the syenitic element and the more basic rocks generally were almost entirely wanting. This does not refer, of course, to the occurrences of many minerals, some containing rare elements, in veins, nor to mere local rock occurrences, but to the impressions received from the general and extended view of the formation as a whole.

The least metamorphosed rocks observed were quartzites, the purest form of which were of clear milk-white or bluish color, excessively hard and compact. Near the lower cañons of Coal and Ralston Creeks, where the largest mass observed had been preserved from erosion, they passed into a series of highly siliceous schists, in places very ferruginous, and which may possibly yet be found to contain workable deposits of iron-ore. They were here associated with siliceous mica schists finely, compactly, and evenly bedded or banded. Above very irregular schists occurred, contorted and blotched, largely composed of lenticular-like masses of white feldspathic and black or dirty-red micaceous material, intercalated irregularly together, with garnetiferous schists. Gneissic and granitic strata are frequent, while below a great granite mass occurs with but remnants of bedding left, but which are apparently conformable with the series above. Both above and traced along the series more and more gneissic and granitic beds come in until they wholly predominate.

At a point farther north, near the Little Thompson, a few exposures of similar quartzites show them to be associated with a highly quartziferous series of greenish color, and apparently impregnated with actinolite, which occurs in small radiated patches. Bedded directly in the mass are many small granitic and gneissic strata. Longitudinally the beds pass into dark, finely-laminated mica schists, but beyond are lost beneath the unconformable and comparatively little disturbed Triassic shales. Beneath them the granitic gneisses occur to an enormous thickness, with schists here and there, all apparently bedded in conformity. Both these occurrences of quartzite are near the limits of the range, and in the upper portion of the series exposed beneath the newer sedimentaries. At two other points only were quartzites observed, one having the radiated actinotite impregnations. Schists inclining to gneisses occur over large areas, but the dominant rocks are granitic gneiss, or even granites, and of these the tendency is decidedly toward a binary granite to which the name of Aplite might apply, a rock with a decided predominance of the quartzose and feldspathic elements, the micaceous ingredient being frequently nearly absent. The latter usually occurs in small black flakes, with the feldspar in greater part orthoclase, in large flat crystals, twined in two thin plates parallel with the flat faces, and of white or reddish color, the mass being rather loosely textured and inclined to crumbling. Great areas are composed of this simple feldspathic granite, and while it may appear structureless for long distances, yet search seldom failed to find evidences of structure, such as inclosed masses of schist, perhaps several hundreds of feet in extent, passing by imperceptible stages into the inclosing granite. Perhaps patches only a few miles in extent, or a congerie of patches all parallel, but separated by the better defined granite, may only remain to attest former structure. When sufficient mica is present a gneissic structure may indicate bedding, but in the ternary granites, or when the mica is in too small flakes to clearly show a parallelism, the less changed and isolated remnants of former structure must be resorted to. In a few instances when bedding was not thus indicated by the mica the tabular feldspar crystals were observed all arranged in parallelism with the bedding, and in others a marked per cent. of the crystals were so arranged as if the crystalizing forces had been partially controlled by the original structure of the mass, just as in well-defined schist or gneiss the crystallizing out of the mica seems to have so been determined.

When the almost structureless granite is homogeneous over considerable areas, the characteristic "dome" form is developed in the erosion and weathering of the country. The most structureless granite of all was an exceedingly compact and hard porphyritic granite which was observed but in a few small areas and bore an impress of an eruptive origin. In it the feldspar crystals were not so tabular, while the rock was closely built and not so loosely textured as in the broader masses of the more friable granite with tabular feldspar crystals; yet in one of these masses, apparent transitions from adjacent schists could be observed.

That the characters noted above are evidences of a structure that once existed throughout the whole mass; that the inclosed schistose patches and areas are neither remnants of foreign schists inclosed in an eruptive granite mass, nor accidental lamination developed by crystallization or motion in a plastic rock, is abundantly proved by the fact that whenever, over a continuous area, a great many of the strikes and dips of such remnants are carefully noted and platted on the map, they are invariably consistent among themselves in indicating a definite structure of the whole, and accord with the structure that may be indicated by neighboring schists and other masses of undoubted bedded rocks. Thus, suppose a horizon of exceedingly well-bedded quartziferous and mica schists to be under or overlaid by granites which possess in general no distinct structure, and that the foldings have been such that a sharp anticlinal has been formed with its axis dipping steeply to the north. The outcropping edges of the schists would thus appear, forming an angle or curve, with the apex directed northward and widening out to the south, while the beds dipped off outward to the west, north, and east. Now going among the granites above and below, and noting carefully the directions and dips of all the little evidences of structure found, however insignificant, it will be found that they, too, all accord with the zone of schists, and indicate precisely the same sort of fold. For many miles, often, such a fold may be traced in this manner, perhaps retaining the same characters as it is clearly shown to have in the schists, or increasing in sharpness or finally dying out entirely and disappearing. And when it is observed that the zone of schists, when traced longitudinally, may also be formed, changed into a similar granite region, with the same indications and remnants of bedded structure, the proof becomes conclusive. Indeed, so constantly and without exception did this agreement of isolated observations occur, whenever chance and time threw a sufficient number of observations into a small enough area, that observations at first looked upon as doubtful, if not misleading, finally came to be regarded as trustworthy evidences of structure, and the conclusion drawn that, however extreme and profound the metamorphism may have been, the tendency of its action was to produce a homogeneous or structureless mass, and never such as to impress on the rock definite indication as of a new bedding; and that where indications of structure do occur they simply represent the remnants of bedding that have not been obliterated by the metamorphism, and thus indicate the original structure of the whole mass. Many observations that were at first considered as wholly questionable and provisional, were afterward found to accord with trustworthy data found not far off. Even a much less expected indication of bedding was noticed at many points, though it was by no means accepted as a trustworthy one. When strata of varying degrees of hardness are inclining somewhat, and subjected to erosion, the irregularities of surface formed are almost always steepest on the sides that exhibit the edges of the strata, the slopes with the inclination of the strata being usually much the more gentle, as shown so repeatedly in the hog-backs. Now, over considerable granite or gneissic areas, especially in the region near Turkey and Last Resort Creeks, the at first apparently structureless granite hills presented their steepest faces to the south, or southeast, or southwest, and in nearly every case the remnants of structure found here and there in them, and which conformed in plan to the plainer schists at the north, bore the normal relation to the form of the hill, *i. e.*, dipped with their gentler slope, and showed their edges on the steeper ones. It seemed strange that such a simple topographical feature should be preserved in such much changed rocks.

Thus it became certain that all the great masses of rock which here compose the archæan areas of the district, the granites inclusive, were metamorphosed *in situ*, and that the latter, as a whole, must be considered as indigenous in its character. This metamorphism would seem to have been deep-seated. Not only would its nature and extent, judging from other regions, indicate it, but the evidence exists to show that an enormous amount of material has actually been removed from the ancient surface to bring to light the rocks as now exposed. The cañon-cutting and surface-erosion of the present has only been in progress since the latest uplift—probably in early Tertiary times—and is almost as nothing in amount, so far as the metamorphics are concerned, compared with erosions in the distant past. Regarding as still correct the evidence from within the district in question, the whole region, except, perhaps, its extreme southwestern portion, stood above the ocean-level at least just previous to the deposition of the Triassic sandstones, and probably did so all during Paleozoic time, and if the erosion then approximated in rapidity to the erosion of the present time, in such a long interval it must have been enormous. That the erosion was by no means gentle is evidenced by the almost universal coarseness of the adjacent derived sediments, the amount of which themselves attest and measure the amount of material removed from off the adjacent archæan areas. The "overlap" and shelving-off of the lower Triassic sandstones all along the east border of the range show a gradual encroachment of the shore-line, a winning of the land by the sea, effected by the slow degradation of the land by erosion. How far and rapidly this extended cannot be told, but all of what is now the Middle Park, and probably much farther up on the range, had, by Cretaceous times, succumbed to this degrading and sea-encroaching process. And yet adjacent land must have existed, as the marked coarseness of some of the Lignitic (Eocene?) beds indicate, composed, as they are, of granitic *débris*, and the complemental and actual evidence exists in part in the archæan rocks themselves. Looking at those that are only now exposed to view, some of the lower horizons showing near the center of the range lie many thousands of feet in geological antecedence below the upper exposed portions, and how much the latter may have been below the surface that existed when metamorphism was in progress, is an unrevealed story, the evidence being hid beneath the ruins of the rocks themselves in the *débris* that now forms the sedimentary rocks of the plains, but which, as said before, show that much more has been removed than now exposed. Thus the thickness to which the archæan rocks were piled up strata upon strata, before even their own *débris* was worked over into the more modern rocks, must be recorded by thousands of feet, if not by miles. Thus deeply buried beneath the surface, heat from below must have gradually invaded the mass, and have played an important part in its metamorphism. That depth, and hence, probably, heat, was a factor, seems indicated by the fact that in a general way the largest and most structureless masses occupy the lowest geological positions, while the less generally metamorphosed regions lie higher up in the exposed series. Some profound plications have occurred in the mass, the strata, generally being highly inclined, and the resistance to this folding, in friction, crushing, and motion, must have added much heat to the invading earth-heat following upon the accumulation of the strata. For the metamorphism itself is ancient, the *débris* of the already metamorphosed rock being frequent in the derived sedimentaries, and I think evidence may be found to show that it probably continued, if it was not most active, during the earlier foldings of the series. The intensity of this heat can hardly be stated. It was not necessarily of that temperature that would be required to melt the granites as they now stand, for the presence of saline waters may have so acted as to have assisted the heat in inducing plasticity or liquidity, to produce a state of "*aqueo-igneous fusion*" without the actual temperature being very great. How far such action really occurs I suppose it difficult to tell, but whatever the conditions, whether more or less heat, assisted more or less by aqueous action, they have apparently been such that plasticity or liquidity has actually been produced in portions of these rocks, and probably to a considerable extent. Such conditions, or a tendency to them, would certainly assist in producing homogeneous or structureless masses of rock, by allowing freer play of the particles in obeyance to chemical and other molecular forces, and the large granite masses, indicating centers of greater metamorphism, probably also indicate areas of once greater plasticity. While metamorphism alone has often left sharp lines of demarkation between differently affected rock, there are also points where movements of the plastic rock seem to have occurred; while, in tracing a line of schist into a granite area, points may occur where the normal granitoid strata regularly belonging to the series may gradually increase in number and thickness, monopolizing the series and producing a normal metamorphism; or tongues of granite may invade the schists, as if an active metamorphism had proceeded outward from the granites, eating, as it were, into the schists, and absorbing first those beds by nature most readily succumbing to the change, and leaving the intercalated masses less changed. Yet the remnants of structure left in the granites still show that no important movement has taken place in the mass, but that the rock remains *in situ*, and is an indigenous granite. But, besides these confusing appearances, lines of the granite sometimes appear as if actually injected or intruded among the schists, sometimes on their bedding, but perhaps across it as eruptive veins. Indeed, there seemed cases where, in approaching the same mass of granite from different points, that at one all the appearances of a truly exotic and eruptive origin might be found—abrupt lines of demarkation and veins; while at another point nearly all the steps of a gradual metamorphism and transition from the schists beyond might be traced, while the remnants of structure through the mass itself would, in greater part, conform to the surrounding system of folds, showing it as a whole to be an indigenous mass. Two observers thus approaching such a mass would justly render different verdicts as to its nature, one ascribing to it a wholly eruptive origin, the other a clearly metamorphic character. A few minor masses of granite did not show well-marked transitions from schists, though in part the ends of the latter gradually, though yet abruptly, merged into the granite, as if absorbed by it, the mass as a whole presenting the character of an intrusive mass. There is no evidence whatever, however, to show that such masses have traveled far, or that they might not have come from a short distance only, and have been derived from rocks similar to those in which they are inclosed, or others of the same series, for their likeness may be found at other points as true metamorphics. Penetrating various portions of the series are granitic, usually mostly feldspathic, veins, many of which probably extend long distances and appear to be of true eruptive character, while other granitic veins, usually of very coarse bluish quartz and white cleavable feldspar, with sheets and large crystals of white mica, seem to be more naturally referred to infiltration, or to be endogenous in character, like many metalliferous veins, some of each kind showing layers of deposition or structure. Nearly all of the metalliferous deposits, for the profusion and richness of which Colorado is so justly celebrated, occur in veins in this great system of metamorphic rocks, or in *débris* derived from the same. The more noted of these were studied with care by Dr. F. M. Endlich during the early portion of the season, and his results will be found as a portion of his report as geologist of the southern or San

Luis division of the survey. A complete knowledge of the general geology of the region as a whole, as well as of these ore-deposits, would probably show connections between the two, and lead, as in other regions, to results valuable to the mining-engineer. To trace such connections, and to master the relations of the veins and their contents to the formation as a whole, could not be expected to be accomplished in a single season's work over an extended area.

A number of porphyry dikes, usually of short extent, have penetrated the metamorphic rocks at many points, perhaps most noticeable in the region drained by Left-Hand, Four-Mile, and adjacent creeks. They have considerable variation of composition, but have not yet been made the subject of special examination by the survey. It is on either side of one of these porphyry dikes, along the planes of contact between it and the inclosing granite, that the rare and interesting telluride ores of Gold Hill are mined.

Dr. Endlich's analysis of specimens from this locality has revealed some new mineral species, while specimens of this and neighboring porphyries furnished with notes upon their occurrence to Professor Benjamin Silliman, jr., of New Haven, have formed the subject of an examination by him, in the American Journal of Science and Arts for July. The description of these ores, and their mode of occurrence, is given in the chapter on mines in Dr. Endlich's report.

THE STRATIGRAPHY OF THE EAST SLOPE OF THE FRONT RANGE.

Three causes combine to render the rapid study of the stratigraphy of the archæan rocks difficult and its results uncertain: First, their structure is not only often complex, but obscure, the evidence of it being at times nearly or wholly obliterated by the metamorphism, and often over large areas very difficult to find; second, this metamorphism renders lithological characters inconstant, so that a stratum that at one point may be characteristic among its neighbors, may, at another, become like them, or all may change so as to retain none of their geological features, becoming again like other series, so that lithological resemblances cannot often be taken as a guide to follow, and may even become misleading; third, the erosion producing the present surface features of the mountain region had the direction of its action determined by movements of the surface which were not closely connected with the extended plications of its rocks; and, moreover, since this erosion has not long been active among these rocks, there appears no well-defined connection between the topography and the structural geology. The ancient erosion gradually wore down the mass to the surface of the sea, and while previously to this it was no doubt directed by the structure, yet the mass was finally leveled off irrespective of structure or relative hardnesses of its beds by the encroaching ocean, which worked over its ruins and laid them down upon the smoothed surface in the form of the Triassic and other beds. The recent great uplift, while it probably added new plications to the accumulated plications of the past in the ancient rocks, was quite simple with respect to their total plication, and left the upper Triassic and other sedimentary beds comparatively simply structured, they having been affected alone by the later movements.

As the mass appeared above the sea and surface erosion once more commenced, but which now acts upon the recent rocks covering probably in greater part the complex underlying rocks, it was directed off from the line of greater uplift down the long slopes of the rising continent to the retiring sea. The channels of drainage started were directed solely by the structure and characters of the upper rocks, and when they gradually cut down through these and commenced sinking their cañons into the underlying complicated rocks, these cañons bore no relation whatever to their complications. It is but recently that the upper rocks have been completely removed from the summits of the mountain-spurs, the ancient level of subaqueous erosion being still indicated by the often uniform level of the spurs and hill-tops over considerable areas, and large plateau-like regions which became very marked from certain points of view. Two or three such levels are indicated at a few places, showing not only that the sedimentaries have once extended up over what are now the mountain rocks, but that the uplifting has been mainly confined along certain partly well-defined lines, the intermediate belts, though uplifted bodily, remaining comparatively level, a type of folding, probably, not uncommon farther west, and which will be referred to again in the following chapter.

Eroded away, worked farther and farther back, the sedimentaries have receded to the line of hog-backs, and having a structure bearing a partly constant relation to the eroding forces, with persistent lithological characters, their topographical features indicate their geological structure, and it is through the former that the latter may be most rapidly and easily read, the long ridges nearly always, as shown in Chapter II, conforming to a particular bed or series of beds harder than their neighbors, and thus traceable as far as the ridge is visible. Not so the metamorphics. Penetrating the formerly covering sedementaries, the cañons commenced sinking into the lower and more complicated rocks, with directions impressed upon them by the latest uplift and the overlying rocks, and bearing no constant relation to the structure of the lower ones in which we now find them. It is true that the structure of the lower rocks has begun to affect the courses of the streams, and in places to a considerable extent. Meeting a softer bed a cañon will often have its course directed by it, and follow it for some distance, leaving the adjacent harder beds plainly indicated by the ridges, and sometimes the sinuosities of structure are very curiously followed by a stream in all its windings, but it soon breaks away and runs independently of the bedding. Many of the smaller ravines have had their positions determined by the structure; but in a broad sense the drainage is from the main mountain crest eastward, independent of structure. Thus, while in places geological features may find expression in surface form, yet, as often, there may be no conceivable relation between topography and geology. The subaqueous erosion, in smoothing all to a common level, destroys all former surface expression of geological character, and the present erosion has not yet been in progress sufficiently long to recreate the lost features.

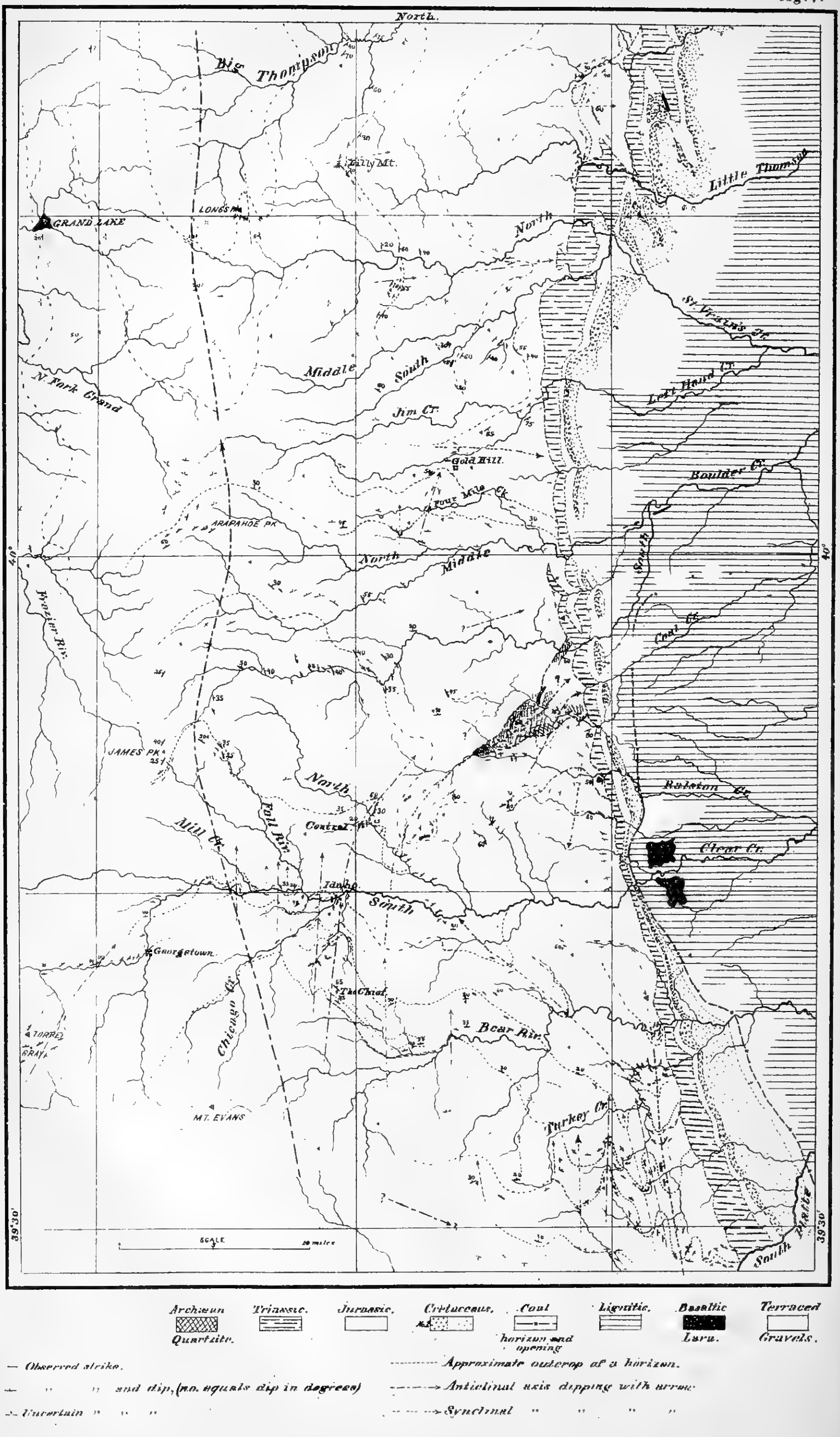
With geological structure but feebly featured upon the surface, and with such structure as does exist, not only complicated, but often lost in metamorphism, it becomes no easy task to trace it out, often requiring close inspection of the rock, and even long search to detect it, while but little definite character can be made out in distant views. On the other hand, the exposures are both numerous and continuous, the many cañons affording fine sections of the rocks, and when sufficient time is expended in their examination I conceive that some exceedingly interesting and clear results as to metamorphic action will follow, to say nothing of structural features, and the connection of both with the filling the innumerable mineral veins which occur in the series with their valuable ores. Notwithstanding the natural difficulties in the way, many observations of the structure of the mountains, more particularly of the eastern slope of the front or main range, were made during the past season. These, though by no means exhaustive, and, in a portion of the region, too scattered or imperfect to there define the structure, yet such material as was obtained seems sufficient to indicate certain general features, and a portion of the material from which the inferences regarding the structure are drawn, together with the inferences themselves, are given below.

Lithological and metamorphic characters are not here regarded as much as they should be in a complete study, nor as much as they may be after the further study of the notes and specimens yet at hand. The accompanying map (Fig. 7) shows the Archæan area over which the most connected observations were made. It is an area extending north and south across the full width of the district, with the main crest of the front range near its western border. The streams along the northern half of the west border belong to the Middle-Park drainage. The main divide passing out from the western border of the map a little southwest of James Peak, comes in again at Gray and Torrey. On the east are the Lignitic beds of the plains in horizontal lining, with the coal horizon and principal masses of terrace gravels approximately shown, followed by the hog-back zone of more or less upturned and eastward dipping Cretaceous, (dotted,) Jurassic shales, (white,) and Triassic redbeds, (heavier horizontal lines.) To the west extends the mountain zone of Archæan rocks to the extreme border of the map. Nearly all the observed strikes or curves of the rock are indicated by the short dashes, the direction of which show the trend of the strike, while the little mark on one side shows to which side the rock dips, with numbers sometimes attached showing its amount in degrees, the dips being from the horizontal. The shorter line extending across the dash indicates vertical strata, with both sides equal, horizontal bedding, and approximate uncertain strikes and dip, seen either at a distance with a field-glass or too small a remnant of structure to be trustworthy, are indicated by the broken dash. A dash may be the result of a single observation of obscure structure in granite, or, more often, may indicate the result of a number of observations, or the whole formation may clearly have the given trend, obviously bending here and there as strikes indicate. Regarding a number of neighboring observations they serve to show the present structure of the region in which they occur.

Drawing dotted lines through a region so that they are parallel to all the strikes near or abreast of which they pass, they may be considered as indicating, approximately, the course the strike would have if the outcrops could have been traced continuously along them. In other words, the dotted lines represent approximately where the continuous outcrop of a horizon, or series of beds, would be if it could be traced. When the structure is clear, or when the observed strikes are rather thickly scattered, these dotted lines may represent an outcropping horizon quite closely, but where the observations are more scattered, the course of the horizon becomes more conjectural, and the line, instead of remaining on its proper horizon, may gradually pass higher up or lower down through the series, while unobserved faults may throw the beds aside and not be indicated by the lines; yet the latter, though so far incorrect, still serve to connect the observation which would otherwise be too disconnected to the eye, and *just so far as the observations go*, truly indicate, if approximately, the curves of the outcrops of the folded rocks. An anticlinal, or synclinal, with north and south *horizontal* axis, would thus have the beds outcropping on either side in north and south

STRUCTURAL MAP OF THE EASTERN SLOPE OF THE FRONT RANGE

Fig. 7.



parallel lines; but if the anticlinal dipped north, the beds would mantle around its northern end in curves, with their convexity or apices directed northward, the beds dipping from it northeast and west, with a northern dipping synclinal would have the curved outcrops pointing south, but dipping northward and inward from all sides. Anticlinals are indicated by dot and dash lines, synclinals by three dot and space lines, the arrow-heads indicating the direction of the inclination of their axes. It is by no means claimed that the map represents with perfect accuracy the geology throughout; it is simply a means of putting together before the eye the observations recorded, and to show, only so far as these indicate, the broader ideas of the structure of the mass. Long study will be required to unravel completely the structure of these rocks, and much that is here inferred may finally have to be modified. The portions represented with least certainty on the map will be mentioned in the following brief and hurried description:

The portion of the region under consideration whose structure was probably most clearly made out is that lying south of South Clear Creek, and having Mount Evans as its great culminating mass. This mountain was approached from the upper branches of Bear Creek, on its northeast side, and for eight miles near the summit no evidence of structure whatever was obtained, the great massive bosses of rock being often sculptured into dome-like forms, with profound gorges and amphitheaters, all composed of normal granites, both coarse and fine, some containing much mica, others with but little, in small, scattered flakes. The different granites were not observed to occur in zones, as if once bedded, but not enough was seen of the mass to say that they did not so occur. As will be seen later, the mass is probably all metamorphic, and a more extended examination of it would probably have developed many evidences of a former structure throughout it. These granites seem to occupy as low a geological position as any rocks observed anywhere in the mountains. At the northeast the high ridge rising opposite the mountain from the other side of Bear Creek, and between the latter and Clear Creek, and which culminates in The Chief, is composed of well-bedded schistose rocks, all striking about northwest-southeast, and dipping from 25° to 60° to the northeast. The Chief itself, and ridges running from it to the southeast, are composed of very irregular and contorted dirty-red and white-banded schists, often granitiferous, which compose a considerable thickness of the formation above. Below, on the southwestern face of The Chief, and extending southeastward, is a well-defined bedded zone of fine, handsome, light-gray granite, with small scattered mica-flakes many hundred feet thick, and in turn underlaid by a still greater thickness of more evenly and finer-banded schists than above the granite, inclined to steel-gray in color, with some irregular schists. The edges of these form the lower southern slopes of the hills, their bases being followed quite closely by the valleys of the main streams, which seem to indicate a well-defined and regular line of demarkation between this plainly bedded series, above on the northeast, and the underlying structureless granites rising in the great slopes of Evans. The impression thus first received is that here are two different and distinct rock formations. The heavier dashed line upon the map here shows the limit of the granites as it follows one of the principal northern forks of Bear River, gradually bending eastward, and indicating, with other strikes observed in the schists above, a flat synclinal, with its axis dipping northward. The dotted extension of this horizon southeastward is but approximate, and will be referred to later, while the extension westward is wholly inferred from the observation farther to the northwest, and was not itself directly traced. Descending from The Chief northward, thus crossing the edges of the steeply upturned schists and ascending through the formation, but at the same time following somewhat along it northward, it is found to swing more and more northward, and then—near a north and south line passing through Idaho—to bend directly around to a southwest strike and northwest dip. It is a sharply-folded anticlinal dipping steeply northward. Still following along the strata, they again swing northwest and again southwest, showing a similar abrupt fold. Following up Clear Creek from Idaho, a number of such folds occur, the dip of the irregular schist and gneiss rocks being invariably east, north, or west, but never south until, near the head-waters of that stream, a more constant southwest strike is attained, with northwest dip, as finely shown in the Gray and Torrey Peaks, and north and east of the same. Thus regarded all together, the Evans mass appears as a broad anticlinal, with its axis dipping northward, and carrying on its face a number of minor crumples, smaller anticlinals and synclinals, like ripples on the greater wave of rock. Naturally these smaller folds render the more general geology very confused. This seems to be particularly the case near Idaho, but many observations showed the same little folds running for considerable distances. The smaller valleys here show some peculiar relations between topography and geology, sometimes following the softer beds in their sinuosities for considerable distances. The numerous minor anticlinals and synclinals here observed are indicated by their proper symbols. The schists and gneisses appear well exposed in the lower portions of Chicago Creek, but higher up granites begin to prevail, very abrupt transitions from one to the other being frequent. Starting from the eastern base of the Gray and Torrey Peaks, and curving around northward, is a most profound and regular glacier-carved gorge, with sweeping precipitous sides towering up on the east side to the rather even-topped summit of MacLellan Ridge. On the west side, plainly noticeable in Gray and Torrey, the handsome gray and rather evenly banded gneisses dip rather steeply to the west and north, while just opposite, on the east side, an opposite dip occurs, the saddle just east of the two peaks being in a sharp anticlinal axis. Opposite the mountain, and a little south, perched midway up the precipitous face of the MacLellan Ridge, its houses held on to the face of rock by chains and rods, and accessible only by the aid of ropes, is the Stevens mine. Here some structureless granite masses confuse the gray gneiss, the mine being in one of them, and faults occur, but it seems to be here that the axis of the anticlinal leaves the valley, for down the latter the general dip is to the northwest. Joining the next fork, the strike still bears east and west, or northeast and southwest, dipping north and west, till about midway to Georgetown, when a mass of hard, structureless, massive, porphyritic granite is met, in which the Terrible mine is situated. The contact between the schists and granites can be quite readily traced up the steep northern slope of the valley just west of the mine, and is mostly very abrupt. The ends of the westward-dipping schists mostly lie up against the granite, but in places bend down into it, being much contorted, and while the line of contact is often remarkably well defined, the change from one to the other being instantaneous, yet in places the change is less abrupt, the irregular ends of the schist-bands being apparently absorbed in the granite mass. Some inclosed patches of schist appeared in the granite, but with no recognizable general arrangement, while below the structureless granite a southeast dip appeared, intimating that the granite occupied an anticlinal axis, probably the northern continuation of the Gray's Peak anticlinal, as indicated on the map.

Toward Georgetown the schistose-gneisses stand for the most part very nearly vertical, with many faults. At one point near Silver Plume, a small hill on the north side of the valley showed an abrupt synclinal structure, a fault apparently passing directly through the axis. About as far below Georgetown as the Terrible mine is above it, a rock on the west side of the valley, and forming a little promontory at the junction of a side stream, shows the same hard, structureless porphyritic granite as at the Terrible mine, with some abrupt lines of demarkation between it and the adjacent schistose-gneisses, but also presenting some examples of more gradual transition than elsewhere, and deserving of more careful study than the time allowed. This porphyritic granite impressed me as being more probably an eruptive mass occupying an anticlinal axis than one metamorphism *in situ*, though it may not have come from afar, nor from rocks of an origin dissimilar from that of its present companions. The dip on the southeast side of this anticlinal must become reversed in rising up against the Evans mass, forming a synclinal between the Gray's Peak anticlinal and Mount Evans, but as this region was not directly entered, it was not observed, and is not indicated on the map.

Returning to the irregular schists of The Chief lying on the Mount Evans granites, and following them eastward, they maintain their characters for some distance, but with increasing granite characters, until they appear to cross Bear Creek and merge into a granite country. The hills are less high and sharp than before and rise from a more uniform plateau-like surface, with southern sides almost always steep and almost invariably steeper than their massive northern slopes. The rock generally appears to be a reddish granite, with tabular trimmed feldspar crystals, and small scattered mica flakes; yet remnants of structure are very numerous and can be found in almost every hill. Patches of the dirty-red and white-contorted schists, similar to those of The Chief, occur, apparently indicating approximately the same horizon. Near the border of the range, and approaching the sedimentaries, schists predominate, a line of white quartzite outcrops being observed at one point extending for a little distance. All the rocks still uniformly incline to the north, or else east and west, and none to the south. A most decided unanimity exists among the very numerous recorded strikes and dips observed in the granites, which is confirmed by the adjacent schists, in indicating a series of minor folds with axes dipping northward, some quite abrupt, as shown upon the map. Though concealed by the sedimentaries, the last-observed rocks on the extreme border of the archæan rocks seem to indicate that the general strike has swung from southeast to northeast, as if the border was near the principal and northward dipping-axis of a great synclinal—the compliment of the main Evans anticlinal, with the rocks within it crumpled into minor folds just as the similar wrinkles exist on the Evans fold. The more southern rocks here are the most metamorphosed, and in tracing them toward Mount Evans evidences of structure become less and less marked until they become so difficult to find in the red and gray granites, that the latter become practically structureless. While the higher mountain-mass beyond may hereafter be found to be partially exotic in character, yet here, upon its southeastern extension, its rocks are certainly clearly metamorphic. It is at points here that an approximate parallelism of the tabular feldspar crystals to the bedding was first observed, though it is a character that readily became lost in a wholly fortuitous arrangement of the components of the granite. Large inclosed schistose masses, with most gradual transitions along their borders into the surrounding granites, to the smallest and most isolated of little collections of mica flakes, gradually dying out more and more in approaching the central mass, afford opportunity for a most accurate and careful study of the metamorphism of bedded rocks into structureless granites of the most absorbing interest. A few uncertain observations in the red granites near the south border of the map may indicate that a southward dipping of the formation begins, and if such is the case, the eastern ridge of Evans may be of an anticlinal structure, the mountain itself thus being at the intersection of an east-west and north-south fold, just as, topographically, it lies near the intersection of a north-south and an east-west range of mountains. About midway between the lower reaches of Clear Creek and Bear Creek the rather obscurely-exposed granites show gneissic areas, having invariably a high southern dip, or the reverse of the rocks of the chief ridge and to the southeast of the same, indicating a northwest and southeast synclinal, as shown on the map. This seems to first appear in the cañon through which Turkey Creek debouches from the mountains, but here affected by one of the minor north and south folds, and from here on the course of the axis seems indicated at three points, where the rocks were found having an abrupt change of strike, the meaning of which was not at the time understood. What is thus indicated of this axis would show it to dip to the northwest, but the complimentary southeast dip that should occur does not seem to be indicated, and its northern end is probably cut off by a fault.

The minor folds upon the Mount Evans anticlinal give to the greater fold a squarish form, the northeast corner of which—that at Idaho—being a sharp bend, while the northwest portion seems to be more rounded. These two outer folds are the two principal components of the main fold, and as the latter lies nearest the main axis of the range, it will be mentioned first. From Clear Creek to James Peak no observations were made. At the latter the general strike of the gray-banded gneissic schists forming the main ridge is northeast and north-northeast, and dipping northwest from 25° to 45°. Following them along northeastward, however, they swing around more and more east to southeast and in places nearly south, with rather low eastern dips, thus indicating an anticlinal, having an axis lying just east of the main topographical crest, and having a northward inclination. South Boulder Creek rises at this point, and for nearly ten miles down its cañon there seems to be an uninterrupted series of schists and gneisses of different varieties, some gray and some garnetiferous, striking more or less northwest-southeast, with northeastern dip of 20° to 50°, till the stream enters an apparently structureless granite mass, which will be referred to later. Following northward along the range, the same swing of the strata appears at the Boulder Pass, and again at Arapaho Peak. Through all this distance, from Evans northward, would thus seem to be a great anticlinal, with a northward-dipping axis, and if the series were uninterrupted, an enormous thickness of rocks must be represented. It is quite possible, however, that unobserved faults occur, the northern side being thrown upward, thus bringing the same series to view more than once. A little north of Arapaho Peak the character changes somewhat; some strikes from the northwest instead of from the southwest would seem to show that the axis of the anticlinal was nearly horizontal, or rather had a gentle southward dip, as if an east-west synclinal fold had flexed the north-south anticlinal fold. From Arapaho, and from points northwest and southeast of the mountain, many fine views of the great cañon-cut mountain-mass at the north may be had, and the structure generally shown is that of a broad flat anticlinal, with a nearly horizontal axis, the plainer bands of rocks showing as doming over in great flat curves, with minor flexures here and there, and steepening in dip on either the east or west. Long's Peak, the grandest mass of all, is mostly of coarse granite, but with several lenticular masses of darker schistose rock plainly showing in its precipitous glacier-scored sides. East from Long's generally the country-rock seemed almost wholly of granite, both gray and deep red, coarse, crumbling, and with large tabular feldspar crystals. But little evidence of structure was noticed, but all that was observed showed eastward-dipping rocks, thus enforcing the general anticlinal structure of the range. Throughout all this northern portion of the map the dotted outcrop-lines are wholly approximate, and intended simply to indicate probable structure.

At Lilly Mountain a more schistose zone, with red granite beds containing garnets, was found, which southward gave way to some reddish granites, but seemed to again show itself somewhat plainer between North and Middle Saint Vrain's Creeks. East of Lilly Mountain but random and uncertain observations were made, but what was seen appears to conform to the nearest more certain observations. Close to the border of the range, between the Little and Big Thompson Creeks, and best exposed in the high and rather isolated hill thrown up by the echelon folding of this region, rocks of well-defined bedding occur, gray schistose gneiss, &c., changing to hard greenish siliceous rocks, as if impregnated with actinolite, while still farther out, and exposed by faults that push aside the covering sedimentary rocks, are clear white quartzites. Between the North and South Saint Vrain's a few strikes in the mostly structureless granites would seem to indicate a pretty sharp east-west anticlinal dipping east. Tracing these outer beds farther southward, a flattening of the formation, south of South Saint Vrain's, spreads the strikes in a peculiar way, opening out or widening the outcrops of the formations. Still, all the dips are eastward, except one small occurrence of white quartzite. This appeared as a ridge, only about 100 feet long, rising above the soil of a flattish contoured region, where all other exposures showed the coarse, reddish, crumbling, tabular-crystalled granites, with but occasional evidences of structure, which, however, as just remarked, all indicate a dip in a general easterly direction. The small patch of white quartzite had a well-defined trend of 15° to 25° east of north, and dipped 45° northwest, as if it represented a remnant of an unconformable series resting on the granites. The joints and seams contained radiated actinolite, and some of the quartzite was tinted green, as if containing the same disseminated in the mass. It thus resembled the green siliceous rocks north of the Little Thompson and elsewhere, which certainly pass into and belong to the schist series. In the neighborhood of Jim Creek the observed strikes appear inconsistent with one another, and are too few to indicate what the structure really is. For a little way above where Jim Creek joins Left Hand, schists or banded gneisses prevail, as well as on down Left Hand to the sedimentaries, all having a general northeast strike and southeast dip. They are probably the same as those a little north, near South Saint Vrain's, the two apparently swinging around to join one another along the eastern mountain base, the higher hills at the west being of coarse granites. For some miles up Jim Creek the coarse structureless granites prevail, with porphyry dikes penetrating them here and there. Some *débris* of true syenite was here seen. This irregularly-banded schist-zone seems to form the high ridge between Jim and Left Hand Creeks, running toward Gold Hill and dipping southeast. From Gold Hill southeast a zone of similar schists and banded gneisses shows here and there in Four-Mile Creek as striking south of east and dipping northward. Running from Gold Hill eastward would thus appear to be an eastward dipping synclinal axis, the included surface-rock seeming to be a coarse gray and reddish gneissic granite, some of it containing considerable mica, but much of it, like most of the granites north, having but little mica, and that in small and scattered flakes. This synclinal may be the eastern extremity of the fold that was stated to flex the great north-south anticlinal of the main range near Arapaho Peak, flattening the axis toward the north. The schists running southeast from near Gold Hill seem to continue on westward in a pretty well defined zone with some small but obvious north-south folds, as indicated on the map, but with general northern dip. A northwest extension of schists, with south dip, as if the east-west synclinal extended through here westward, does not appear from the few and imperfect observations made in this direction to exist here, indicating that a fault must be resorted to to explain the curious outcrop that the map indicates. South of these schists there seems to be shown a pretty sharp line of demarkation between them and a coarse granite region across which the North and the Lower Middle Boulder Creeks cut their impressive cañons. Along the cañon of the latter a very few imperfect east-west strikes, with steep north dip, seemed indicated, which lower down, near the sandstones, swing southward. South of here, between the Middle and South Boulder Creeks, though no direct strikes were observed, yet the different granites were plainly arranged in zones trending about north and south, but running more southwest in following them southward. Near the mouth of the South Boulder Cañon, and resting on these zoned but otherwise structureless granites, the quartzites first appear in force, with a south-southwest strike, and dip of 60° to the southeast. Though mostly quite pure, yet these quartzites may be traced into siliceous schists and are associated with mica schists and gneisses. The above-described structural relations would seem to indicate that these quartzites were the stratigraphical equivalent of the Four-Mile schist zone, though here by no means so far metamorphosed, and that could the covering sandstones at the east be stripped off, the two might be traced out till they unite and become continuous. The quartzite ridges are well marked, and near the southern end the rocks appeared to show as if folded upon themselves into a sharp synclinal, the east side being thrown even beyond the vertical, and if this is so it may be the northern prolongation of the flatter synclinal that appears east of The Chief, as indicated on the map, but this is very uncertain. Attention has already been called to the sharp fold near Idaho, and forming the northeast corner of the greater Evans fold. The region lying directly between Idaho and Central was not passed over, but at Central the rocks indicated a sharp fold similar to that at Idaho, and in view of the persistence of the fold south of Idaho it would seem to be the northern extension of the same, as likewise shown on the map. It would then pass on northward and be lost in the structureless granites below the quartzite. These here form the bulky mass of Ralston Butte. The granites here are not red, but gray, the feldspar being mostly a clear, translucent white, and the rock very coarse-grained and exceedingly handsome. Still one or two small isolated gneissic patches were observed. If the stratigraphy is here indicated by the dotted lines this granite area must represent much flattened strata in order to widen out the formation as it appears to do, yet all the observations made near its edges were of steep dipping rocks. The relations, however, all through here are not so clear as it could be wished. In the region near Ralston and Clear

Creeks, and just back of the "hog-backs," the straight-banded gneissic and siliceous schists and the irregular red and white garnetiferous schists seem folded into a pretty clear case of a southward dipping anticlinal with the west side thrown over past the vertical. Such a structure, however, would be inconsistent with the general structure immediately west, unless we assume the west side of the fold to be in the normal position and the eastern rocks tipped past the vertical. As some of them lie quite flat it hardly seems as if the inversion could have been so great. Notwithstanding the many observations here made the structure does not seem to have been clearly made out, and no attempt is made to indicate it by the dotted approximate horizon lines. The western slopes of the main range, as well as the other areas of archæan rocks generally, were not studied even as carefully as the east slope, and but little can be said of them. The western slope of the main range, in its northern portion whenever it was observed, appeared to have a general western dip, which was also indicated in all the general views obtained of it. Crossing the great trough-like valley of the Upper Grand River, the high southern portion of the Medicine Bow range, where visited, was of a very sharp anticlinal character, the rocks appearing folded quite flatly upon themselves. It is quite possible that the fold is recent and that the sedimentary once mantled over it, filled the trough of the Grand, and ran far up on the main range. When the broad rolling ridge of the Park range was touched, at the extreme northwest corner of the Middle Park, it presented only a massive granite of the very coarsest description, with great crystals of feldspar, and no observed structure whatever.

Many miles south, where the range rises on the great Blue River group of mountains, schists and gneisses predominate. These all seemed to have a pretty uniform trend, following pretty closely the remarkably sharp spurs running out northeastward from the main ridge and dipping southeastward. In Ute Peak the trend runs nearly east and west with a nearly vertical dip. In Mount Byers, the northwest spur from the Berthoud Pass group of mountains, the strike was mostly with the spur. The great east-west ridge connecting the Evans group with the Park range, and forming the divide between the Middle and South Parks, was not examined.

It is unfortunate that more definite and positive results could not have been arrived at, but when the extent of the area traversed, and the short time employed, together with the fact that other rocks demanded attention, and the peculiar difficulties in the way of this special study, are all taken into consideration, the outcome of the season's work cannot be regarded as so very small. The fact that the great front range is practically composed, throughout this region at least, of metamorphic rocks, and that these rocks possess a definite and accessible structure, is certainly shown, and while errors may be found in minor points, yet it is believed that the more general structure of the range as shown in the map will be ultimately found to be substantially correct. Some of the topographical features of these rocks are dwelt upon in the early part of the following chapter, when speaking of the upper valley of Grand River, and later when describing the Blue River Mountains. It is hoped that a more complete digest of the notes, with study of the specimens, aided perhaps by chemistry and the microscope, may not only add interesting results to the lithological and metamorphic questions involved, but assist in perfecting the knowledge of the stratigraphical structure of the range as presented above.

CHAPTER IV.

THE MIDDLE PARK.

In Chapter I was given a brief description of the principal topographical characters of that region, the drainage system of which, as a whole, may be considered as composing the Middle Park. The general symmetry of this drainage, with Grand River as an axis, its radiating tributaries, as well as the remarkable isolated character or unity of the system, all of its waters finding their exit through the single outlet—cañon of the Grand—were there noticed, and attention called to the fact that, notwithstanding the great basin-like character of this area, as indicated by these features, yet this character is in great part lost by the prominence of many of the ridges separating its secondary drainages, and the general diversity of much of its surface, wherein it presents a striking contrast with the far-better defined basin-like character of the North and South Parks on either hand. The fact that this isolated and independent system is the easternmost region in the United States, in which Pacific waters take their rise, was also referred to, while it was suggested that, as a geological basin, the northern side is wanting. The general course of the streams forming the system, as well as the more salient features of their valleys and separating ridges, were also briefly sketched out.

The distribution and structure of the rocks forming this region will now demand our attention. (See map at front of chapter, Fig. 8.)

All the eastern, southern, and western rim of this isolated drainage basin, as well as the massive mountain areas bordering much of the same, chiefly on the east and south, are composed of apparently the same system of metamorphic crystalline schists and granites that are found on the east slope of the range, excepting always certain smaller areas of Paleozoic sedimentary rocks, which occur near the sources of the Blue River, and which are quite separated from the younger sedimentary rocks to follow, and will not be further considered in this report.

All the northern and middle portions of the park, which include all the lower and more truly park-like portions, are composed, excepting a few areas of Archæan rocks along the Grand, of younger sedimentary rocks, which are not, as a rule, greatly disturbed.

THE CRETACEOUS FORMATION OF THE MIDDLE PARK.

Apparently the oldest of this series, resting, where found, directly upon the crystalline rocks, is the Cretaceous. This formation seems to vary from about 3,500 to about 4,500 feet in thickness, and is divided much like the Cretaceous upon the east side of the range, with some very strong lithological resemblances existing between some of the divisions.

At the base is a series of sandstones, some of which are red, and both massive and shaly, but the most characteristic feature of the group is the presence of hard, whitish or white, highly siliceous sandstones, often conglomerates, which, at times, form such compact quartzites that in hard specimens the rock can hardly be distinguished from some archæan quartzites. Being so hard, erosion has generally molded these sandstones into prominent exposures, leaving the softer beds in less noticeable positions, while their marked persistent lithological characters

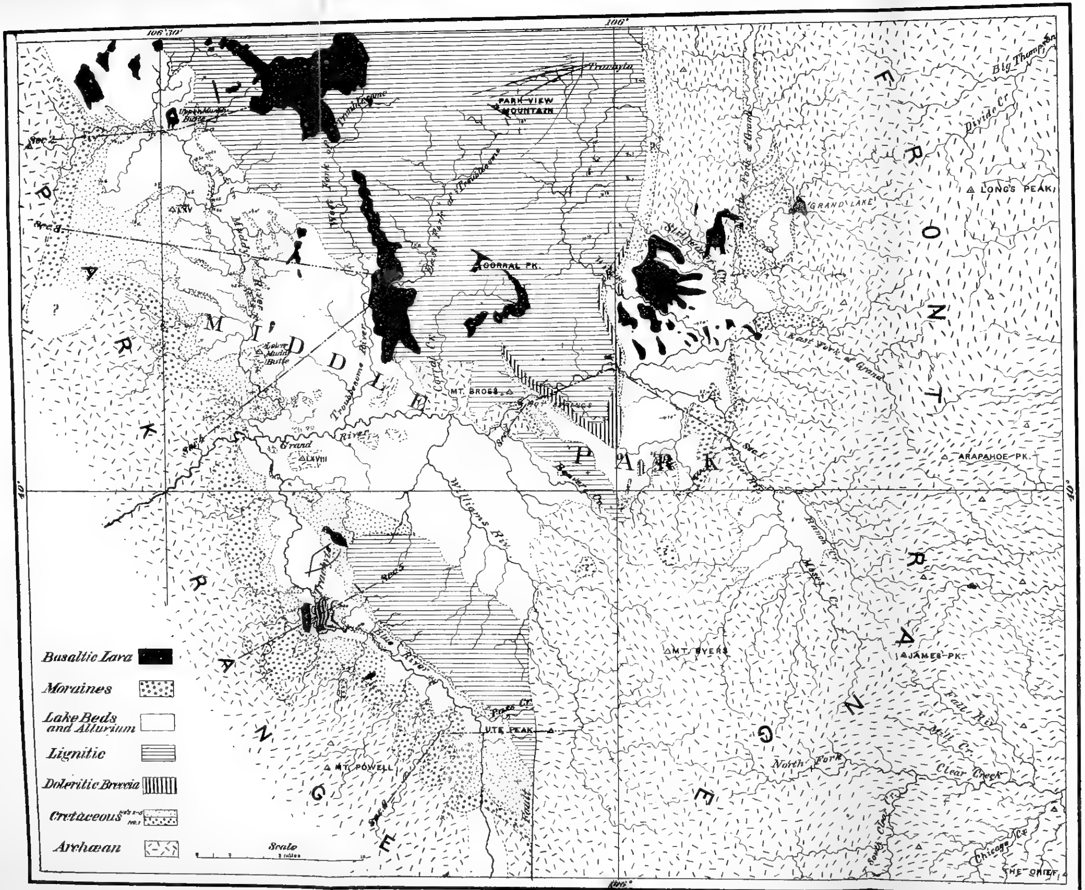
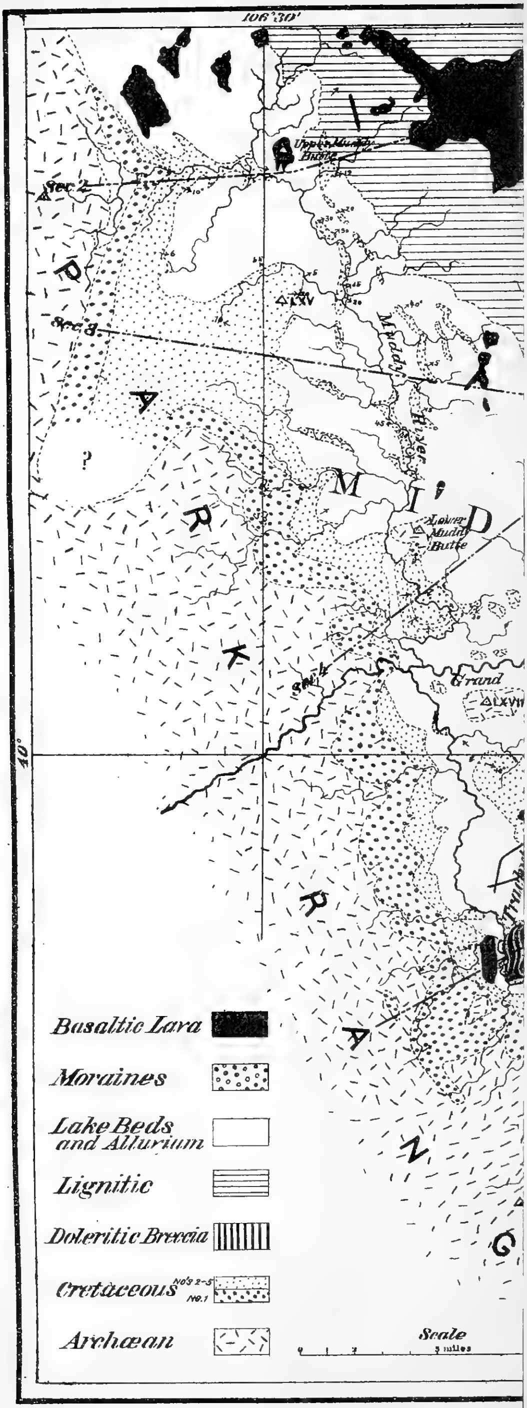


Fig. 8.

GEOLOGICAL MAP OF THE MIDDLE-PARK

SHOWING THE POSITIONS OF THE SECTIONS ON PLATE III.

To accompany the Report of ARCH. R. MARVINE MIDDLE PARK DIVISION. 1873.



106°30'
Upper Muddy Butte
Sec. 2
Sec. 3
LXV
Muddy River
M I D
Lower Muddy Butte
Grand
P A R K
R A N G
40°
Basaltic Lava
Moraines
Lake Beds and Alluvium
Lignitic
Doleritic Breccia
Cretaceous No's 2-5 No. 1
Archæan
Scale
5 miles

render them easily recognizable. These sandstones, therefore, naturally occur near to, and dipping at angles of from 10° to 50° away from, the ridges of archæan rocks surrounding the Cretaceous areas. This group appears to vary from about 350 or 400 feet, near the Hot Springs, to, perhaps, 1,200 feet, near the head-waters of the Muddy.

At the summit of the formation there is also a series of sandstones. Here, however, the predominent colors are rusty-brown or yellow, and while shaly sandstones occur, the more massive beds are soft and friable in nature, and often concretionary. From only about 700 feet at the east, these may become 1,600 feet thick farther west. Between these two series of sandstones, and all through the middle of the formation, embracing an average thickness of, perhaps, 200 feet, dark argillaceous slaty shales prevail. These naturally contain arenaceous beds here and there, which sometimes become quite numerous, more especially toward the top. No well-defined division of these middle beds was observed. In the northwest portion of the park, however, and about one-quarter or one-fifth of the way up from the base of the shales, is a horizon at which calcareous beds tend to occur. These usually appear as thin limestones, consisting sometimes of two or three more prominent beds, with several minor ones, the thickest reaching, perhaps, not much more than 15 feet. Though inclined to tabular, or irregularly thin-bedded, the limestone is sufficiently harder than the adjacent shales to appear, when thick enough, as a hog-back-like ridge above the surface. It is brownish compact saccharoidal, and often almost wholly made up of Cretaceous fossils, the principal one of which resembles closely *Inoceramus acutirostris*, a fossil of the Cretaceous No. 2, of the Nebraska section of Meek and Hayden. These limestones bear constantly a characteristic odor of petroleum.

The usual Cretaceous fossils are found here and there through the middle shales, and appear quite numerous in the upper friable sandstones. At one point in the latter, fossils, probably the *Inoceramus barabini* (Morton) of the Cretaceous No. 5 of Nebraska, were found.

There thus appears to be a very striking resemblance between the general arrangement of these groups and the five divisions of the Cretaceous, while the lower and upper sandstones present lithological characters remarkably similar to those of No. 1 and No. 5, respectively, of Hayden's divisions of the Cretaceous as present east of the mountains. The true equivalent of No. 3 may not have been recognized, and though the *Inoceramus acutirostris* (M. and H.) of the thin limestones which occur in the lower middle slates may indicate it as belonging to No. 2, yet this horizon of calcareous sediment would seem, on other grounds, to be the real representative of No. 3, and is so given on sections 2 and 3, Plate III. A complete examination of the fossils is needed to establish the true correlations. All these softer portions of the formation occupy the valleys, and are mostly covered with subsequent beds, rendering their characters not readily studied, and not always clear. The representatives of Nos. 2 and 4 are much more strikingly argillaceous than along the east base of the range, and may be undistinguishable from one another unless the beds assumed as No. 3 occur distinctly enough to separate them.

Though no fossils were observed in the lower siliceous sandstone, its relations to the beds above, as well as its lithological character, show it to be identical with the Cretaceous No. 1, east of the range. Near the entrance of the park, and on the Upper Muddy River, there was a much greater thickness of the redder and softer beds lying between the more characteristic quartzites of No. 1 and the archæan rocks below, than in the remaining portions of the park. These may represent small portions of the Jurassic caught between the Cretaceous and the underlying archæan; and if so, the Jurassic should be represented as occurring in the park. On the other hand, however, they do not strongly resemble the variegated arenaceous shales of the Upper Jurassic, which, both east of the range and west of the park, occur below the Lower Cretaceous, while they do contain thick beds of siliceous sandstone very like those characterizing the undoubted No. 1, just above; and, moreover, in beds laid down upon a newly-prepared sea-floor of far older and non-conformable rocks, as these were, unevennesses of the underlying surface and corresponding abrupt changes of thickness of the newer beds are to be expected. I have, therefore, in view of these considerations, and in the absence of fossils, regarded these beds as forming a portion of the Cretaceous No. 1. The transition between No. 1 and the slates above is abrupt, while the shales of No. 4 and sandstones characterizing No. 5 appear to commingle, giving no marked line of separation between them. As was first distinctly pointed out by Newberry* east of the range, so here in the middle park, the general aspect of the formation as a whole is that of a "circle of deposition," an encroaching shore-line deposit of sandstones attending slow submergence, followed by a deeper water sediment forming slates and shales, but not reaching sufficient depth or attaining the proper conditions to develop extended limestone deposits; in turn followed by a shallowing sea, with more arenaceous accumulations. The latter shallowing probably accompanied, perhaps as an effect of the same cause, the formation of a gentle anticlinal fold, found along the lower portion of the Grand River, and which occurred shortly after the deposition of the No. 5 sandstones, and before the laying down of the next great sedimentary deposit, as will be seen later.

A thin seam of coal occurs in the lower mid-cretaceous slates, a few hundred feet above the quartzitic sandstones of No. 1, at the Hot Springs, indicating that coal-forming conditions existed far below the usual lignite horizon just east of the range. The latter, as shown later, seems to be also found in the park, but very poorly indicated.

DOLERITIC BRECCIA.

Above the Cretaceous No. 5 the next youngest rock is a local occurrence of volcanic doleritic material, consisting partially of subaqueous-arranged material—dolerite, tuff, and breccia—and partially as accompanying lava-flows; in all, reaching a maximum thickness of 800 or 900 feet.

THE LIGNITIC FORMATION OF THE PARK.

Resting upon the latter when it occurs, but elsewhere upon Cretaceous No. 5, and apparently conformable with the latter, except at one point where there is a decided unconformability, is a series of beds which reach a thickness of about 5,500 feet. Not being capped with any beds following them in direct geological sequence, it is impossible to tell how much thicker they may originally have been, erosion having already removed an unknown amount of them. They are composed in part of sandy shales, in places more or less argillaceous and quite soft, spaced rather regularly with more prominent and characteristic hori-

*American Assoc. meeting, Newport, R. I., 1860; also, later, Proc. Am. Assoc., Aug., 1873, p. 185, &c.

zons of coarse sandstones, which are often inclined to grits and fine conglomerates. The texture of the latter is usually open and not firmly compacted, while the material of which they are composed is characteristically the *débris* of the archæan rocks of the mountains, granitic *débris* prevailing. While some of the finer-grained massive beds are somber brown in color, the usual colors are light gray or whitish. Escarpments of the harder gravels, reaching 30 feet in height, separated by shaly slopes of 5 to 10 feet, often make up the hill-sides, while every few hundred feet in altitude a predominance of the more massive gravels has caused the erosion to carve the whole formation into a series of high terrace-like steps, in places well defined, but in others indicated only by changes of steepness in the long, wavy, graceful slopes of the hills. It generally forms a high broken-terraced region. Impressions of deciduous leaves are quite numerous at favorable localities and small isolated patches, and one or two thin seams of carbonaceous material were also observed. No other fossils were observed in these beds. It has been strongly affected by the last great folding accompanying the formation of the Rocky Mountains, portions of it being abruptly upturned, together with the underlying sedimentary rocks. In position and character, therefore, this group of beds appears to be the equivalent of the lignitic group east of the mountains. Here, as there, in view of the as yet disputed age of these beds, whether Cretaceous or Eocene-Tertiary, and to avoid possible error, the non-commital name of lignitic formation will be at present retained. These beds are intersected to their highest points by dikes of handsome light-gray, porphyritic trachite.

LAKE BEDS OF THE MIDDLE PARK.

After the lignitic there is a geological break, the beds next following being of far more recent age. These occur nowhere at the higher elevations, but occupy all the lower basins. In these, and following the streams, they usually form broad, low terraces, often much cut by the lateral streams into isolated pieces or long even-topped tongues running out from the valley sides. Near the borders of these areas these beds often plainly show that their material was derived from the adjacent rock, often being of coarse granitic or schistose *débris*, or of the lignitic sandstones worked over; more frequently they are of finer sands and of characteristic marls of exceedingly white color. They are usually found resting on the archæan rocks, as along the Lower Grand, or on the softer shales of the Cretaceous, which, in former times, as now, afforded the weakest lines for erosion to work most successfully at, and which, therefore, occupy nearly all of the lower areas. Along such lines, then, the streams cutting through these terraced beds, constantly expose beneath them the more or less upturned edges of the Middle Cretaceous beds. They show a thickness of probably not over 300 feet at any one point, though their vertical range seems to reach to or above a thousand feet. A few dips of ten, possibly of fifteen, degrees, were observed in them in the eastern portion of the park. Unfortunately no fossils were found in these beds, leaving a satisfactory determination of their age impossible, though they are undoubtedly very late, or, perhaps, Post-tertiary. They may, following Dr. Hayden, be very appropriately called lake-beds.

GLACIAL.

In the Upper Grand, and at the base of the Blue River Mountains, are extensive glacial moraines. Though no good exposure was observed proving the fact conclusively, yet the manner of their occurrence is such as to indicate that they were, in part, contemporaneous with the lake beds, the upper terraces of the latter apparently covering and mantling around their ends.

Alluvial material occurs here and there adjacent to the streams, and may in places have been taken for lake beds, being probably the same material worked over. Indeed, the alluvium is in places the later product of the same or similar forces which produced the lake beds. With the alluvium should be classed the meadows inclosed by the glacial material.

Basaltic lava covers wide areas, forming some of the highest points, where it usually caps, as a protective covering, the lignitic sandstones, though it has also run down into the lower regions, covering large areas of the lake beds.

Having spoken thus generally of the various rocks composing the Middle Park, their more special characters and distribution will now receive attention, taking up in succession the various areas which compose the park.

THE VALLEY OF THE UPPER GRAND.

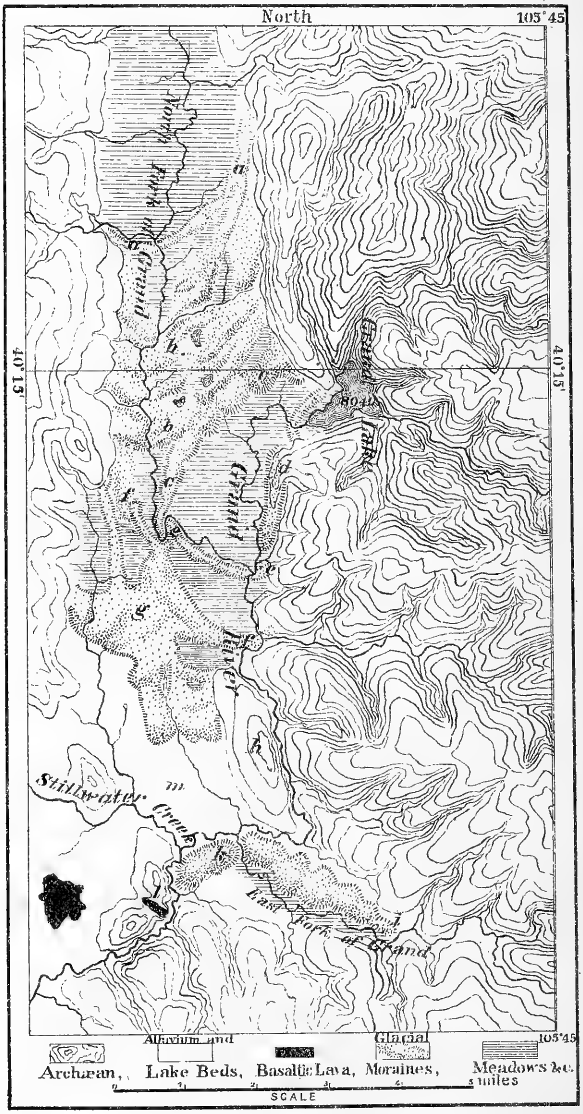
The North Fork of the Grand River occupies a profound valley lying between the southern end of the Medicine-Bow range, upon the west, and the Long's Peak group, of the main range, upon the east. Looking up this great valley from the south, the walls of rock seem to rise in great, abrupt, but rather even, massive slopes to a pretty general mountain level on either hand, the bottom of all the lower portion of the valley being quite flat, and averaging about two miles in width. Within the valley, however, the numerous great gorges coming down from either side, chiefly from the east, so break up the apparent regularity of the sides as seen foreshortened from the south, that the impression is of a maze of rugged mountain spurs and cañons. Those from the west are of lesser magnitude, the Medicine Bow crest being only from three to four miles west of mid-valley. At the north this crest is a sharp and ragged ridge, but southward it becomes comparatively even and rounded in outline, a massive ridge, falling gradually until covered with lake beds near the junction of the East Fork with the Main Grand. The eastern valley side retains its ruggedness all the way to the East Fork. The principal drainage of the latter area is that collecting into Grand Lake, and is by a system of the profoundest mountain cañons.

All this surrounding mountain region is of the archæan rocks, schists, and gneisses. The few dips and strikes that I had opportunity to actually observe, together with the impression obtained from the style of weathering of the rocks, indicated that the valley might be a great synclinal, but this is by no means certain. The apparent appropriate uniformity of form and slope of the valley sides seems hardly a product of erosion, but as if the general surface of the metamorphics had been covered, as at the west, with sedimentary rocks, perhaps the Cretaceous, and as if all had then been folded together to form an anticlinal over the Medicine Bow, a synclinal in the Grand Valley, the latter probably originally determining the course of the drainage, and hence of the greatest erosion which has since removed all of the sediments, but not quite yet destroyed the general impress left by the fold upon the harder underlying rock.

All the main portion of the valley is occupied by a mass of morainal matter, (see Fig. 9.) Below where the upper cañon portions widen

Fig. 9.

SKETCH MAP showing the GLACIAL MORAINES in the Valley of Grand River near Grand Lake, Middle Park.



into the flatter valley, the bottom becomes a swampy, grassy meadow, between one and two miles broad. Some pretending gneissic masses show *roche-moutonée* forms. This meadow has a semicircular border at the south, where it is limited by a not very prominent, but well-defined terminal moraine, *a a*, (see figure.) Below this is a great mass of morainal matter, *b*, with a well-defined southeastern border, *c c*, indicating a medial moraine lying between the glacier which occupied the main valley, and that from the Grand Lake cañons. The northern part of *c*, and the main portions of the mass *b*, are thrown into piles and ridges reaching altitudes probably 300 or 400 feet above the meadows. Its surface is exceedingly uneven, abrupt depressions, perhaps 60 feet in depth, existing here and there with no outlet, while the general tendency of the ridges is across the valley in semicircular forms, marking the stoppages and accumulation of the material from the surface of the slowly-retiring glacier. Several small meadows are scattered in the lower portions of this mass. The tributary cañons of Grand Lake also contain, I am informed by Major Powell, equally strong evidences of glacier occupation, both in their erosion and morainal *débris*. A small terminal incloses the lower end of Grand Lake, while the lake itself, though not well examined, gave the impression of occupying a true rock basin of deep ice erosion. From the west end of the spur just south of the lake an exceedingly well-defined lateral moraine (*d*) commences, and extends southward nearly two miles. Though probably over 800 feet high where it leaves the spur, it falls uniformly and evenly to its end. The southern end of ridge *c* is low but well defined. The North Fork cuts through it in a curious manner, bending back northward to run along the upper side of the terminal moraine, (*e e;*) also a low but well-marked ridge, through the eastern end of which the united streams pass. Below is a meadow, limited likewise on the south by still another but more prominent terminal moraine, (*ff.*) The eastern end of the latter moraine rests against a granite mass, while a small meadow lies below its adjacent portions. The upper end is rather confused with smaller side moraines. The central portion merges almost imperceptibly into the irregular morainal mass, (*g*,) which rises in low rolling hills and indefinite border from the flat terraced, sage-brush valley *m* at the south.

All these morainal masses are covered with a scanty soil and a thick growth of pines. The latter have been blown down in all directions, often in great broad swaths, and as often partially burned, rendering passing directly across the moraines, without resorting to the little open, marshy meadows, all but impossible.

Good exposures of their rocky contents are not numerous. So far as observed the boulders seldom retain well-preserved scratches, much surface disintegration having taken place. Indeed, such is the general rule with all the glaciated rock masses of the Rocky Mountains. The *roche-moutonée* form is frequent, but the schists and granites succumb early to surface disintegration, and there has not been, as at the East, a boulder clay or tuff to preserve them from weathering. It is rather a curious feature that the Grand, instead of passing through the lower portion of the valley occupied by the morainal mass, (*g*,) has cut a cañon through the higher rolling spur of hard archæan rocks, (*h*.)

The East Fork of the Grand commences as a well-defined open gorge at the base of Arapaho Peak, and running about north 25° east for nearly six miles, it gradually swings around to a nearly westward course near its mouth. Throughout this course this valley is exceedingly well defined. The tendency is to a **U** rather than a **V** form, indicating, as well as the usual scoring of the rocks, its glacial origin. The massive and rather uniform rocky slopes rise on the north to the rugged mountain mass of Long's Peak, and are cut by several deep cañons, while on the south they emerge in great curves with the smoother and more plateau-like granite mass lying on that side. From the end of the massive spur, which comes down over this cañon valley between two and three miles from its mouth, commences a great glacial moraine, as indicated at (*i k*) in figure. It is at first several hundred feet high, and presents a most rugged and uneven surface, with great irregular depressions and a tendency to a parallel ridge structure. Enormous boulders, many 20 feet upon a side, are found scattered upon its surface, while here, again, a maze of fallen timber lies around. It is rather singular to see the East Fork cutting a rather abrupt passage through this mass at a point where it rises perhaps nearly a hundred feet above the stream on either side, while to the west the continuation of the main valley on to the Grand is perfectly free from obstructions, the soft surface soil rising but little above the stream. This fact would seem to have its explanation in the explanation of another singular fact, which is, that the main Grand, rather than follow the main open valley west of the granite mass *l*, has cut a rugged cañon through the latter as indicated in the figure. It would seem as if originally it had followed the former course, passing north and west of *l*, while the glacier, reaching to *l*, and being deflected northward by it, had a terminal moraine, which was but the extension of the lateral, the glacier stream having its natural outlet northward through it at some point *k*. Certainly the outlet of the East Fork could never be at *k*, if the original course of the Grand was through *l*, as it is now, while it is inconceivable that the Grand should have selected the hard and higher spur *l*, in which to cut a channel, rather than the low depression occupied by soft sedimentary beds, except influenced by some abnormal cause. The cause that would seem to have deflected the Grand from the main valley to its present course would appear to be the flood of lava which has poured down from the region between Willow and Stillwater Creeks; (see map at head of chapter, Fig. 8.) As will be seen later, many of the hills are capped with remnants of this lava, while at many points it occurs low down, as if occupying former stream beds. These remnants, as shown in the figure (9) prove that this lava stream reached to the granite *l*, and occupied as high a level as it, as indicated by the table-topped hill near by. The small mass of lava on *l* appears to occupy a little cañon, probably that of a stream running from the granite mass on the south across *l*, northwestward to join the old course of the Grand.

Thus dammed off by the flow of lava the accumulating waters rose in a lake, and escaping at the lowest point around the end of the lava, gradually wore out the present channel through the granite. At that time, the waters must have passed through the channel *k*, but there was probably sufficient water present to also wear the outlet between the end of the moraine *k* and the rock *l*, as the lower portion of the cañon through the latter was slowly cut. If this explanation is the true one, and the facts, so far as known, admit of no other, this lava is more recent than the older glacial phenomena. Some of the lava near by seems even still younger than that here shown. A few miles farther down the Grand a small sheet rests on the gentle surface-slopes of lake-beds, apparently so recent that erosion has not yet had time to throw it into prominence by the wearing away of the softer beds on which it rests.

Another point seems explained by the action above described. The small area *m*, lying between the Grand and Stillwater, west of the rolling hill *h*, and south of the morainal mass *g*, is occupied by loose gravel deposits covered with a fine dusty soil, which occur in a flat terrace, rising about 50 or 60 feet above the main stream. Near the center of this area is a low ridge which much more resembles the lake deposits farther down the Grand. No exposure showing the actual relations between this ridge and the lower terraces was observed, but the general impression received was that the former was the older—a hill of erosion, surrounded by the more recent terraces. If so, the latter were probably deposited beneath the waters of the lake formed by the dam of lava, and filled up the previously eroded valley surface.

The Grand, after leaving the small cañon through the granite mass *l*, flows out into a flat terraced basin, where it is joined by Willow Creek and the Frazier River, and which forms a portion of the most interesting geological region of the park, before describing which, however, we will turn to the drainage basin of the Frazier.

THE FRAZIER BASIN.

South of the East Fork of the Grand the westward mountain-slopes, as has been previously mentioned, are far more smoothly contoured and gently molded than north of that stream. These massive slopes fall to the area about the junction of the Frazier and Grand, and form a low northern side to the upper Frazier basin. Southward, the lateral extension of the same slopes, which retain their former characters, descend from the main divide and form the east side of the basin. Sweeping around westward they fall from the Berthoud Pass ridges northward to its southern border. The western border of the basin is more ridge-like, with accompanying hills; is much lower than the east and south sides, but retaining a rather even top.

The James Peak group stand at the southeastern corner of the basin, Mount Byers at its southwestern corner. The natural outlet of this basin is at the northwest corner, where the surrounding granite ridge rises scarcely 300 feet above the river in a broad gentle divide, passing over into the basin of the Grand, and across which the Berthoud, James Peak, and South Boulder trails, after uniting, pass to the Hot Springs.

The Frazier, however, has cut its outlet by a rugged and impassable cañon—about six miles long and several hundred feet deep—through the spur of metamorphic rocks a few miles east of this divide. All of these surrounding mountain-slopes are of the metamorphic crystalline archæan rocks. Their contours seem to indicate a surface of former subaqueous denudation, covered subsequently with sedimentary rocks, which have not so very recently been entirely eroded away, leaving their impress still on the underlying rock surfaces. Indeed, some appearances upon the western side of the basin would seem to indicate that patches of such sedimentary rocks may still remain, though they were not visited.*

Glacial action alone could never have effected such wide-spread uniformity of character.

All the flat lower central portions of this basin, forming an area approximately five miles in diameter, are occupied by sedimentary rocks which have been eroded into distinct though low terraces. The distribution of trees is here quite marked, being confined to the granite slopes, and apparently to above a certain level on the higher terraces,

* Major Powell informs me that he found some small areas of siliceous sandstones, probably Cretaceous No. 1, thus resting on both sides of the western ridge of the Frazier basin.

though these pine-covered areas may, in part, be granite bosses rising above the surrounding beds. All the lower terraces and bottoms are free from timber. Between the terraced filling may still exist remnants of the sedimentary rocks which probably originally filled the basin. The only sedimentary rocks examined, however, were along its northern border. East of where the Frazier River enters its cañon, and along the stream, followed by the Boulder Pass road, there are a few exposures which the stream has cut out of the adjacent terraces. One, about a mile east of the cañon mouth, is between 60 and 80 feet high, and is composed of light-drab sandy beds, weathering white, from four to eighteen inches thick, mostly somewhat indurated; considerable clayey sand, and some lenticular bodies of gravel. Pebbles in the latter are of gneissic and granitic rocks, reaching two inches in diameter. Some of the sand is quite fine, with scattered pebbles, and some layers of grains of chalcedonic or agate-like quartz.

The dip of all is from 5° to 10° to southwest. This branch of the Frazier River lies mostly in these beds, but at a few points near the granites on the north it cuts through little southward-projecting points of the latter which are surrounded by the sediments. The lower river terraces have much sage-brush sprinkled over them. In the northwestern corner of the basin, from two and a half to three miles west of the cañon entrance, the low hill-slopes near the road show some dull, dark, somber, brown-colored sandstones of coarse texture, which dip 8° or 10° to the southwest. They are at first composed mostly of quartz and fieldspar, with some mica, *debris* from the surrounding metamorphic rocks; but farther on small pieces of red and whitish sandstone occur, growing larger as one advances, till frequently one-half to one inch in diameter, and usually brecciated rather than rounded. They are probably derived from the hard sandstones of Cretaceous No. 1, which occur farther on, and show that these beds of the Frazier do not belong to the older sedimentary series of the park, while their general characters indicate that they are very recent, probably the same as the usual lake beds, and derived from the rocks immediately around. The fact that these recent beds incline slightly is interesting.

About three miles from the cañon the road passes from these beds to the smoothed granite region of the low divide, and passes over into another portion of the grand drainage, to which we will now turn.

THE REGION IN THE VICINITY OF THE HOT SPRINGS.

The region that will next attract our attention is shown in the accompanying map, (Fig. 10,) the relations of which to the park in general may be seen by glancing at the general map, (Fig. 8.) A section (A. B) across the same is given on Plate III, section 1, which shows, also, the character of the country lying north of the section.

It is but a mile or two after leaving the sandstones of the Frazier basin, across the low granite divide just spoken of, to where the road enters the lower side of the map. It soon divides the right-hand trail going to Grand Lake, the left-hand road continuing on to the Hot Springs. Following the latter a little past the branching, some of the recent sandstones, similar to those just left, appear upon the granites, followed by a small ridge of a hard white sandstone, dipping at an angle of 55° to the northwest. The exposure is small, and the outcrop was not observed extending toward the hills to the southwest. Following along the exposure over the ridge to the northeast, and in the valley

Fig. 10.

GEOLOGICAL MAP OF THE REGION

in the Neighborhood of the Hot Springs and the Upper Grand; Middle Park.

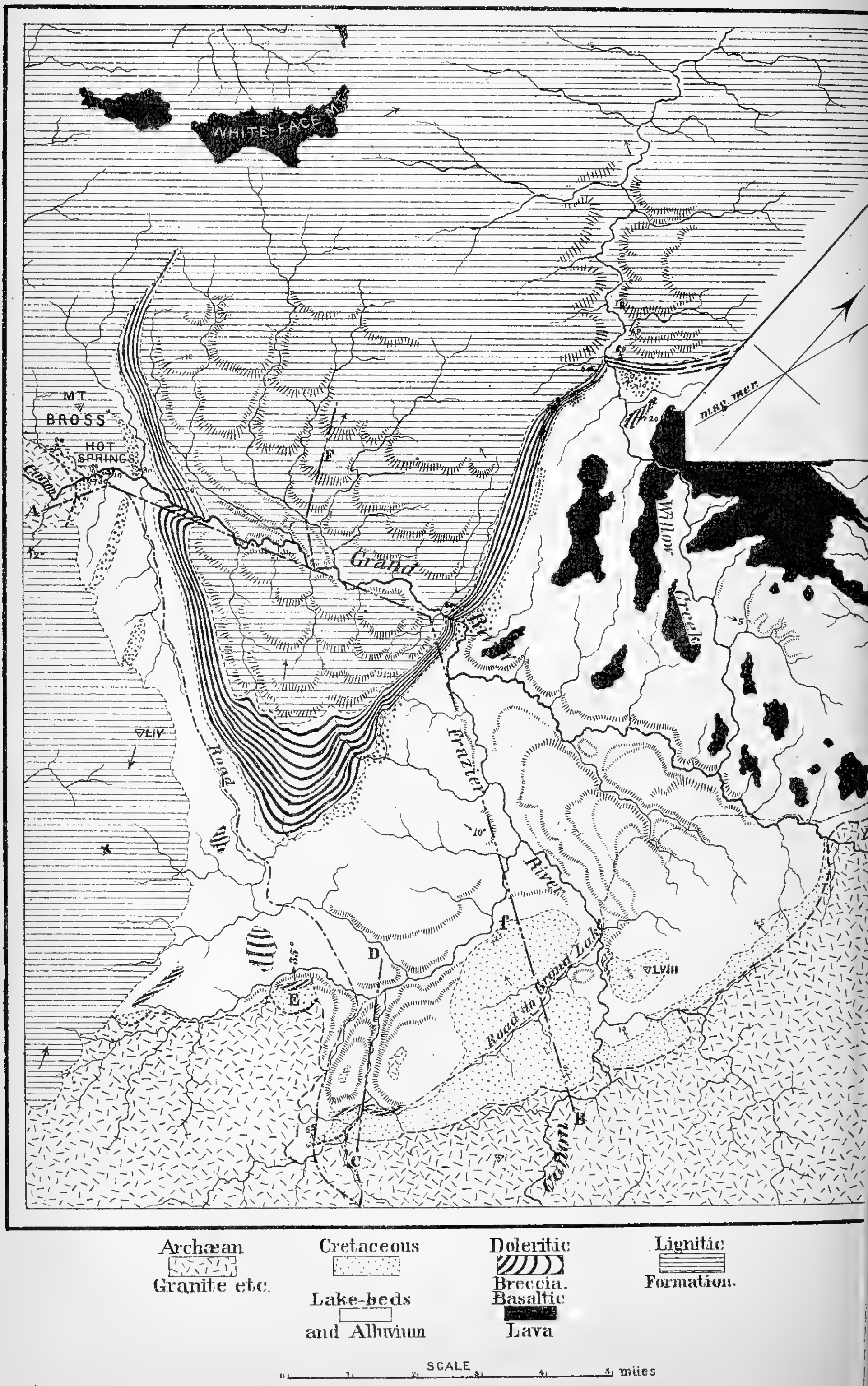
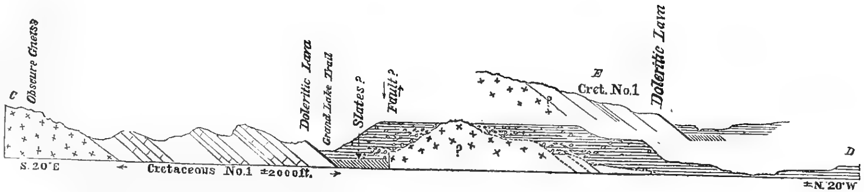


Fig. 11.



Section ten miles southeast of the Hot Springs, near the junction of the Grand Lake and Hot Springs roads, Middle Park.

followed by the Grand Lake road, a better cross-section is exposed along the road as follows:

Section of Cretaceous No. 1, *near junction of Hot Springs and Grand Lake roads, entrance of Middle Park.*

Nature of strata.	Estimated thickness.
Strike about north 20° east, dip about 35° northwest.	*Feet.*
Doleritic lava	15
Covered	150
Sandstone, white and yellow, fine, gritty, siliceous, iron-stained	125
Covered, red soil, *debris* of soft brown sandstone, and near base of purple shale and some limestone	225
Sandstone, massive, white, some cream-colored, red blotches, siliceous, gritty	80
Covered { red soil	50
Covered { soil	150
Covered { *debris* of brown sandstone and fine cherty limestone	100
Ridge; white, fine, gritty, siliceous sandstone, some cream-colored and red	100
Covered, red soil, (red shaly sandstones?)	60
Coarse gray granite, considerable mica, obscure gneissic structure. Strike ± north 35° east, dip 50°–80° southeast.	

This section would indicate a thickness of about a thousand feet for those beds, and affords an example of the greater thickness which I suppose the lower Cretaceous beds occasionally attain. But ten miles to the northwest, at the Hot Springs, a thickness of only about 360 or 400 feet is indicated, but the same general characters are there found as here. The lava forming the top is composed of a dull, dirty gray, fine granular matrix, with numerous black, quite well-formed crystals of augite scattered through the mass. It weathers a dirty brown, with narrow white seams two or three inches apart, parallel with the bedding, and speckled with black augite crystals, as well as by both rusty and white-colored spots. It is probably a dike occupying the line of junction between the hard sandstones and the softer Cretaceous shales, which probably occur immediately above, though they are not here exposed. At one or two other points in the park the weak point between the sandstones of No. 1 and shales of No. 2 have afforded a very natural outlet for eruptive matter, and such is probably the case here. After passing across this section the Grand Lake road leaves the stream, and, turning to the right along the outcrop, passes up a small valley, having the little ridge of dolerite lava on the right. From the lava ridge, and on either side of the main stream, is a steep slope rising to the summit of a terrace. The channel of the stream passes into this, cutting a sharp V-shaped gorge, the east side of which rises some 50 feet higher than the general level of the west side. The material of this terrace thus cut through by the stream is coarse angular *débris*, of highly micaceous schistose gneiss, of the dirty-red and black-banded variety, and some granite. On the summit some large masses indicate that these metamorphic rocks are in place. These facts would indicate that a fault had been passed; one which had thrown the outcrop of sandstone just described downward on the southeast side, bringing the granite upward on the northwest side, as in the accompanying section, Fig. 11, the position of which is shown by the line C D, Fig. 10.

Passing on northwest, the coarse *débris* terrace is found to fall in three pretty-well defined steps of about 90, 140, and 80 feet respectively, to a stream, on the opposite side of which is a low-terraced treeless park, about three miles broad, rising in rounded slopes to a ridge capped with a broken pallisade beyond.

On the left (southwest) the terraces abut against and run out from a hill which looks off in the same valley, and on its northern sides lie the same sandstones, dipping northwestward at an agle of 35° with the bed of dolerite lava on their top just as before. See section E, Fig. 10 and Fig. 11. Low terraces abut against the lava and run out occupying the valley basin beneath which, however, as we will see later, lie the Cretaceous shales. The hill and region lying south of E was not personally examined, and, while the sandstones may mantle over it, it is apparently of granitic rocks as indicated on the map. On the right, also, and a few miles in an opposite direction to E, similar beds may be seen likewise dipping westward beneath the main valley.

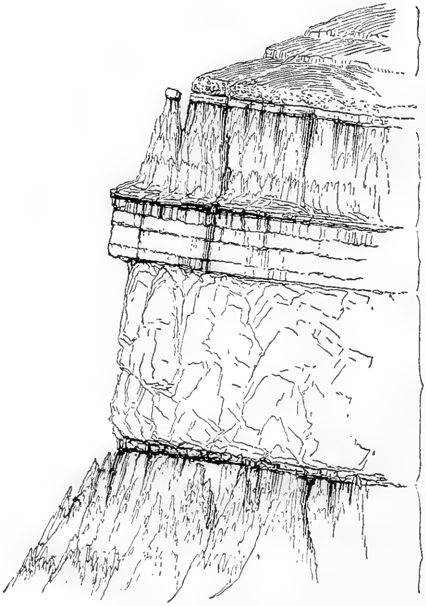
Returning to the Grand Lake road and following it northward, it is found to pass over into the head of another valley leading down to near the mouth of the Frazier Cañon. On the right (east) is the ridge formed by the edges of the sandstones resting on granite below, and dipping down underneath the trail. Near the Frazier these edges overhang the cañon and form the top of its western wall. Beneath the valley through which the road passes, however, the beds are flexed, forming a synclinal of the valley and an anticlinal of the ridge just west of it, (see section 1, or A B,) the western slope of which, just as at E, dipping westward beneath the terraced valley. The mouth of the Frazier Cañon is through the ridge of upturned sandstones, after which the valley opens somewhat, with terraced lake-beds before entering the main valley. The exposure upon the west side of the cañon gave the following section (at B, section 1, Plate III.)

Section of No. 1 Cretaceous at the mouth of the Frazier Cañon.

Nature of strata.	Thickness.
	Feet.
Covered hill-slope, inclining west, facing east, dipping west into hill 15°, very compact, hard siliceous sandstone, mostly white, gritty	40
Covered *debris* of brown sandstone, and compact blue-gray limestone	80
Sandstones, reddish, thin-bedded, some shales	25
Compact gray-blue limestone, somewhat cherty, blotched	2
Sandstones, in 2 to 5 feet beds, white to yellow pink shales	30
Covered, *débris* of snuff-colored and rusty brown sandstone	85
Gray, rather granular granite, with but little mica, containing very large scattered crystal of feldspar to river.	

These beds are probably liable to considerable local changes, both in characters and thicknesses. They are probably the same as a portion of the lower beds of the preceding section, the higher ones having been here swept away by erosion, and being found west. Crossing the Frazier northward, station LVIII is found upon a hill of the siliceous sandstones. Its surface has a gentle eastward slope, the sandstones dipping also east, but curving up again they are found lying as usual on the granites, thus forming a little synclinal. The upturned edges of these sandstones are leveled off in a peculiar way, being evened off with the granites behind them. (See section near B.) The west side of

Fig. 12.



Lake Beds, four miles southeast of junction of Frazier and Grand Rivers. Dip 10° east.—W. H. Holmes.

hill LVIII is abrupt, and shows in its upper portions the edges of the sandstones, with, at the base, some granite and gneiss beneath them, and again, just west, but lying low in the stream, some of apparently the same sandstones, but gently inclining west. In other words, a fault passes at the west base of LVIII, in which the east side has been elevated, and which is probably the equivalent of the anticlinal just south, and the fault still farther south, near the Hot Spring road.

The terraces mantle about the west and north base of LVIII, concealing its sandstones in these directions, but the main ridge of sandstones resting on the granites continues on northward to the Grand River. The ridge is not prominent—the sandstones dipping steeper than farther south, reaching 45°—while from it the nearly horizontal lake-beds, which reach high upon it, sweep out between the Grand and Frazier Rivers in many long, low terraces. The ridge of Cretaceous sandstones is lost beneath these lake-beds near the Grand, where the latter issues from its short cañon through the granite mass below where the East Fork joins the main stream (*l*) of the map of the moraines of the Upper Grand. The sandstone ridge does not appear lying on this granite, the lake beds surrounding it instead. At the north, and just without the map on the right, are the valley of the Upper Grand and the south end of the Medicine Bow ridge. Near Willow Creek and the Grand the lake-beds predominate also. The north side of the Grand is lined pretty continually with two low terraces of white lake-beds lying from a quarter to a half mile from the stream, the country rising from them in long slopes, and rounded hills lying between it and Willow Creek. A fine, dirty, dark, basaltic lava lies at one or two points on the upper terrace, and appears also to cap the hills, while much of the terraces are covered with lava fragments and jaspery pebbles. The small patches of lava near the mouth of Willow Creek occur but little above the stream, and seem to cap low surfaces, dipping gently to the northeast. East of these the larger area near the edge of the map is a mesa, or table-hill, capped with lava. (See section.)

Ascending Willow Creek, the beds of the valley are apparently of the usual lake-beds. Where the dip of 5° east is indicated there occurs, among light-gray sandstones, white marls, and other beds, a more indurated bed of semi-compacted gravel, in the composition of which pebbles of lava, often scoriaceous and up to four inches in diameter, enter largely, as well as metamorphic rocks. While considerable false bedding occurs, the general dip seems to be 5° or 10° to the east, a little north. Just above, in some similar light-gray crumbling sandstones, a dip of 10°–15° northeast was observed. While the hills seem lava-topped, much basaltic lava here occurs in the valley also. At first a tongue of a dark, decomposing irregular lava touches the river from the north, but above the river is lined more continuously on the north side with a very irregular, red, brown, and black lava rock, often having the appearance of a consolidated mud. On the south, the rounded hills rise more abruptly, but still seem lava-capped. A little farther up the lava occupies both banks, and appears as if coming from an extensive flow on the north and east, the eastern tongues of which cap ridges running out toward Stillwater Creek. At the north rise hills adjacent to the Medicine Bow ridge, which show somewhat in the section, but which will be referred to later.

We have seen that between the Frazier and Grand are the long, low terraces, and that they also occupy most of the area drained by the main tributary of the Lower Frazier, and that near the metamorphic rock, at one or two points, they are composed of coarse *débris*, with some finer uncompacted sediments. Farther out they are of soft, crumbling, white marls, with surfaces usually sprinkled with boulders, often quite large pieces of metamorphic rocks, as remnants of a bed which had existed above the present surfaces, and had been eroded away. It was in this neighborhood that the following section, Fig. 12, was observed and illustrated by Mr. Holmes, when accompanying Dr. Hayden's party, and shows well the characteristic weathering of these soft beds when exposed, as sometimes happens, in a cliff. Here also is an inclination in these recent beds of 10° to the east. Thus, a greater part of the eastern corner of the map is of lake-beds, in part covered with basaltic lava, and at the east abutting against an outcropping fold and ridge of Cretaceous sandstones, which dip west beneath them, and rest on metamorphic rocks. They form a flat terraced and treeless valley, but at the north and west rise in higher bulky hills. Just west of the junction of the Frazier with the Grand rises an abrupt, sharp, well-defined ridge, several hundred feet high, which is broken through by the river in a narrow gate-way. Just outside of this gate-way, at the north side of the stream, and directly beneath the ridge, there are exposed by the ravines cutting through the terraced lake-beds, a thickness of about 300 feet of brown concretionary, friable sandstones—the characteristic features of Cretaceous No. 5—and which yielded an *Inoceramus* and joints of *Baculites*. These beds dip westward beneath the ridge at an angle of 25°. The gate-way exposes the larger ridge to be composed of a rough, sedimentary aggregate of volcanic material; a series of conglomerates, breccias, sands, and irregular material, of which the most distinct rock is of a doleritic character, consisting of a gray granular base, containing occasional small crystals of a trichinic feldspar, and more numerous, larger, and well-defined crystals of augite. This more compact portion is a similar rock to the lava dike resting in the siliceous sandstones near the entrance of the park.

This volcanic detrital series attains an estimated thickness of from 800 to 900 feet; the lower part being a massive accumulation, and not showing distinct stratification, the upper part being well bedded, and often of fine materials. These strike nearly north and south, and dip westward at an angle of 60°, though the higher portion of the ridge on the south shows an abrupt bend, dipping but 25° or 30° west, (see section.)

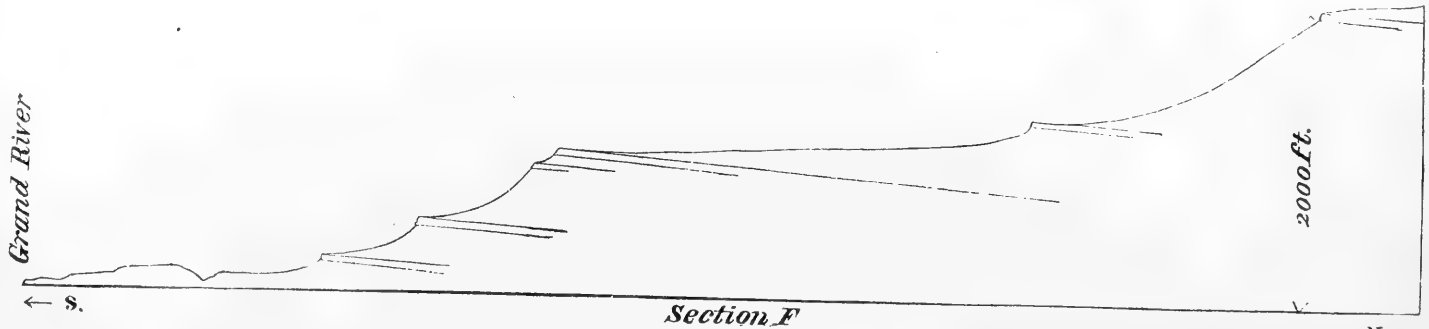
Passing down-stream through this gate-way, the valley again opens out, but its character changes entirely. The beds that lie above the doleritic breccia and sands, though likewise abruptly turned up and dipping west immediately adjacent to them, suddenly become nearly horizontal, with a gentle northern dip, and form, all along the north side of the Grand, a series of regular and high terraces running in long tongues out toward the river.

There are two principal terraces, the lower one rising nearly a thousand feet, and attaining this level between one and two miles back from the river. Harder beds on its face break up the front slope of this terrace, tending to mold its face into minor terraces two or three hundred feet high.

The second terrace stands about a half mile back from the edge of the lower one, and rises in a more even slope, unbroken by intermediate beds, to an altitude of about a thousand feet above it. The accompanying section, Fig. 13, gives an idea of the profile of these well-marked terraces, which attract attention even from Long's Peak far to the east.

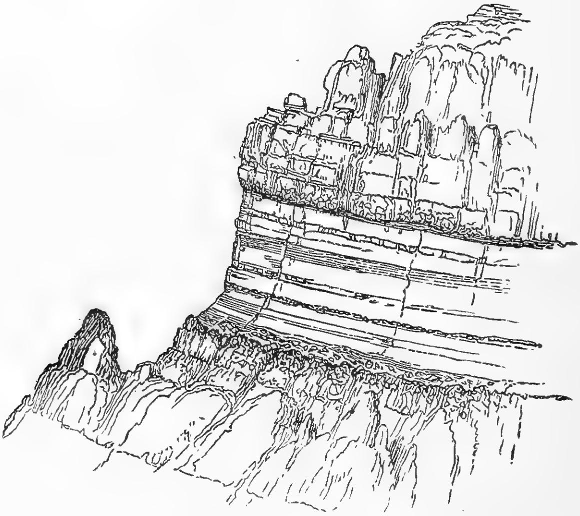
Back a few miles rises still another terrace, estimated at about half the height of the last one, or about 500 feet. Estimating that there were at this point about 100 feet of beds beneath the river, and be-

Fig. 13.



Profile of Lignitic Terraces on north side of Grand River four miles above the Hot Springs, Middle Park. [See sec. F. Fig. 10.]

Fig. 14.



Volcanic Breccia Bed, one-half mile north of Grand River, above the Hot Springs, Middle Park.—W. H. Holmes.

tween it and the volcanic breccia, there occurs here a thickness of about 2,700 feet of sedimentary rocks lying above the breccia bed. The ravines from the north cut deep into these terraces, breaking them up into promontories with squarish fortification-like fronts facing the river. Upon the south side of the river these features are far less defined, and here only the lower and softer beds occur, while the northward dip increases. The valley, after passing the breccia bed, is quite open, the river being lined with much beautiful bottom-land. Below the gate-way some of the lava appeared to outcrop low down near the river, but its relations were not examined.

These terraced beds are of the characteristic lignitic group, and are very different lithologically from the undoubted Cretaceous beds lying below the breccia. Nearly all the exposures here show them to be sandstones, the more prominent ones, or those which give the terrace-form to the eroded beds, being mostly grits, quite coarse, often becoming conglomerate, not very firmly cemented, and composed almost wholly of granitic and metamorphic *débris*, (except that the mica is naturally absent,) while feldspar crystals, sometimes retaining much of their form, occur. The color is mostly somber dark brown, though some are quite white. Some finer and more compact beds occur, with occasional fossil leaves.

In descending the Grand, the terraced beds on either hand are found to become slightly inclined to the northeast, amounting perhaps to about 10°, the river thus passing down through the lower beds as before it passed up through these, until at about four miles in a straight line from the upper gate-way, another and somewhat similar passage is found by which the river again breaks through a ridge of precisely the same material as before. It is, in fact, the same bed again appearing to view from beneath the same lignitic sandstones, the strike being about northwest and southeast, but the dip about 15° to the *northeast*, the bed therefore being folded into a synclinal form, the east side being bent downward more abruptly than the western side. As before much of this series is massive, or wholly indefinitely bedded, and some compact lava occurs, as if of distinct lava-flows. The latter seems to be doleritic, crystals of augite being quite frequent, though some is more basaltic, being fine, and quite homogeneous. Most, however, is of a distinct conglomerate and breccia, some very coarse, of pebbles like the accompanying lava, many scoriaceous, while much is of fine material, finely and evenly bedded. Their total thickness was estimated at about 800 feet at this point. The accompanying sketch, Fig. 14, of an exposure about half a mile north of this gate-way was made by Mr. Holmes, and shows the distinct bedded nature of this volcanic ash, &c.

THE NONCONFORMITY AT THE HOT SPRINGS, MIDDLE PARK.

Passing through the short break by which the stream cuts through this ridge, the western edges of its gently eastward-dipping beds are found extending northwest and southeast as a continuous line of black palisades which look down upon valleys tributary on either side of the Grand, that at the south being wider and flatter than the one from the north.

Regarding for a moment the section found immediately along the Grand, (see Plate III, section 1,) there appears above the alluvium on the north side of the stream, and a little west of, and nearly parallel to, the breccia ridge, a hog-back like ridge of sandstones which dip at an angle of 25° or 30° northeast below the breccia. Some baculites were found in the sandstones which are undoubtedly the equivalents of the beds that bear similar fossils and lie below the breccia east of the upper gate-way, and near the junction of the Grand and Frazier. It is Cretaceous No. 5. This ridge extends a mile or more from the river, gradually flattening and bending westward. Following down the stream, nothing but river alluvium is found for nearly a mile, when, along its southern bank beneath the alluvium, there are exposed some 800 feet of black clay, shales, and slates, at first dipping up-stream only 20°, but increasing to 40° farther down. After passing these slates the river breaks through another ridge, but this time of the quartzite and siliceous conglomerates rising out from beneath the shales, and, like them, dipping 30° up-stream. Behind the first ridge some small longitudinal valleys, with minor ridges of quartzite and siliceous conglomerates with dip lessening to 20° occur, while from 600 to 700 feet below, where the quartzite hog-back is first met, the river passes into a cañon cut in a smooth-topped mass of reddish granitic gneiss, thus giving an actual thickness for the quartzite series of about 360 feet. These beds are the Cretaceous No. 1, the shales above being No. 2, while directly on the line between the two issue the well-known Hot Sulphur Springs of the Middle Park.

From the granite, upon the eastern edge of the map, to the granite below the Hot Springs upon the western edge, the line of the Grand River passes, therefore, directly across, at least so far as the granites, the Cretaceous, and the volcanic breccia bed are concerned, a synclinal fold, the eastern side of which has some minor flexures, (see section.) Not so the lignitic beds, however. Immediately above the Hot Springs, Mount Bross rises abruptly for over 1,500 feet. It is composed throughout of the characteristic lignitic beds, mainly coarse grits and sandstones, yellow, gray, and white, with laminated arenaceous shales, which contain many fossil leaves, barely, if any, disturbed from a horizontal position. Though direct contact between these and the Cretaceous in the river at their base was not observed, the position of the mountain is such that its beds must rest unconformably upon the upturned and eroded edges of the Cretaceous sandstones and shales below. As may be seen in the section, the tops of the great terraces above the lower gate-way of the Grand sweep in long slopes up to White Face Mountain, which is also composed of the lignitic beds, slightly inclined and capped with recent basaltic lavas, which will be spoken of later. The southern face of the mountain is steep, and beneath it the northwest extremity of the breccia ridge disappears. Around the latter appear to sweep the lignitic beds, and to connect directly by a high ridge the west spur of White Face with Mount Bross, throughout which ridge the lignitic strata appear nearly, if not quite, horizontal. The western end of the hog-back like ridge of No. 5 sandstone, about a mile above the Hot Springs, likewise seems to disappear beneath the eastern side of Mount Bross, apparently surrounded by its horizontal beds, as is the end of the breccia ridge by the similar beds of the White Face mass. Mount Bross itself shows an indistinct terrace form, though not well pronounced, and its lower terraces in the west run out and appear to quite cover the quartzites of No. 1, if not to reach to and rest directly upon the granites beyond.

These facts clearly show that here was a local folding of the rocks which occurred *before* the lignitic formation commenced to be laid down, and probably close upon the completion of the deposit of the friable and concretionary sandstones which have been designated as No. 5. Closely connected with this folding, and probably an effect of the same cause, was the eruption of the material which forms the breccia-bed.

Fig. 15.

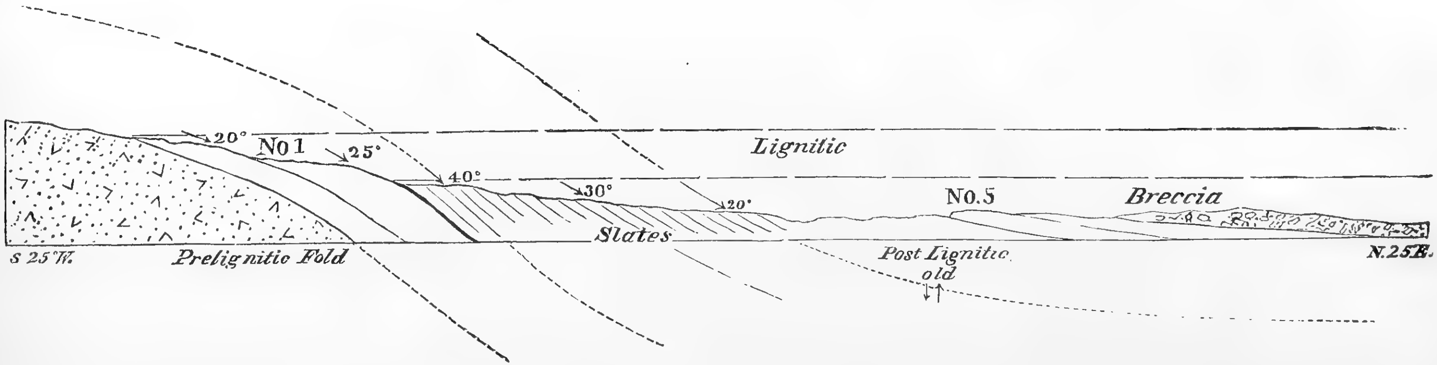


Diagram section at the Hot Springs, Middle Park, to show the probable section after the erosion of the Hot Springs fold and before and during the deposition of the Lignitic Beds.

As the Hot Spring fold gradually rose, the edges of the Cretaceous and of the breccia must have been eroded back to where the latter was nearly horizontal, before the lignitic beds were deposited upon their edges. This state of things is shown in the following diagram, Fig. 15, in the western end of which, near the springs, the dips are as they now exist, indicating the flexure to be as shown by the dotted lines:

Since the Eocene beds in and on the west side of the breccia synclinal are inclined eastward with the breccia slightly, some movement must also have taken place since their deposition. This probably occurred at the same time that the *east* side of the synclinal was upturned, which obviously took place after the lignitic period, for upon this side the lignitic beds are everywhere upturned steeply with the breccia and Cretaceous below. This was at the great mountain-forming period, when the greatest recent folding of the Rockies occurred. It was at this time, probably, that the rocks of No. 5, as shown in the hog-back ridge above the Hot Springs, were inclined from a flatter dip to their present dip of 25° or 30°, while this later fold seems to be also indicated by a very gentle anticlinal appearance beneath White Face Mountain.

Let us turn to the evidence of this unconformability between the Cretaceous and lignitic south of the Grand River. The Grand flows close to the southeast base of Mount Bross. On the south side of the river there is no corresponding eminence, the tributary from that side of the stream occupying a rather flat and open valley. The edges of the breccia ridge line this valley on the northeast, and following them along they are found to swing eastward and then northward, joining the southward extension of the upper breccia ridge of the Grand. In other words, the breccia outcrop is continuous throughout, showing the fold to be a synclinal, with its axis dipping northwest, thus exposing the edges of the bed in the form of a great spoon, with the point directed southeastward, and filled with the lignitic beds in terrace form, the eastern side being bent up much steeper than the western one. The map shows this clearly, while it is far better presented pictorially in the accompanying sketch, Fig. 16, made by Mr. Holmes from points upon Mount Bross. The terraces and breccia palisades, with the many picturesque accessories of the region, as seen from this point, form a very interesting as well as beautiful view.

Thus the lignitic beds do not lap over and cover the edges of the breccia south of the river as they do between Mount Bross and White Face south of it. South of the valley, and opposed to the breccia palisades, however, the lignitic again occurs, the edges of the nearly horizontal beds appearing on the rather steep slopes leading up to station LIV. From this point the spurs of the LIV ridge extend westward toward the granite cañon below the Hot Springs, showing very indistinct terrace-forms, but sufficient to indicate a very nearly horizontal bedding throughout. In the valley, at their northern base, and southeast of the springs, however, are two or three ridges of cretaceous sandstones outcropping from the otherwise soil-covered valley. These dip eastward toward the breccia ridge, and trend toward the lignitic mass on the south in such a way, and approach so near to it, that, though no direct contact was seen, they must pass unconformably beneath it, (see sketch.) Two or three miles west of these ridges, and nearly a mile west of where the quartzites of No. 1 would appear to pass the lignitic beds, and but little south of the cañon, the western extension of the LIV mass shows the characteristic coarse brown sandstones of the lignitic in a precipice two or three hundred feet high, dipping 10° or 12° to the south. These sandstones must here rest directly on the granite.

What appeared to indicate unconformability occurred at one other point. Leaving the Hot Springs and following the road southeastward, we pass over a gentle saddle, having the breccia palisades on the left, and the lignitic rising to LIV on the right, and proceed on to where the road first enters the portion of the park that we have been considering. Standing upon the outcropping ridge of Cretaceous quartzites, E, before described, and looking southwestward, there lies on the left a hilly region, apparently of the metamorphic rocks, and upon the right the flattish valley occupied mainly by terraced lake-beds. Across the line of vision extends the ridge on the northern end of which station LIV stands. From the station the top of the ridge lowers very slightly in going south in a long convex curve, rising in about six miles to a somewhat higher point. The whole east face of this ridge is steep, and shows the edges of the lignitic beds which compose it, and which dip, like the top, very gently south at the north end and north at the south end.

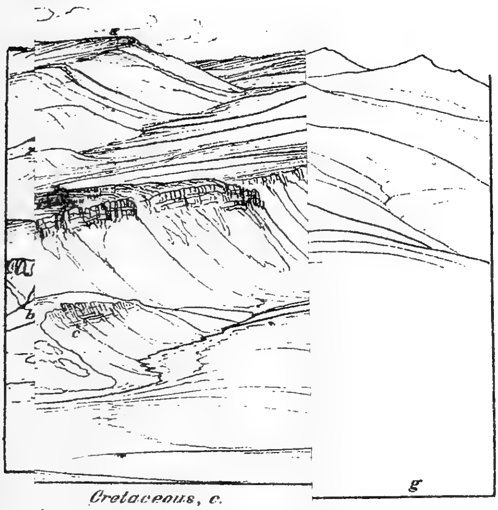
At the small notch which ends this part of the ridge at the south, the contour of the ridge changes, and all the rest of the way on up to Mount Byers, of which it is a continuation and spur, it appears to be of the metamorphic rocks. In the line of vision, however, at the base of this ridge, and near where the lignitic appears to rest on the metamorphic, is a small ridge like the ridge E, and apparently of the same rock outcropped in the same manner. If so, the Cretaceous quartzite would here also pass unconformably beneath the but slightly-disturbed lignitic beds. I have already expressed the uncertainty of the nature of the hills lying southeast of the point last mentioned and E, and bordering the west side of the Frazier basin. Some ridges here are not decidedly of metamorphic outline, but may contain patches of the Cretaceous quartzites with which, as before remarked, the contour of the spurs would indicate that they were once all covered.

In the low region near the point of the breccia "spoon," and near E, are a few small hills or ridges of doleritic lava, like that composing the breccia bed. They appear irregular in their mode of occurrence, not bedded, but more like dikes. Precisely the same lava has been mentioned as occurring on the summit of the Cretaceous quartzites in sections C, D, and E. It would appear as if these were quite likely the points of outlet for the material which composes the breccia bed; that above them at the then surface of the country were actual rents, possibly volcanoes, from which issued the lava and ash and breccia which now lie between the Cretaceous and lignitic beds. If so, these rents have been most completely swept away by erosion, part of which quite probably taking place immediately after the deposition of the main portion of the bed, and before covered with the lignitic beds, for some of the lower lignitic beds in the breccia "spoon" contain volcanic *débris* along with their usual metamorphic constituents. Moreover, the breccia thins in going northward, the thickness where it crosses Willow Creek being less than where it crosses the Grand.

WILLIAMS RIVER VALLEY.

From the western side of the lignitic portion of the LIV ridge, its indistinctly-terraced spurs appear to break off indefinitely into the valley of Williams River, but whether the beds dip gently down beneath the lake-beds, which occupy all the lower parts of this valley, was not ascertained.

The Grand, after cutting an irregular cañon through the flat-surfaced granite mass below the Hot Springs, enters this lake-bed region about



Cretaceous, c.

t. Bross, Middle Park.

enclosed Lignitic Beds, e

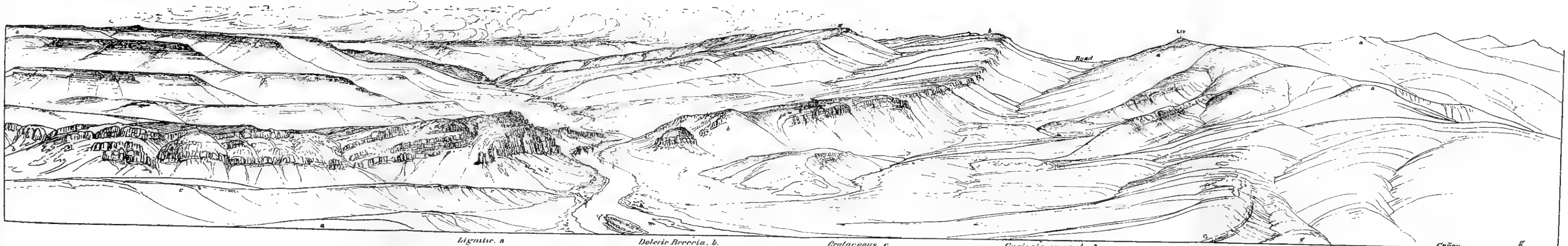


Fig. 16.

View east up Grand River from Mt Bross, Middle Park.
Showing the Breccia basin and enclosed Lignitic Beds, etc

four miles below the Springs. These extend in broad terraced surfaces far up the Williams River Valley, forming all the flat lower and treeless portion of the valley. The southern and eastern borders of the valley appear to be wholly of metamorphic rocks, which rise in massive spurs and slopes to the Mount Byers ridge; and though the upper cañons of this drainage cut deeply into these rocks, a uniformity of contour is pretty well preserved among the great spurs. Though not examined directly, some appearances on the eastern border of this valley seem to indicate the presence of the lower Cretaceous beds resting on the archæan rocks. The western side of the valley is of the lignitic beds which compose the Williams River Mountains, and which dip gently northeastward and probably beneath the lake-beds of mid-valley. At the south a great north and south fault occurs, in which the west side has dropped several thousand feet, leaving the metamorphics on the east and the lignitic on the west. The fault probably dies out in coming north. It will be referred to more in detail when speaking of the geology of the Blue River Valley. The details of the Williams River Valley were not studied.

THE NORTHERN LIGNITIC AREA.

The lignitic beds which have been described as occupying the "breccia basin" above the Hot Springs, and as lying unconformably upon its western arm as well as upon the Cretaceous below in the nearly horizontal beds of Mount Bross, spread out in their northern extension, and form the greatest continuous area occupied by any one geological formation expressed upon the map, except that covered by the archæan rocks. Throughout this area, except along its eastern edge, the rocks are but very slightly disturbed, their inclination being generally less than ten degrees and being in various directions, though mostly northward.

Though the region as a whole is one of elevation, its surface is uneven and rises in four principal masses, which stand high above the intermediate country. This unevenness is due wholly to the erosion having eaten farther down into the mass of nearly horizontal beds in certain areas than in others, and this erosion has been thus directed along these channels by the intrusion of eruptive rocks rather than by more profound structural causes, as folding, &c. The southernmost and lowest of these four elevated points is the White Face and Coral Peak mass, lying a few miles north of the Hot Springs, which has withstood erosion better than the surrounding country, and hence retained its elevation in virtue of the protective cap of hard basaltic lava which here covers the softer lignitic sandstones. The divide between the middle and north parks is also naturally elevated, but it attains special height at two points: one, Park View Peak, which, though higher than any of the others, is composed of a smaller mass, and hence has more abrupt slopes; and another, the great mesa-like mountain mass lying west of the Park View, and between the head-waters of the Troublesome and the Muddy. This latter elevation is due to a great capping flood of basaltic lavas covering the lignitic, while Park View and the divide adjacent, though having no lava-cap, is intersected by great dikes of porphyritic trachyte, which give to it its sharpness as compared with the other and lava-capped masses. The fourth elevated mass of lignitic strata is the high and exceedingly even-topped ridge which is almost completely surrounded by Willow Creek and its principal eastern branches. Though unvisited, this ridge appeared to be caused less by the presence of eruptive rock than by the fact that the drainage, and hence the erosion, had been directed away from it because of its being somewhat upturned against the Medicine Bow ridge of metamorphic rock lying just east of it.

From these four masses the country descends in slopes, which are broken up into innumerable small ridges, to the main drainage of Willow and Troublesome Creeks. There is a tendency throughout to a terrace form, but nowhere is it so pronounced as in the breccia "spoon" above the Hot Springs. Just north of the White Face group, this is partially due to the gentle northward dip of the beds, the inclination of the surface being in the same direction, while the northern part of the region is in the upper portion of the lignitic series, where there is less difference in the hardness of the beds, and hence less opportunity for the erosion to create terrace forms. The tendency still exists, however, the form of Park View being very graceful, the steeper slopes running out in flattish spurs to become rather abruptly steep again, but not attaining escarped edges. The valleys of the Willow and Troublesome, therefore, show forms characteristic of the geology of this lignitic region, and are very different from the forms of valleys elsewhere in the district. Nowhere in the lignitic area are the streams bordered by low, flat, terraced banks like the lake-beds adjacent to portions of the Williams River and the Grand, nor do they flow in sharp-cut, rugged cañons, as in archæan areas. Instead, a bottom usually but a few times wider than the water-course accompanies the streams, often marshy from the presence of beaver-dams, but not terraced, from which steep slopes rise on either hand for several hundreds of feet in escarpments which show the edges of the harder sandstones, with lesser slopes of softer beds between, and finally merging by curves, rather than abruptly, into a pretty general terrace-like level, rising on and on, perhaps, with other indistinct terrace steps to the higher masses beyond. In the Eastern or Willow Creek ridge these slopes run quite evenly to the top. In the White Face mass the last slopes up to the lava are abrupt and lined with some palisades of lava. The slopes up Park View are steep but graceful, while the western mass is surrounded by great palisades of black lava, white volcanic tuffs, and conglomerates eroded into pinnacled forms, and looking down into the upper cañons of the Troublesome. The southern border of this great lignitic mass as it occurs near the Grand River has been already described.

In ascending Willow Creek from its junction with the Grand, and after passing through the rounded hills of lake-beds, most of which dip gently eastward, and the accompanying basaltic lava, as before described, there is found crossing the stream about eight miles from its mouth the same ridge of dolerite breccia that crosses the Grand at its upper gate-way. About half a mile before reaching the principal ridge, however, an outcrop of similar material (breccia, &c.) is found on the east side of the stream, dipping 20° to the northeast, and just beyond and between the latter and the main continuous breccia ridge, which dips 60° to the northwest, are several outcrops; also, on the east side of the stream, of Cretaceous No. 5, here containing many fine cretaceous fossils. The upper outcrops near the main ridge dip 20° northwest, but following along them northeastward, they swing more and more east, dipping north 10°, and appear as if they swung around to become conformable beneath the lower occurrence of the breccia. The dips are given in the Hot Springs map, (Figure 10,) and would seem to indicate a small local anticlinal, with the axis dipping north. These beds were not directly traced farther northward along their outcrop. The main breccia ridge, however, after crossing Willow Creek, appears to pass along the eastern base of the high, even-topped Willow Creek lignitic ridge. The line of junction of the sedimentary rocks of this ridge and of those beneath it, with the metamorphic rocks of the Medicine Bow ridge, must lie along the valley between the two ridges. Unfortunately this was not examined.

The facts presented near the Frazier and Grand Rivers, the apparent gentle westward dip of the Willow Creek ridge, and the smoothed appearance of the west slopes of the Medicine Bow ridge, would all seem to point to the fact that all along between the two ridges the Cretaceous underlying the lignitic, together with the breccia between the two, are abruptly turned up against the Medicine Bow ridge, dipping steeply westward away from it. From Park View appearances seemed to indicate such upturned ridges of rock coming out from behind the north end of the Willow Creek ridge, lying along the base of the Medicine Bow ridge, and passing on north into the North Park. The narrowness of the valley between the two ridges, as well as the apparently slight western inclination of the lignitic of Willow Creek ridge, however, may indicate that a great fault lies between the two ridges, separating the archæan on the east from the Cretaceous and lignitic formations in the west, the down-throw being upon the west side. Such a structure is by no means improbable, as the tendency of all the folds throughout this region is to an abrupt western down-throw, which often passes into a fault.

Where Willow Creek breaks through the doleritic breccia-bed the latter forms a well-defined ridge a few hundred feet high, striking a little east of north, with irregular curving, and dipping west about 60°. It is here only about 500 feet thick, and considering its greater thickness near the Grand, it is probably thinning in going northward. Passing up the Willow through the gap formed in the ridge by the stream, a small, sharp valley is found on either hand behind the ridge, with some exposures of soft brown sandstones, mostly shaly, dipping 60° west. A thousand feet beyond, a ridge parallel with the breccia ridge is passed, which is composed of coarser and harder brown sandstone, mostly of granitic material, like the lignitic terraces of the Grand, dipping 50° westward. Two or three hundred feet farther on a smaller ridge shows a dip of about 40°, and but little over half a mile above the breccia ridge, the dip is reduced to five or ten degrees, or even less. Here the dip is more across the river to the north than up it, the valley being a partial monoclinal, though the dip is very gentle. The terraces near the stream are somewhat marked, but best so on its northeast side. The first slope is between four and five hundred feet high, quite abrupt, in escarpments of coarse gray sandstones, some rather finely and compactly banded, and conglomerates, all of metamophic *débris*, sometimes 30 feet abrupt, with slopes of 5 to 10 feet of softer shaly beds. Some exceedingly fine, compact, dark-blue argillaceous bands occur, carrying small black spots of carbonaceous material. Dips of 5° to 10° or 12° generally occur, mostly to the north, the observer constantly rising through the formation in going up the stream. At a point about southeast by east of Park View, however, a dip of about 10° to the south occurs along the stream for a half mile, ending at the north in a dip of about 30° to the south, till the up-throw of the beds on the northern side is perhaps 150 feet, when the gentle northern dip is again resumed. About in line with this small southward-bending fold, and perhaps a prolongation of it, there occurs upon the southern spurs of Park View Peak, a short south dip of about 15°, but the usual northern dip is here, likewise, at once resumed. In a spur just northwest of Park View, the reverse may be observed, a northern dip of 25° being observed for a short space, but soon flattening to 10° again. The whole slope north of Park View seemed to indicate a continuation of this northern dip, carrying the lignitic beds down into the low flat basin of the North Park. To the west the abrupt palisade edges of the great lava-cap covering the lignitic in that direction show, extending in a high promontory northward into the North Park; and here, also, a gentle northern dip seemed to be apparent at a few points.

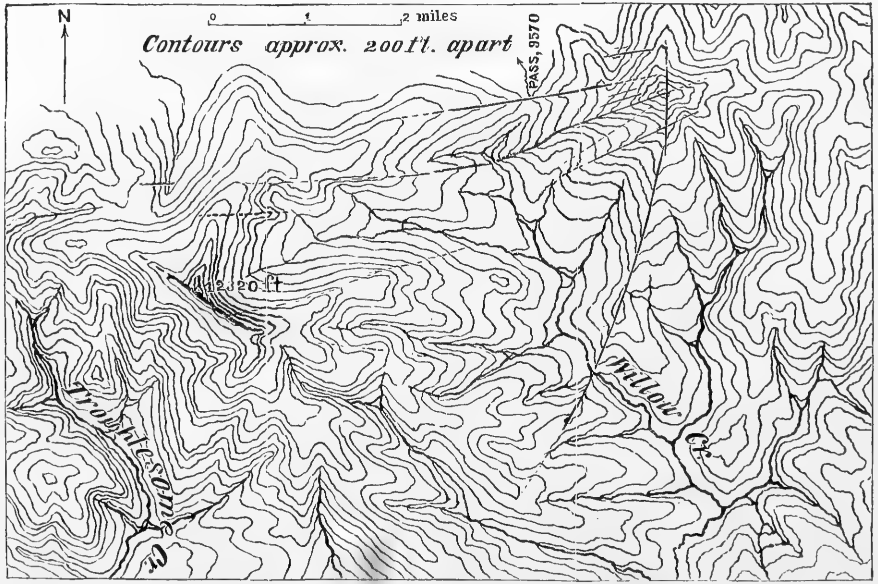
Though a large dike and several smaller ones occur in Park View Mountain, their connection with the topography is best shown in a hill northeast of that mountain, and across the westernmost fork of the Willow from it. These dikes vary from 5 to 30 feet in thickness, some being apparently over five miles in length, and extending across the country like huge broken walls. Where several intersect or occur near one another, their combined resistance to erosion has formed a hill, every spur of which contains a dike. Between the two mountains is the pass for the Willow Creek trail over into the North Park. The accompanying sketch-map, Fig. 17, shows the forms of these two points, and their connection with the dikes. There are probably several large dikes upon the northern spur of Park View, and on the hills to the northwest, which are not indicated in the map, as they were not clearly seen.

The dikes are of a very handsome porphyritic trachyte, a grayish green micro-crystalline or granular paste containing, as the more noticeable ingredients, numerous large, well-formed crystals of white orthoclase, and short, well-formed, hexagonal crystals of a soft, dark-green chlorite.*

The lava capping Corral Peak has some peculiar features which should be mentioned before leaving this lignitic area. The summit of the mountain is a squarish, rugged mass, rising precipitously at the southwest end of a ridge that runs about three-quarters of a mile northeastward from it, where it is crossed at right angles by an equally long but excessively sharp ridge, trending nearly northwest and southeast. This whole top descends steeply, especially on the northwest and south sides, for several hundreds of feet to the lignitic beds on which it rests. The northeast ridge, though not examined at its base, appeared as if it were the dike through which the eruptive matter found its outlet. This ridge rises a little higher than the broader neck connecting it with the main point which rises some 500 feet above either. The sharp ridge and all the main top is composed of a dark, nearly black or brownish-black, brittle basalt, which possesses a resinous luster on a fracture face because of the very large proportion of olivine permeating the mass. This lava weathers very peculiarly, breaking in thin flakes or slabs, sometimes shaly, usually standing nearly vertical, with flat conchoidal faces, which meet along the edges as do the facets of a cut-glass tumbler. These slabs are highly phonolitic; and in weathering, the surface sometimes looks like a reddish, even-grained sandstone. The columns which compose the western precipice are remarkably well formed. Some of them are two or three feet across, sharply cut generally into five sides, cross-jointed into lengths of from a few feet to a few inches, with, on the upper surface of each joint, an exceedingly well-formed convex spherical surface, rising two or three inches above the surface of the joint, and with its circumference nearly tangent to the sides of the joint. A corre-

* It is intended that a proper chemical examination of this lava, as well as of all the volcanic and other rocks that require it, shall be made to be used in the final report of Colorado.

Fig. 16.



Sketch map of Park View Peak and vicinity, showing the Trachyte Dikes penetrating the nearly horizontal Lignitic rocks, and their relation to the topography.

sponding depression, of course, exists in the lower side of the section above. This upper columned, jointed, splintered mass of lava shows no signs of bedding, but it rests below in a mass of volcanic conglomerate, containing patches of white-weathered tuff, in all a few hundred feet in thickness, dipping somewhat to the northwest, and forming a zone of most curious pinnacled forms surrounding the base of the steep upper slopes of the peak. At the very base a small patch of lava was observed, consisting of a hard white matrix, with numerous imbedded grains of sanadine and quartz, apparently a typical western rhyolite. The conglomerate and basalt probably rest directly upon it.

The summit of White-Face Mountain and its western spurs seemed covered with the same lavas as covered Corral Peak.

In the upper part of the East Fork of Troublesome Creek several dips of the lignitic sandstones were observed at right angles to the stream, or southeastward, some of perhaps 10°, thus forming a gentle monoclinal of the valley. Lower down, dips of 5° or 8° to the southwest take their place, and the inclination of the strata being greater than that of the stream, they gradually disappear beneath it. The valley is not as deeply cut as that of the Willow, the first more abrupt rise being less, and the semi-terraced slopes rising rather gently on either hand, intersected by innumerable small ravines. A little lower, about five miles above the junction with the West Fork, the river turns westward and approaches a ridge into a narrowing gorge through which it enters, the high hills on either side becoming capped with volcanic material. As the stream cuts through the gently westward-dipping lignitic beds, the capping lava descends more and more, until the palisaded cañon is wholly in it, the lignitic disappearing beneath it, the stream finally emerging from between the gradually lowering sides to its junction with the West Fork, in the flat, low-terraced basin of the Lower Troublesome tributary to that of the Grand. This volcanic material lies upon the hill-slope with a western dip of 6° to 1°, and consists of poorly stratified or irregular volcanic conglomerates, some white tuffs, but mostly of dark or black basaltic lavas, some columnar, which form the palisades. On the south side of the cañon a well-defined bed shows at one point a thickness estimated at seven or eight hundred feet. Some of the lavas observed were very fine-grained, with conchoidal fracture, some with rough resinous surfaces, with the usual variations of appearance common in basalts. Except the peculiar tabular structure, some were undistinguishable from those of Corral Peak, and it is quite possible that these lavas flowed down from that source. Inclining westward, the lava ends abruptly at the cañon's mouth in a steep slope of about 100 feet, which descends to a narrow lake-bed terrace skirting its base, which in turn descends in a slope of 40 feet to the river "bottom" of the West Fork. (The section is shown in Plate III, section 4, east end.) Down the Troublesome, the lava seems to end abruptly along the river in a similar manner for some distance, being bordered on the west by the terraced lake-beds of the stream, and thus concealing the western edge of the great lignitic area from view. From here to the Hot Springs the southern limit of this formation was not traced. It is probably somewhat concealed by this same lava flow, but it seems quite likely that near Corral Creek, and on to Mount Bross, the lignitic beds may rest on the granite, or on the upturned edges of the Cretaceous, as it certainly does just beyond, near the Hot Springs. Somewhere near this line, and not far below the junction of the two forks, are some sulphur springs said to be similar to those near Mount Bross, but cold. As it is not unlikely that the former may have an outlet similar to the latter, their presence may indicate here the upturned edges of the Lower Cretaceous beds. Northward a few miles from the junction of the two Troublesome Creeks, the lava on the east slope of the West Fork seems to draw away from the stream, leaving it apparently on the lignitic beds. A little west of the stream, some exposures dipping westward below the low terraces seem to continue these beds in this direction. (Plate III, section 3, east end.) Beyond the hills merge gently into the slopes leading up to the great northern lava mass, and are cut by the deep cañon of the North Fork, (not shown in the perspective of the sections.) The extreme western border of the lignitic area, that bordering on the valley of the Muddy, will be described when speaking of that valley.

LOWER TROUBLESOME VALLEY.

West from the junction of the two forks of the Troublesome, the gentle slopes of two or three low terraces rise to the low divide between the Lower Troublesome and Muddy Rivers. The lower terrace rises about 40 feet above the river-bottom, which is here a few hundred feet wide. Upon the divide the uncompacted, crumbling, light brown and gray sands and white marls of the lake-beds are well exposed, and all the terraces of the adjacent valleys are probably of them. Much alkali here abounds, and the terraces support a thick growth of sage-brush and little if any grass. These beds seem to effectually conceal the structure and relations of the rocks beneath. The divide and adjacent slopes are covered with boulders, pebbles, and smaller *débris* of basaltic lava, and moss-agate stones are frequent. Near the divide a few of the higher elevations of white lake-beds are lava-capped, and at one point a mass of lava occurs, as if occupying the ancient channel of a small stream in the lake-beds, (Plate III, section 3.) The lava-flow, of which these are the remnants, must have originally extended quite widely over this region, and the greater resistance to erosion due to its presence may have determined the present position of this divide. The latter ends at the south in the rather abrupt and high knob of granite, the Lower Muddy Butte, which will be referred to later. This broad-terraced valley of the Lower Troublesome opens out upon the similar region adjacent to the Grand, and agrees in general features with the lower portions of the Williams River Valley, which opens in a similar manner upon the southern side of the Grand.

VALLEY OF THE LOWER GRAND.

The region adjacent to the Lower Grand is of terraced lake-beds, through which protrude several small knobs of the metamorphic rocks. The Grand emerges from its cañon in the red, crumbling, gneissic granite, four or five miles below the Hot Springs. At first, the granite forms its northern bank, terraced beds being on the southern side, extending on up the Williams River Valley. A little lower, the river cuts somewhat into the latter, leaving a narrow zone of terraces lapping up on the low granite mass at the north. There are here two terraces; the lower about 90 feet high, mostly of soft, dark-gray, friable sands, some compacted, and a few brown conglomerates, a few hundred feet back from which rises the upper terrace, about 125 feet high, capped with a brown conglomerate of granite *débris* which forms a small escarpment at the top of the bank. The ravines cutting into the latter open out on to the lower terrace, but do not cut deeply into it. An exceedingly gentle dip of 2° or 3° up-stream toward the granite was here observed. The conglomerates strangely resemble some of the lignitic conglomerates in general characters, but lake-beds at this point, being naturally made up of *débris* from the granites and lignitic beds adjacent, might readily resemble the latter.

A little farther down the river again approaches the red granite, which rises ruggedly to form its northern bank, the lake-beds being again confined to its southern side, and here of a rolling rather than of a terraced character. The granite appears rather smoothly surfaced, and is cut through by the cañon of Corral Creek, which flows from the lignitic area upon the north. Nearly opposite its mouth, and west of the mouth of the Williams River, is a high hill with a great white exposure, so characteristic of the lake-beds, on its steep, north face. Near its eastern base are evidences of formerly existing sulphur springs.

After leaving the Corral Creek granite area the river-bottom is often a half mile wide, bounded on either side by a terrace of about 80 feet in elevation, except where the latter has been cut back by erosion, when the rise is often 150 feet, or to the summit of the second and higher terrace, direct. The latter terrace surface, rising in more gentle slopes to 200 or 250 feet, forms the general level between the Grand and lower Troublesome Creeks. From it here rises a rocky knob composed of granitic gneiss and dark irregular gneiss. South of the Grand, also, are two hills showing granitic outcrops, the lake-beds stretching past them southward, their relations to the Upper Cretaceous or lignitic beds of the north end of the Williams River Mountains not being examined. Exposures of highly cross-stratified sands are here exposed on the south bank of the Grand. Farther down the river the well-defined terraces, each of about 80 feet in height, are quite continuous. On the north side a few small knobs of metamorphic rocks protrude through them, while a quite large mass of the same (Station LXVIII) rises on the south, close to which the river runs, with steep slopes rising to it. A spur of the same runs quite to the junction of the Blue and Grand. Here a large flat alluvium area spreads out, lying, when visited, only about five feet above the river, and probably subject to inundation in very wet seasons. Passing it, the river breaks through the Lower Cretaceous rocks lying up against the eastern granite slopes of the Park range and enters its impassable cañon through the same, carrying with it all the drainage of the Park. The rapid deepening of this cañon will probably ere long retrieve the rich alluvium bottoms just above from serious inundations. Nearly all the terraces of this region adjacent to the Grand are covered with *débris* of metamorphic rocks, and sustain a poor vegetation of sage-brush, with very little grass, though the river-bottom appears very fertile. In the softer lake-beds much alkali is present, and the ravines are boggy. Though obscuring the underlying rocks as they do, enough is visible to show that the zone along the Grand is one, essentially, of the archæan rocks. Taken in connection with the sedimentary rocks both to the north and south, it would seem to be a gentle anticlinal, with an east and west axis, extending from the Hot Springs to near the mouths of the Blue and Muddy, with the overlying rocks swept away by erosion and replaced by the later lake-beds; while the apparent continuity of the mass with the granite of the Hot Springs would suggest that possibly the fold throughout was of the same age as the Hot-Springs fold, viz, post-Cretaceous, but pre-lignitic. The lake-beds so cover up the edges of the adjacent formations that the relations between them are readily seen, but ravines might be found exposing sufficient to really determine these relations and the true nature and age of the fold. As before mentioned, several sulphur springs occur a little east of the Lower

Troublesome, while indications of former ones are said to exist in the Lower Williams River. It is by no means improbable that, like the Hot Sulphur Springs at the base of Mount Bross, these, also, have their outlet between the Lower Cretaceous sandstones and the shales above; and if so, indicate that these rocks, though now covered by lake-beds, still occur beneath, and dip off northward and southward away from the archæan area of the Grand. The relations of the Cretaceous to the western portion of this archæan area will be given shortly, when describing the lower portions of the Muddy and Blue Rivers where they join the Grand.

THE VALLEY OF THE MUDDY.

The Park range forms the western limit of the Middle Park drainage. North of the Grand, and all along west of the Muddy Valley, it is by no means a high and rugged mountain-range, but a great rolling, even-contoured swell of archæan rock, on the gentle eastern slopes of which rest the Lower Cretaceous quartzites, extending more or less far up on it, and dipping off to beneath the Muddy River, which has excavated its broad valley in the soft Middle Cretaceous shales. At the north, the gentle eastern slopes of the valley are made up of the western edge of the great northern lignitic area; at the south, the low ridge of lake beds lying between the Muddy and the Lower Troublesome Valley, limit it on the east. The Cretaceous shales and sandstones of midvalley are, however, nearly concealed by the long low terraces of lake-beds which cover their upturned edges, and occupy nearly all of the main valley, reaching far up on either side, the underlying Cretaceous rocks being exposed at innumerable points in the many ravines which cut through the lake-beds in all directions. The valley, however, is not wholly a simple monoclinal. The Park range trends west of north, and from it, at one or two points, low anticlinals run out in an east of north, or north, direction for a few miles and then terminate, the beds flattening out at their ends, the river meanwhile being forced more and more east, as it passes around their northern ends. In the following more detailed description of the valley, reference should be made to the geological map of the Middle Park, (Fig. 8,) and sections 2, 3, and 4, of Plate III, the positions of which are indicated on the map.

The main source of the Muddy is the westernmost one, rising on the long even massive slopes of the Park range, which are here composed of very coarse granite. The waters collecting on these granite slopes flow down to a small north and south valley at their base, which is formed by the westward facing edges of the Lower Cretaceous beds which lie on the granites. Breaking through the ridge formed of these in a narrow cañon, the stream flows out into the more open valley. (See west end of section 2.) The lower beds are mostly soil-covered, but seem composed mostly of soft red sandstones, with a few harder beds, especially at the top, where a prominent layer of hard, white, quartzitic sandstone occurs. The estimated thickness of these beds is about 1,200 feet, or nearly three times the thickness of the corresponding beds at the Hot Springs, or about the same as the section noticed southeast of the Hot Springs. Considerations as to whether a portion of the Jurassic may be here represented, or whether all should be referred to No. 1, have been given before. In the absence of fossils the latter is the most natural conclusion. They appear to become much thinner in their southern extension, approaching the usual type and thickness of No. 1. Passing east through the cañon, the river flows across another little north and south valley, and breaks through a smaller uniclinal ridge, likewise dipping east. The side valleys are in dark slaty shale with occasional arenaceous and calcareous beds, reaching a thickness of about 350 or 400 feet. This outer ridge is capped with two strata of thin bedded limestone about 8 feet thick, separated by a thin shalier layer, all dipping eastward at an angle, near the river, of 10°, flattening to 6° higher up. The limestone varies from coffee-brown to gray in color, is inclined to saccharoidal, possesses a strong petroleum odor, and contains many imperfect fossils of a few Cretaceous species. The one occurring quite to the exclusion of others is a small *Inoceramus*, which Mr. Meek informs me closely resembles *Inoceramus acutirostris* (M. and H.) of Cretaceous No. 2 of the Nebraska section. Passing on down the river, there appears here and there beneath the terraced lake-beds forming its sides a long series of dark argillaceous shales, which dip eastward at a very low angle.

The lake-beds, indeed, which here at first rise in a few low terraces, then gradually merge into the adjacent bulky and irregularly contoured hills, everywhere so obscured these beds that no good section was obtained of them. There appeared to be no prominent beds among them, however, and as the limestones last described are quite characteristic and appear at other points, I have, for convenience, designated the horizon as No. 3, though, as indicated by the fossil above, it may be lower than No. 3, when paleontologically considered. If these beds are not regarded as Cretaceous No. 3, there does not seem to be any horizon here which could be so regarded. The shales above, which then become No. 4, are probably thirteen or fourteen hundred feet thick.

Just east of where the stream receives its main fork from the north, rises the Upper Muddy Butte, a steep precipitous mountain reaching some 2,400 feet above the river, and standing in its abruptness in strong contrast with the surrounding country. Before reaching it, the horizontal lake-beds which rest on the eastward-dipping shales sweep northward in low sloped hills, with many small ravines, to a series of hills which are lava-capped, the lava having flowed down from the great basaltic mass resting on the lignitic at the east. The lava-capped hills which remain near the sources of the North Fork are not visible in the section, being hid by the Upper Muddy Butte, though five of the western ones are seen. The Butte is also a mass of basaltic lava, the steep west front being faced with many columns; planes of division cut through the mass, dipping east of an angle of 25°, giving the impression that the mass has been upturned into that position. This lava reaches lower down than any of the other masses, as if it occupied a depression in the former surface. On the south side of the stream, opposite the Butte, are two or three connected, indefinite hills, all of the lake-beds, which extend westward across a small terraced valley, and lap up on the ridge of Cretaceous No. 3. Upon and about them many lava boulders are found, often scoriaceous, and not well rounded, the remains, probably, of a southward extension of the lava flow, the remnants of which cap the hills of the north. It is this flow which would seem to have determined the divide between the north and middle parks, which is here a gentle swell, hardly worthy of the name of pass. Whether the northern lava masses rest on lake-beds or on a westward extension of the lower lignitic beds was not ascertained. The latter is quite possible, as the lake-beds would have to reach unusually high to cover the whole pass, while the lignitic beds appear to flatten in their northern extension, and may swing around somewhat to the west.

Just south of the Butte a branch joins the main stream from the east, up which the eastern end of section 2 was made. A little south of this branch and near the main stream, ridges of sandstones are exposed by the ravines cutting through the lake-beds. These show a higher dip than the shales to the west, being tipped up eastward at an angle occasionally above 30°. The intermediate beds are not exposed, and are quite likely to be shales eroded away more than sandstones. The latter, however, give the character to the horizon, being absent in the shales lying below and to the west. A line of exposures a little east of the main stream shows a dirty, dark, somber-brown sandstone, medium grained, about 10 feet thick. Strike north 20° west, dip 45° northeast. A more continuous line of outcrops (all in the ravines) is about half a mile to the east of the main stream. There are here, beside the line of more prominent exposure, several minor ones, all being of sandstones, mostly light, but some dark brown, thin bedded, friable, and though not concretionary, strongly resemble the Cretaceous No. 5 in the region near the Hot Springs; the common eastward dip here is from 20° to 30°. Up the east branch, about two miles from the Butte, a small side stream from the north has cut a deep valley, exposing a cliff of a few hundred feet in height upon its east bank, (*a* in section.) At its base is a uniclinal ridge (strike north 15° west, dip 10°–15° east) which exposes a thickness of about 250 feet of light, gray, friable, thin-bedded sandstones, some perhaps of the consistency of freestones, none thicker than one foot, but mostly shaly. Above, for about 225 feet, and forming the lower portion of the cliff, the beds are shaly, and some almost earthy. A band of about four feet in thickness here is of bituminous shale, quite irregular, and contains some thin seams of black but weathered and shrunken lignitic coal. The cliff is capped by about 150 feet of coarse, massive sandstones composed of metamorphic *débris*, the characteristic and unmistakable beds of the lignitic group. Though the eastward inclination of the upper beds is small and much less than those below, the transition between the two is gradual, showing a flattening of the fold, there apparently being no unconformability anywhere in the series. Here, then, the lignitic must rest directly on the Cretaceous without the intervention of the doleric breccia bed of the Hot Springs. That the latter marks the most natural line of demarkation between the two horizons follows from the entire change of lithological characters which it separates, as well as from the unconformability between them at the Hot Springs, and, so far as known, from the complete change of life which here occurs, molluscan life giving way to plant life. Near the muddy, however, the line of demarkation between the two horizons is not so well marked. From the fact that in the breccia basin, on both the Grand and Frazier Rivers, a few hundred feet of shaly beds lie beneath the lowest coarse sandstones, and between them and the breccia it becomes no unnatural inference to suppose that the carbonaceous shales which underlie the coarse sandstone escarpment here near the Muddy probably form the base of the lignitic, thus leaving the lower sandstones of the ridge below as the probable summit of the Cretaceous. Though no fossils were found in these beds directly, yet sandstones characteristic of No. 5, with fossils, occur just below. No. 5 might thus be taken as probably being very nearly 1,500 or 1,600 feet thick, making the total thickness of the Cretaceous here in the Muddy Valley about 4,500 feet. These thicknesses, though checked by scaled distances on the map, may be in error from incorrect estimation of average dips, as so much is obscured by the lake-beds. I think that they may be much too small rather than too large.

A little north of the lignitic escarpment, a few exposures indicated a flattening of the formation, as if the lignitic beds might extend northward and westward toward the Pass into the North Park, as before intimated. Following on eastward up the valley, all is covered with a curious porous soil to its head, where the high escarpment of the great volcanic mass is met.

Flows of black basalt, lined with columned escarpments, great thickness of volcanic conglomerate and white tuff, and red scoriaceous masses show on this western face. The thickness of the volcanic mass must exceed a thousand feet. The peculiar porous soil of the valley is probably due to soft volcanic material. The ridge running toward the exposure of the lower lignitic rocks (*a*) has some small lava masses on it, while a long arm stretched northwestward would seem to indicate the direction of the lava flow, which reached all around the northern sources of the Muddy.

Southward from the Upper Muddy Butte, the formation, as indicated by the more frequently outcropping sandstone ridge of No. 5, would seem to follow very closely, in its changing trends, the general course of the river. The effect on the topography of the intermingling of the flat lake-beds with the including upturned Cretaceous, is here very curious. For ten miles down the river the lateral streams from the east are very numerous, and have cut the lake-beds into long, often irregular, tongues, whose ends fall in a steep terrace slope to the river, and the sides falling similarly to the cutting ravines. These, however, often cut through ridges of the Cretaceous sandstones at right angles to their course, which close to a narrow cut the ravine-shaped valley, and modify in many ways the naturally regular forms of the lake-bed erosion. The types of these tongues are flat and even, all of pretty uniform length, with surfaces sweeping up in long, graceful curves to the gently molded hills bordering the valley on the east, and which are probably of the lignitic rocks. Near the river the Cretaceous shales, and the sandstones just east of them, dip rather steeply or up to 30° or 40° eastward, but they flatten in going either east or west. West of the upper part of this region, and partially encircled by the southward bending of the Muddy, are the rolling hills of lake-beds, which have been before referred to. South of these, however, the ridge in which Station LXV is situated, is of a very different character. Northwest of the station, and in the deep ravine at the base of the hill, is a small ridge striking N. 40° E., and dipping 55° to the *northwest*. The beds about show it to be swinging around the northern extremity of the station, and beneath the hills of lake-beds just north. It is of limestone, in all respects similar to the bed called No. 3, a few miles to the northwest, and is undoubtedly the same bed. Following the main ridge southward, this bed forms a minor, but parallel, ridge on its northwest side, which dips as high as 65° in the same direction. The southern end of the main ridge is quite broad and flat, and is surrounded by a small palisade facing south and east, which appears to be the same bed capping the hill and dipping gently east. It is through here that section 3 (Plate III) is drawn. Outcrops of the same limestone, which is still composed of two prominent layers, but is thicker than farther north, appears as if broken downward along the east side of the ridge also. All along the lower slopes upon this side the slates of No. 4, where observed in the ravines in the confusing lake-beds, dipped gently eastward toward the river, some being barely inclined, and few, if any, exceeding 30°. The ridge, indeed, is an anticlinal, with a gentle east side, an abrupt west slope, trending about north-northeast, and flattening at the north. To have sections 3 and 2 (Plate III) in their proper stratigraphical relations, section 3 should be moved eastward until the anticlinal on the left comes under the Upper Muddy Butte in section 2.

The flatness of the dip near the Butte is probably due to the effect of this fold.

Southward along the east slope of this fold the valley widens before its contraction at the Lower Muddy Butte. On the west, the slopes coming from the anticlinal ridge are less cut up by intersected ravines than at the north, the terraces being more continuous and longer, running from the ridge in long flat slopes, and falling in one or two steeper descents to the river. On the east side of the river the lake-beds have here been more extensively eroded away than at the north, and the sandstones of No. 5, being here quite flat, are exposed with their western edges showing in low escarpments facing the river. Back, (eastward,) they disappear beneath the ridge of the lake-beds which separate the Muddy from the Troublesome. West of one of these flatly dipping tables of No. 5, and about five miles north of the Lower Muddy Butte, and a little south of section 3, some of the Cretaceous beds are exposed in the face of the lake-bed covered river-bank, and show a folding of the formation along a north and south line, the dip to the west being 45°, that to the east at first 20°, flattened to about 10°. The horizon again brought to the surface is probably the No. 3 limestones. Here, then, is another anticlinal fold indicated. It was not directly traced southward, and since the soft beds have been leveled by erosion, and probably almost wholly covered by lake-beds, there are no easily traced surface features to indicate its extent or nature. A few exposures on the east side of the stream, and a little south of this point, would seem to show that the beds on the east side of the fold were swinging somewhat eastward, as if to pass to the east of the Lower Butte, but they then become concealed by the ridge of lake-beds. This fold is indicated in section 3.

A pretty constant outcrop seems to be of a harder horizon of sandstones in Cretaceous No. 5. These usually outcrop east of the river, and, as indicated on the map, seem to show the effect of these two folds in their line of strikes. At first quite flat, the outcrop in going north gradually steepens, and trends more and more west, till, on a northwest strike, it forms a hog-back ridge nearly 200 feet high, and dipping 40° northeast. It would seem to be here running around the north end of the eastern fold, but, feeling the influence of the western fold, it turns more northward. Again it runs northwestward, as if tending to mantle around the northern end of the latter fold, but near the Upper Butte it turns northward, probably farther north to swing west again.

The Lower Muddy Butte is a high knob rising abruptly on its north and west sides to a height of about 1,800 feet above the river. It is of granite, with its base almost wholly surrounded by the low-lying lake-beds, and is probably the northwestward extremity or arm of the granite mass shown to exist along the lower portions of the Grand.

Westward, but a few miles from the Butte, and across the narrowed valley, may be distinctly seen the limits of the Lower Cretaceous quartzites and sandstones, as they lie up against the granite of the Park ridge and dip down eastward toward the Butte. The broad, low valley stretches northward, and occasional outcrops of its Cretaceous rocks may be seen beneath the terraced slopes; but in this direction, as said before, all is so leveled and covered with the terraces that the relations of the Cretaceous to the granite of the Butte are not apparent. Whether the former are upturned against the Butte, or whether a fault separates the two, or whether the Butte may not represent an elevation of the granite which existed before the Cretaceous beds were laid down surrounding it, is not readily seen. The abruptness of the hill, the apparent total absence of upturned beds, and the undisturbed appearance of the usual Park range fold on the west, would indicate the latter. But the fold spoken of as being found a few miles north of the Butte, as well as the unusual presence of granite masses protruding through undisturbed Cretaceous rocks, would seem to lend probability to the view that the Butte owed its presence to at least a post-Cretaceous disturbance, which folded or faulted the Cretaceous rocks about it, though erosion and deposition since have almost totally obscured the evidence of such action. South of the Butte, however, is evidence indicating the latter origin. Here, between the Butte and the Grand, is a curious area of Cretaceous beds. It is a true geological basin, the beds dipping toward the center from all directions. The west and south sides are best preserved, the others being confused with lake-beds. This portion is composed of two ridges, their abrupt slopes being presented outward, their gentle slopes inward toward the center, so that, approaching the center radially from the south and west, we would have to rise a hundred feet or more up a steep slope, showing the edges of crumbling shaly sandstones, (some argillaceous,) to a harder bed on top sloping gently in the opposite direction, when another sharp but steep ascent would have to be made before descending again gently to the center and the river; for the Muddy, breaking through the north edge of the basin, curves around through over half a circle in its very center, finally breaking through the south-eastern side to join the Grand.

To the west the steep faces overlook a narrow belt of lake-beds, from beneath which appear the Lower Cretaceous beds rising in the Park range. To the south the steep faces overlook the broad alluvium bottom of the Grand, which probably here covers the Lower Cretaceous beds, for just south of the river, near its junction with the Blue, some schist-knobs are indicated by the terraced beds of schist *débris*. East of the basin, the terraced beds cover nearly everything, but a ravine shows the lower beds dipping 30° westward. Farther east is the area of terraced lake-beds, with a few protruding knobs of granitic rocks. It is across in this direction that section 4 (Plate III) is drawn, extending on to the junction of the two forks of the Troublesome. Beneath the lake-beds here forming the surface, the Cretaceous may dip off north and eastward from the granites, which show above the surface here and there, and beneath the lava-covered lignitic beds of the Troublesome.

Nearly at the steep southern base of the granite butte, and exposed in a small ravine, is a small patch of white saccharoidal or quartzitic sandstone, lithologically like the characteristic beds of No. 1, and dipping from the granite about 30° southwestward. It not only dips from the granitic, but it lies in a small sharp ravine in the granite, and appears to be folded with the ravine. A little farther out the same beds dip gently toward the granite, its edge facing out over the river, descending to which the beds of the basin are found as before described. (See the small section just above section 4.) A little west of here, and at the northern end of the basin, a southward dip is also found, which turns west as if curving around the west end of the butte.

It would appear from these facts, then, that south of the butte, and crossed by the Lower Grand, there occurs a patch of Cretaceous rocks which have been folded into the form of a basin, surrounded on the north, east, and south by the metamorphic rocks, and running up on the Park range on the west, as part of the strata forming that fold, and that the butte itself had been brought to its present position by a fold which has turned up the Cretaceous rocks about its southern slopes; probably about its northern slopes also.

THE VALLEY OF THE BLUE RIVER.

The sources of the Blue River are in the area of arcæan, with some small patches of older sedimentary rocks lying between Gray's Peak on the east and Mount Lincoln on the southwest. From their mountain-surrounded valleys, the collected waters, at about thirty miles from the river's mouth, pass into an area of Cretaceous rocks, and it is this lower portion only which will be regarded at present. For this thirty miles up from its mouth, the Blue, in several respects, is the direct complement of the Muddy, and especially as it occupies a monoclinal valley in Cretaceous rocks, the valley bottom being eroded in the soft, eastward-dipping, mid-cretaceous shales, with the hard lower sandstones lying up on the archæan rocks of the Park range on the west, and the sandstones of No. 5, with rocks above, forming the eastern side of the valley. But it is a far better-defined valley than that of the Muddy, being both straighter, narrower, and deeper, though there is yet room nearly all along mid-valley for a zone of recent terraced beds, which, as in the Muddy, conceal most of the Cretaceous shales from view, and take away any idea of ruggedness of bottom, which might attach itself to the term narrow, as applied to the valley.

From its monoclinal nature, the river naturally lies nearer the eastern side of the valley, or the base of the Williams River range. The first steep slopes of these mountains rise along a very straight line, and while the Blue is for a short distance close to their base, a zone of terraces from one to two miles wide usually sweep from the mountain-base westward to the river. The range is exceedingly symmetrical in its outline, both in cross-section and longitudinally, the highest point, which rises some 3,600 feet above the river, being nearly in the center. From this point the summit-line, which varies in distance only from two to four miles from the river, descends in uniform wavy slopes both northwest and southeast, while in cross-section the eastern slope is comparatively gentle, the one facing the Blue being very steep. This west front is made up of the edges of the strata, which show upon it as horizontal bands. There are two bands which are more prominent than the rest, forming escarpments, one about half way up, where the range is highest, the other near the base. Toward the northwest, where the range falls, the upper horizons are eroded away, and the lower bed forms the general summit of this lower portion of the range, reaching to within five miles of the Grand. Both of these more prominent beds appear as bands of ashen-gray color, and are apparently sandstones, separated by a series of shales, weathering gray, with many white bands.

The summit of the Park range varies from six to eight miles from the river on its opposite side. For fifteen miles south from the Grand, except being somewhat narrower, this ridge has much the same character as north of that river, a massive rolling ridge of the archæan rocks with the Lower Cretaceous sandstones lying up against it. South of this point, however, it rises in one steep slope to the jagged crest of the main Blue River range, the principal characteristics of which will be described a little later.

Proceeding up the valley, the long middle slopes of the Park range, capped with the Lower Cretaceous sandstones, lie on the right; the upper portions of the ravines cutting through these to the metamorphic rocks below. Lapping up on these slopes are the terraced beds which run out toward the river in long graceful slopes. The stream usually has a much narrower bottom or flood-plain than the Muddy, and it is therefore much less serpentine in its course, the lower terrace generally rising close to the stream. This first rise is perhaps about 100 feet to the top of the lower terrace, then a long gentle rise to a subordinate terrace (often absent) of 30 or 40 feet steep slope, then another long slope to the highest, but less distinct terrace, of 150 to 250 feet in height. Just above the middle subordinate terrace another low terrace is sometimes present. The lower slope is the most marked, and is often several miles across.

The Cretaceous shales are frequently exposed in the ravines and river-channel. On the left is the hill of Station LXVIII, with the shorter terraced slopes of coarse archæan *débris*. Mixed with this *débris*, on its northwest side, is also much *débris* of shales, as if the Cretaceous rocks laid up against the granite. In the ravines near the river some exposures showed a bending of the strike of the strata from southward around to the eastward, at first with a flat northward dip and then a steeper southward one; in other words, as if the strata were mantling around the southern side of the archæan area of the Grand. Though perhaps too few points were observed to make the fact absolutely certain, yet, where seen, the strata occupied just such positions as would exist at the junction of two folds, one (perhaps the older) bringing the granites of the Grand to the surface, with rocks here dipping off to the south and west, the other, the Park-range fold, trending nearly at right angles to the former, and lying just across its western end. Indeed, the LXVIII hill, in its geological characters, is probably the complement of the Lower Muddy Butte, and seems to be the southwestern extremity of the east and west fold of the Grand, which, judged by the unconformability at the Hot Springs, occurred before the deposition of the lignitic beds, and preceding by a long interval the great final folding of the mountains.

About five miles from the Grand there rises above the terraced-slopes, on the east, an escarpment of bedded rocks, about 400 feet high. These are mostly of buff-colored with some brown friable sandstone, showing in four prominent and nearly horizontal layers. At first, at the northern end, a low dip to the south is apparent, again a probable indication of the fold of the Grand. Their usual dip, however, is gently to the east, and into the flattish-topped mass which they mostly make up, and all along the west face of which they show in banded escarpments. The exposures, meanwhile, in the ravines of the valley seem to be, so far as observed, almost wholly of shales and slates, so that these bluffs would appear to be the Upper Cretaceous sandstone No. 5. The horizon can be quite readily traced by the eye all along the base of Williams River Mountains, and in it, near the south end of the range, was found an *Inoceramus*, which Mr. Meek identifies as being closely allied to *I. barabini*, (Morton,) a fossil of Cretaceous No. 5, of the Nebraska section. All the lower portions of the Williams River Mountains, therefore, are composed of Upper Cretaceous strata.

For five or six miles these sandstones mostly form the flattish northern arm of the range before it rises in rounded curves to its higher and more ridge-like middle portions. At one point they are covered with a large mass of apparently eruptive rock, probably basalt, or trachyte, but which was not ascertained. Southwest of those lava-covered escarpments are two dikes of trachytic lava, which appear as low ridges crossing the terraces on the east side of the valley, the westward trending nearly south, the other trending more southwest; the two intersecting near their southern ends. The one is vertical, the other apparently dipping northwest at an angle of 60° toward the other, and probably joining it below. The rock is of a hard, fine, semi-vitreous base, light gray or greenish-white in color, and inclosing crystals of orthoclase or sanadite.

The trend of these two dikes is toward a hill which lies about eleven miles from the Grand, and which, in its isolation and abruptness, presents a unique topographical feature on the otherwise regularly formed valley, and therefore indicates some equally unique geological fact. The main valley seems to lie between this hill and the Williams Mountains, but the river appears to leave its valley and turn out of its course to cut a deep cañon around the western base of the hill, which rises to a height of 1,500 feet above the stream. Looked at either from up or down the river it shows a series of massive beds, with softer layers between, all dipping eastward, the upper beds at an angle of 30°. These massive beds are of trachyte; the softer beds are Cretaceous shales, and the bedding is apparently so perfect as to give the impression that the lava was contemporaneous with the sedimentary rocks, and that here were trachytes of Cretaceous age. But either north or south of the hill the Cretaceous shales in the neighboring ravines show very flat eastward dips, indicating that the lavas are but intrusive masses of post-Cretaceous age, which, instead of breaking across the strata, here followed along their planes of bedding, and forcing apart and upward the strata between which they wedged themselves, caused them to incline eastward at a steeper angle than those on either side. Examination of the hill confirms this idea. In a single section made about in the middle of the hill several points were found where the lava broke abruptly across one or two feet of the shales, breaks of a few inches being common, while a generally uneven surface exists between the two. At one point a limestone rested on a lava for a little ways, and then slates commenced to wedge in between the two, generally with broken edges. The section is indicated in Plate III, section 5, and is given in more detail below. The three thick lower beds of trachyte indicated in the section are all joined in one on the southwest corner of the hill, and form a high pinnacled cliff overhanging the river. Near here, and a little south, may be seen what appears to be the side or edge of a flow, where the undisturbed slates lie on the south, dipping at an angle of 10° eastward, and abutting against lava which from there north forms a layer, and on which rest the slates which have been turned up by the lava. On the opposite (west) side of the river is a massive hill, also apparently of the trachyte, a remnant of the thickening dike, with the capping slates eroded away. On the hill-slopes to the southwest appear some disturbances of the Cretaceous beds, possibly caused by the incoming of the lava. In the river cañon about 80 feet of a white siliceous sandstone is exposed, probably the upper bed of the Lower Cretaceous sandstones No. 1. It dips but a few degrees to the east. The beds included between the trachytes gradually increase their dip in ascending the hill. They are mostly of dark argillaceous shales, with some blue-black slates, and one or two limestones. The usual Cretaceous fossils occur here and there. Considering the preponderance of lava in the hill the sedimentary rocks seem to have been but very little affected by any heat that may have accompanied its eruption. What little effect it has produced, however, is as markedly on the beds lying above lava as on those below it. The lava throughout is a handsome trachyte, with a tendency to very large feldspar crystals, which are inclined to glassy, and seem to be of the sanadite variety of orthoclase, though the usual orthoclase forms are more common than the square tabular crystals. Some of the latter are from one to two inches across. The upper trachytes seemed usually more porphyritic than the lower ones, the average size of the very numerous feldspar crystals being, perhaps, from a quarter to one-half an inch. While much of the matrix was greenish, some was olive-brown, and, though mostly fine-grained, some was slightly vesicular, and a little was observed inclining to scoriaceous. The following is a record of the section down the west side of the hill, the thickness being obtained, as usual, by using an aneroid, pacing, and estimation:

Section of hill in Blue River Valley, eleven miles from Grand River.

Nature of strata.	Thickness.
	Feet.
Trachyte	100?
Slaty shales	200?
Coarse trachyte	100?
Shale	25
Trachyte	110
Slates, mostly shaly, very fine, blue-black, at center heavy bedded to 18 inches; uneven and broken surface	120
Trachyte; somewhat porphyritic, but mostly fine, irregular, and some scoriaceous; breaks of one and two feet across slates	10
Fine shales	60
Limestone, fine, compact, dark blue; beds eight inches thick, subjointed to shaly; brittle; in part shales below	10
Trachyte	80
Shales; dark, fine	100
Trachyte	275
Shale	20
Trachyte	150
Siliceous sandstone, white	80
River.	

Across the valley, eastward from the hill above described, on the west face of the Williams Mountains, is a little projected ridge, apparently a short dike, passing through the lower beds of the mountains. It is indicated in section 5, and modifies the section of the range, here near its highest point, by causing the lower bed to run farther out in a terrace form than in the usual mountain section, which shows the west face as steeper, and more as in the dotted line. A few miles south, in a steep east bank of the main river, a vertical trachyte dike was observed, about a foot thick at the base, thinning to nothing about 80 feet up, and so disappearing before reaching the surface, on which no indications of it existed.

THE PARK RANGE AND BLUE RIVER MOUNTAINS.

Meanwhile, the Park range has undergone some change. The rounded ridge has gradually risen until, near the base of the abrupt slope up to its southern extension as a rugged range, it is at the timber-line. The Cretaceous sandstones, resting on the ridge, are here cut up more than nearer the Grand. A remnant caps the very summit of the ridge, but greater erosion has cut much of the sandstones away, leaving the valleys in the granites. Much of this erosion has been glacial. The valley, which has the steep and rugged slope of the northern ridge of the mountains rising from its southern side, and the more even-contoured massive ridge on its northern side, *i. e.*, the first valley north of the greater mountains, is a glacier-cut gorge, widening and narrowing, with many glacial lakes scattered here and there, while its whole bottem is a maze of uneven *roche-moutonée*, which frost and vegetation are now fast breaking down, and gradually obliterating. It has cut deep into the granites, apparently leaving the Lower Cretaceous sandstones bordering the northern edge, and, farther to the east, where the main ridge falls to a lower and flat-topped spur, the southern edge also. Lower down, where these flat-topped spurs fall off rather abruptly, morainal masses run out from their ends on either side, and, first running down the valley, finally cross it and join in a bulky terminal mass below, which covers the granite, and then hides the upturned edges of the lower sedimentary rocks. One or two of the valleys draining off the rolling Park ridge north of this one present some similar features, being cut through the sandstones and exposing much metamorphic rock. About midway of this ridge, toward the Grand, a higher point presents some of the characteristics of a lava mass. It is probably basaltic.

THE BLUE RIVER OR MOUNT POWELL GROUP.

The Park range, after its abrupt rise from the broad rolling ridge at the north, entirely changes in its characters. It appears to be a rectangular-shaped mountain mass cut into the most profound amphitheatral headed gorges, which are separated by the most rugged and sharp sawlike ridges of rock imaginable. The main ridge lies along the southwestern side of the mass, and from it the valleys and their sharp separating ridges trend in a general northeast direction. The northernmost spur was composed of a very distinctly and evenly bedded series of schists, gneisses, and granites which had a strike nearly with the ridge, and a dip of 40° or 50° to the southward. Looked at from the east, the general impression is received that all of the large ridges of the range have a similar structure. These rugged ridges, in their easternmost portions, (see Plate III, section 6, west end,) present a pretty uniform general elevation, (*a b*,) and as the northern ridge expands at its end into an even-surfaced table-like mass of rock, the impression is given that all of these sharp ridges are but the remnants left from the cutting away of a plateau-like step which once followed along the mountain-face. These ridges also end quite similarly along a pretty straight line, and descend to rather a uniform level. Regarding now more particularly the northern ten or fifteen miles of the high range, which includes but four or five of the ridges, it is observed that at the base of each steep end, the lowered spur does not continue on as a sharp ridge, but slopes off, a flat-surfaced, plateau-like area, descending gently eastward, (*c d*, section 6.) Since upon the corresponding area at the base of the northernmost ridge great quantities of *debris* of the Lower Cretacerous sandstones were found, abundantly proving that they covered the area, it appears that all of these flattish areas either are now, or have comparatively recently been, covered with the same sandstones. Such features would seem to indicate that the Cretaceous had once extended high up, or quite over the whole range, and that the latter, in its upfolding, had received the most pronounced uplifts along certain well-defined lines, the intervening portions not being tilted up at high angles. It is by such a process that the front range, at least from the Big Thompson to the South Platte, has received much of its uplift. Major Powell and Mr. Gilbert have noticed similar folds in the Kaibab plateau and adjacent regions on the great Colorado plateau of Northern Arizona, through there the sedimentary beds have not (by many a thousand feet) been stripped by erosion from off the underlying rocks. It is a form of mountain-building, which I think is not uncommon in the West.

The cañons issuing from the high Park range, or Blue River Mountains, are glacier-scored, and cut deeply into the metamorphic rocks between the supposed Cretaceous covered areas, which lie between their mouths. From the edges and ends of these areas commence the moraines, which extend valleyward and end in broad indefinite morainal masses, reaching nearly to the river. The metamorphic rocks exposed in the cañons probably extend some distance down them, and finally become covered by the moraines, encroaching on it from either side before the edges of the Cretaceous sandstones which underlie the main valley appear crossing the stream-bed; these edges apparently being covered by the moraines, as indicated by section 6. In this section the plateau area *c d* is not shown quite high enough to be in its proper relation to the moraine.

From the lower surfaces of the moraines the terraces sweep off to the river, the upper terraced beds evidently lying directly on the morainal mass; the two formations being probably to a certain extent contemporaneous.

THE SOUTHERN END OF THE WILLIAMS RIVER RANGE.

Opposite the portion of the Blue River range last considered, lies the southern end of the more symmetrical portion of the Williams River range, which terminates at a saddle at Pass Creek, its highest point being nearly midway between that stream and the northern end of the range. The Blue River bends near this point, the valley turning from a southeast to a south course, in going up stream. Looking down the valley from a point above the bend, the eye sees, then, the southern end of the Williams Mountains, (see section 6, east end,) with the edges (*x*, *x*) of the prominent upper bed of the range running across it. As shown in the section, it seems to be folded or faulted somewhat. On the south side of Pass Creek is Ute Peak, rising some 3,800 feet above the Blue. This mass shows as somewhat offset to the east with respect to the Williams Mountains. Its western face is terraced like the west face of the latter, the uppermost bed appearing running prominently across it, with the lower prominent bed showing on a portion of the face, and both dipping slightly eastward into the mountain, but all the mountain summit is of the metamorphic rocks. There are here mica, schist, and gneiss, rather finely banded, but somewhat distorted or irregular, with some feldspathic seams, the strike being about north 10° east, with a dip vertical or high to the south. Its eastward slopes carry one at once into a country characteristic of the archæan rocks and different from the valley just left, the first eastward descent being directly to the deep cañons of the Upper Williams River, and then on and up on to the massive, deep-cut spurs leading to the Mount Byers and Gray's Peak groups of mountains.

To the south all seems likewise a mountainous region carved from the hard metamorphics. The western face of the hard archæan rocks, which form the summit of the mountain, is abrupt for about a thousand feet down to the uppermost layer of the sedimentary rocks. Close to the base of this steep upper slope some of the sediments dip slightly away from it, but their inclination just abreast of the peak is mostly toward the latter, at an angle of 8° or 10°. There passes through here, therefore, a great fault, which separates the sedimentary rocks of the Blue River and Williams Mountains from the metamorphic rocks of the peak and the region at the east, the down-throw being on the western side.

The sedimentary rocks which form the valley and lower portion of the peak cannot be taken at less than nearly 6,000 feet thick, probably much more, while the schists of the peak rise more than a thousand feet higher, so that, making no allowance for an unknown thickness of material eroded from the summit of the peak itself, the western side of the fault must have moved down, with respect to the eastern side, a distance of at least 7,000 feet.

This great fault passes northward east of the Williams Mountains, but was observed nowhere along the Grand, and probably dies out in that direction. Southward it appears to form the eastern side of the valley of the Blue for some distance, while it may be the northern continuation of some of the great faults that occur in the neighborhood of Mount Lincoln, but the connection was not traced out at all.

The beds which make up the west side of the peak are in part the same as those of the Williams Mountains. At the base, but best exposed on the north side of Pass Creek, or in the south end of the Williams Mountains, are the series of somber, dull-brown sandstones, exposed in several heavier beds, with narrower, slatier beds between, which lie all along at the base of the range. Those here exposed seem to be the upper portion of this zone. It was in those beds that the fossils allied to *Inoceramus barabini*, (Morton,) before referred to, were found, confirming the age of this horizon as being Cretaceous No. 5.

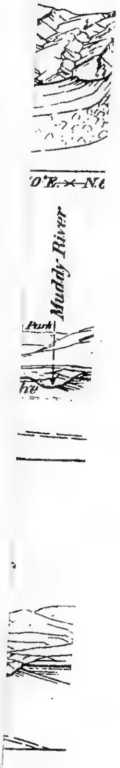
Above follows a slope of shalier beds, perhaps 500 feet thick, capped with the bed of sandstones which forms the upper prominent layer seen along the west face of the Williams Mountains. The characters of this sandstone I seem to have failed to record, except that the main massive portion was about 80 feet thick. Above were 500 feet, mostly shaly, with another harder band of thin-bedded, dull-brown sandstone, about 40 feet thick on the summit. In the slope of about 600 feet of softer beds, lying still above, some black argillaceous shale was observed, and at the top harder sandstones, some shaly and dull-brown as before, and some white, inclined to saccharoidal, a few of the harder beds being 18 inches thick. No fossils were observed. Some of the sandstones noticed were whitish and reddish, and rather coarse, while a few only seemed plainly composed of *debris* of metamorphic or granitic rocks, and to resemble therein the characteristic coarse lignitic sandstones of the other sections. Indeed, the series seems more to belong to the lignitic horizon because lying above the usual thickness and divisions of the Cretaceous rocks, rather than by the close lithological resemblances so well marked elsewhere in the park. Though differing from the Cretaceous in lithological characters, and having no place in the usual Cretaceous series of the park, they yet retain but to a slight degree the characters of the lignitic rocks farther north. I have considered them the same, however, and have so represented them on the maps and sections. Search would undoubtedly be rewarded with fossils proving their age.

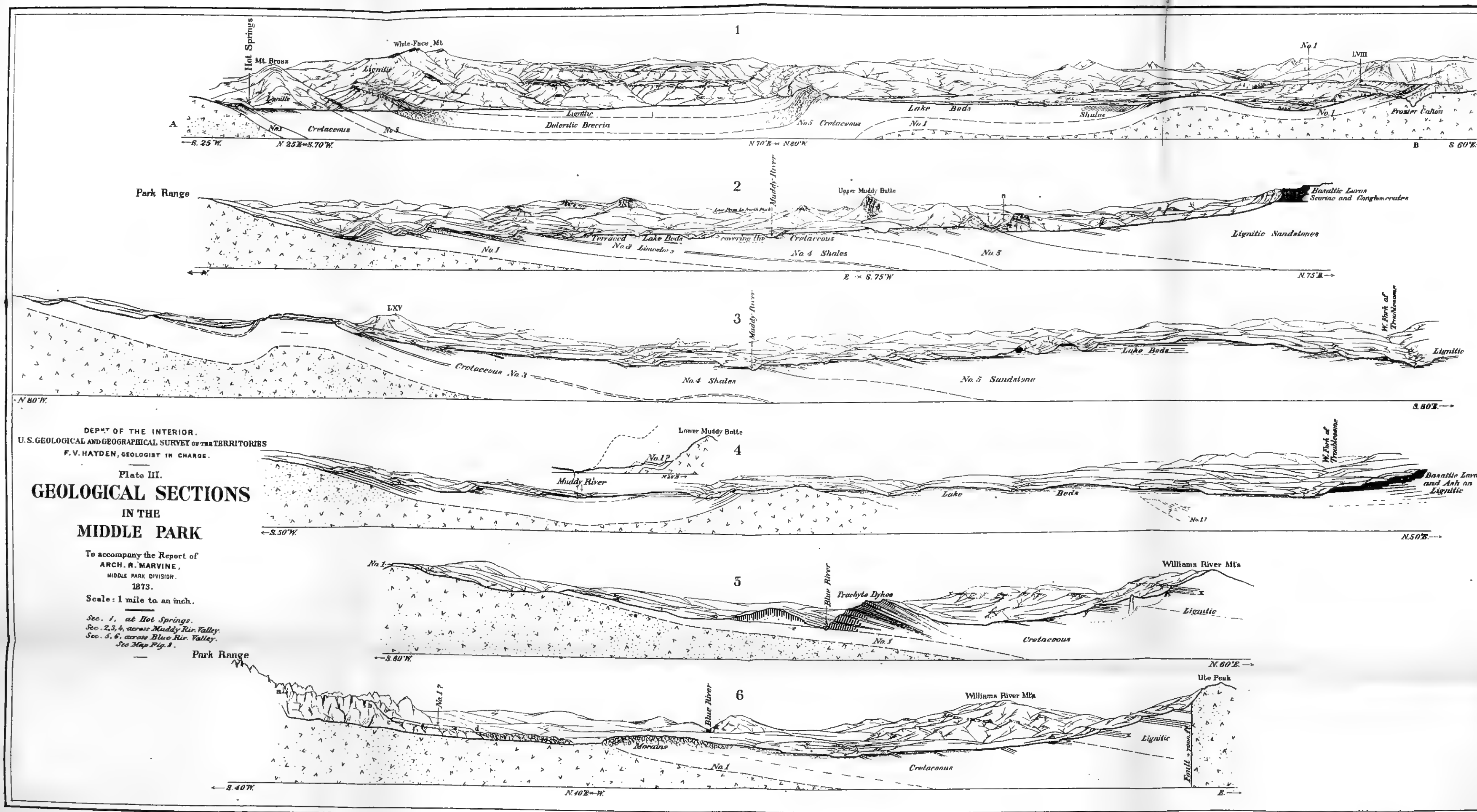
From the base of the high terraced front of Ute Peak the long, low, terraced lake-beds sweep out to the Blue, close to the west side of which are the lower indefinite masses of morainal matter from the Blue River Mountains, partially confused with the lake-beds. A few miles to the south the terraces are broken by a broad, uneven rise lying directly across the valley, and through which the river flows in a cañon. Approaching it, it is found composed of the Cretaceous beds, the harder beds forming ridges running across the main valley, and dipping northward, with the valleys of softer beds between partially filled with the terraced beds. Meanwhile, on the west, the flat areas at the base of the high mountain-spurs, and which I have considered as covered with Cretaceous No. 1, have approached the Blue, swinging around to a more eastward trend and northward dip, as if to cross the stream; while on the east the upper escarpments on the face of Ute Peak are eroded away and come to an end, the lower escarpments rising higher, and exposing more of the face of the main ridge, thus showing the background of the metamorphic rocks which compose it. When first encountered crossing the valley, the northern Cretaceous ridge dips at an angle of 25° or 30° to the north. A little farther on this is followed by a nearly flat dip, and again by a steepening northward one, showing a reflexed or double curvature of the fold. Besides, on the side toward the Ute Peak ridge the sedimentaries, instead of dipping down toward it, seem to have felt more the action of the fault, and dip slightly away from it, so that the valley is now rather a synclinal than a monoclinal, and a synclinal with the axis dipping northward, and its eastern edge cut sharply off by the great fault which has thrust the archæan rocks so high up upon the east, and brought them in direct contact with the edges of its slightly upturned lower strata. A little further south, and the edges of the Lower Cretaceous quartzites are found swinging across the valley to their broken contact with the wall of rock upon the east, and the road passes over them on to the granites, which then form the whole floor and sides of the valley, though still for a little distance farther some remnants of the sedimentary rocks lying up against the fault on the east side are visible. From here for a number of miles southward the valley still retains its open though profound character. The southern continuation of the Blue River group still rises most ruggedly and impressively on the west, bordered at its base with great morainal masses; while the lowered spurs of the Ute Peak ridge and adjacent mountains border the valley on the east; the terraced gravels and sands still occupying and concealing the middle portions of the valley. *Debris* of shales and sandstones was observed at a few points, and may indicate the further presence of some of the Cretaceous rocks. At the junction of Ten-mile Creek from the west and Snake River from the east—the two principal tributaries of the Blue—an area of reddish beds occurs; and again, at the very southern sources of the drainage, and forming a portion of the high mountain divide between it and the South Park, a thick series of sedimentary rocks present themselves which are apparently of pre-Cretaceous age. Neither sufficient examination was here made either to determine their limits or structural relations, nor to ascertrin whether other similar masses might not be present, the region, which is mostly composed of the archæan rocks, and contains important and interesting mines, being left for the coming season's investigations.

It is hoped that in the preceding pages the main purpose of these reports has been accomplished, viz, to present a description, not only of the surface features of the region examined, but also of its interior structure, as to the nature, position, and extent of the rocky masses that compose it, which will be sufficiently clear to be intelligible to the general reader interested in our West. It is further hoped, however, that scattered through its pages may be found some new facts which will ultimately aid in explaining more in detail than heretofore some of the problems of the gradual growth of this portion of the continent, such as the former extent of its lands and waters, and the nature of the foldings, dislocations, and erosions which have been mainly instrumental in developing the present state of things and in giving us the country as it is now found. Some conclusions touching such points were briefly suggested when the facts upon which they more directly depended were described. By considering together many of the facts thus separately presented, more extended and interesting conclusions may be arrived at, but the facts are confined to too small an area, and are as yet too isolated to afford reliable data for generalization, and as this is not the place to collect facts from other sources and regions, the temptation to draw general conclusions as to the former history of the district is resisted.

ARCH. R. MARVINE.

JUNE 19, 1874.


Muddy River
Park



DEP^T OF THE INTERIOR.
U. S. GEOLOGICAL AND GEOGRAPHICAL SURVEY OF THE TERRITORIES
F. V. HAYDEN, GEOLOGIST IN CHARGE.

Plate III.

GEOLOGICAL SECTIONS IN THE MIDDLE PARK

To accompany the Report of
ARCH. R. MARVINE,
MIDDLE PARK DIVISION.
1873.

Scale: 1 mile to an inch.

Sec. 1. at Hot Springs.
Sec. 2, 3, 4, across Muddy Riv. Valley.
Sec. 5, 6, across Blue Riv. Valley.
See Map Fig. 3.

REPORT

OF

A. C. PEALE, M. D.,

GEOLOGIST OF THE SOUTH PARK DIVISION.

WASHINGTON, D. C., *May* 1, 1873.

SIR: Herewith I hand you my report upon the "South Park District" to which I was assigned as geologist during the season of 1873.

To the report of Mr. Henry Gannett, who had charge of the division, I refer for details of organization, routes followed, and the topographical and geographical features. I have confined myself somewhat strictly to the enumeration of geological facts, leaving deductions and generalizations mainly for the final report to be made when the entire territory shall have been explored.

The limited time at our disposal, the want of an accurate topographical map, and the rugged character of a large portion of the region examined were disadvantages under which we necessarily labored, and which will account for any real or apparent deficiencies in the work. In addition to the absolute value of the results recorded, I am satisfied that the data obtained will be of great service to future more detailed investigation.

My plan of work was as follows: With Mr. Taggart, my assistant, I instituted a division of labor. One of us did the detailed work at or near camp; the other accompanied the topographical party to the station of the day, and made a drainage-map of the surrounding country, upon which the geological boundaries were defined in color. This station was usually the highest point in the region, and the work done from it was of course based upon the details previously obtained. I shall therefore color the final geological map, not from memory nor solely from notes, but from field geological maps. By this plan I am enabled to present a much larger number of detailed sections than I otherwise could have done.

I have appended to the report the usual catalogues of rocks and minerals.

In conclusion, I wish to express my obligations to Mr. William R. Taggart, who acted as my assistant, and by his zeal and efficiency contributed largely to the success of our division of the survey. My thanks are due to Mr. William H. Holmes, not only for invaluable illustrations, but also for useful notes on several localities not visited by myself. I desire to thank, also, Messrs. George Summers and M. France, of Colorado Springs; Messrs. Stevens and R. A. Kirker, of Fair Play, and C. L. Hill, of Oro City, for favors and information afforded.

With great respect, I remain your obedient servant,

A. C. PEALE.

Dr. F. V. HAYDEN,
United States Geologist.

CHAPTER I.

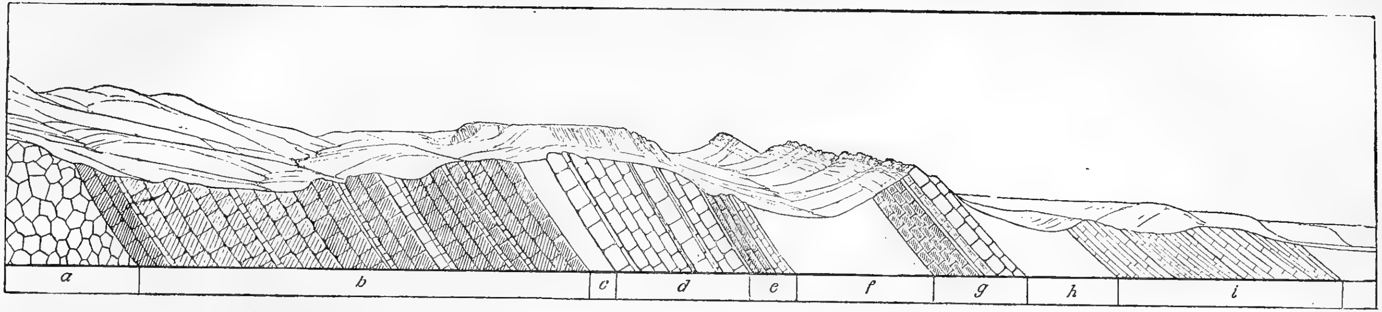
FROM DENVER TO COLORADO SPRINGS—FRONT RANGE—BERGEN PARK—HAYDEN PARK.

On the 29th of May the division of the expedition with which I was connected as geologist left Denver, and proceeded southward to commence the summer's work. On the 1st of June we crossed the northern line of our district a short distance north of the mouth of the cañon of the South Platte River. Here our work commenced. As we look from the plains westward before us rises a plateau-like mass of hills, beyond which we discern the snowy peaks of the main range. I will consider, first, the front range, or the foot-hills, as they are called by the settlers. Seen from a distance, the height of this range seems very uniform. Ascending the hills, however, we find they are much cut up by the various small streams that drain them. The range is made up almost entirely of plutonic rocks, so covered up that little can be definitely determined in regard to them. North of the Platte cañon they were thoroughly studied by Mr. Marvine, and to his report I refer the reader. On the south the general strike seems to be nearly north and south. The inclination at some points seems to be toward the west, and at others to the east. There is probably a series of folds, for the elucidation of which more time than we were able to give will be required. Toward the outside of the range the schists are of a bright-red color, from the predominance of the crystals of flesh-colored feldspar. They are also porphyritic. As we approach the center of the plateau, gray schists prevail, much finer grained, and containing considerable *epidote*: they are also more micaceous. The general elevation of the range, two miles south of the Platte River, is 6,735* feet. Five miles farther, at Station No. 7, it is 7,979 feet. About nine miles south of this station we have, on the western side of the range, rising considerably above it, a rough granite ridge, to which the name Platte Mountain has been given. Its elevation above sea-level is 9,027 feet. About five miles below it the general elevation is 8,448 feet, while on the eastern edge of the range, twelve miles south of Platte Mountain, the elevation at Station No. 11 is 8,986 feet, and this, five miles farther south, at Station No. 12, increases to 9,124 feet. We see, therefore, that as we go south there is a gradual rise toward Pike's Peak, which seems to be the culminating point. The width of the range varies somewhat, but it will average from six to eight miles. The question of the elevation of the range, as well as the consideration of its western slope, I will leave to a subsequent portion of the chapter. I will refer next to the sedimentary formations, which are beautifully exposed along the eastern edge of the range, extending from our northern to our southern line, south of Pike's Peak. My first section was made on the south side of the South Platte River, just as it leaves the cañon, and flows toward the plains. Its course here is about north 70° east.

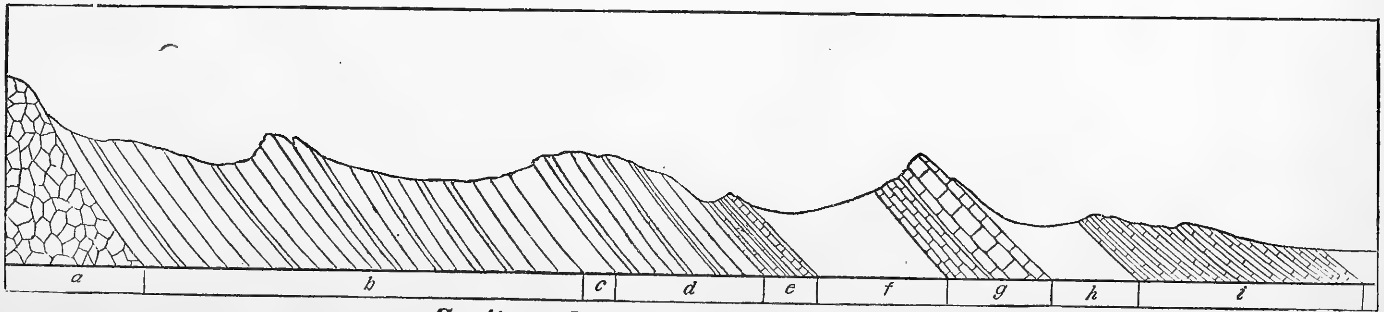
Resting immediately upon the granite rocks we have very coarse sandstones, mottled red and white. Close to the granite the sandstone is coarsest, and contains pieces of unchanged granite. In other places the sandstone appears to pass by gradation into the granite. They were

* All the elevations in this report are based on the elevation of Denver, which is assumed at 5,069 feet above sea-level.

Plate 1.



Section near South Platte Cañon.



Section along Willow Creek.

evidently deposited in shallow water and near a shore-line. The angle of inclination is about 65°, and the dip is north 65° east.

Above, the sandstones soon become uniformly red in color and somewhat finer grained.

Fig. 1, Plate I shows the beds on the north side of the river, their relations being exactly the same as on the south side, where the section was made.

The following is the section:

Section No. 1, on south side of South Platte River.

In descending order:

*i.	1. Fine-grained white limestone, with cross fracture		600(?) feet.
*i.	2. Gray limestone, (fossiliferous)		
Cretaceous No. 2, *h.	3. Space covered up.		
g. Cretaceous No. 1.	4. Gray and yellow sandstones, 70 feet		930 feet.
	5. Shaly sandstones, (fossiliferous,) 12 feet		
	6. Fine-grained white sandstone, 3 feet		
	7. Rusty, yellow sandstones, 245 feet		
	8. Space covered up, estimated 600 feet		
*e and f. Jurassic.	9. White arenaceous limestone, 5 feet		150 feet...
	10. Pink calcareous limestone shales	45 feet	
	11. Arenaceous and pebbly limestone		
	12. Space covered up	100 feet	
	13. Compact red limestone		
b, c, and d. Triassic.	14. White sandstone with red bands		600 feet.
	15. Space covered up		1,500 feet to 2,000 feet.
	16. Red sandstones		
	17. Coarse white and red mottled sandstones.		
*a.	18. Granite.		

The thicknesses in this section are for the most part estimated. The letters correspond with those in Fig. 1. Beds 14 to 17 will still have to be considered as Triassic (?) both from their general character and their position. Although there are exposures of these red sandstones all along the edge of the foot-hills from Denver southward, I could find in them no fossils, even after the most careful search. They are for the most part so coarse in their texture as to be unfavorable for the preservation of animal remains. The space No. 15 in the section is, in all probability, filled with red sandstone, of which No. 16 is the continuation. In No. 14, the white portions are somewhat conglomeritic, while the red bands are fine grained and calcareous. The red bands vary in thickness from 4 feet to 6 feet, while the others are 20 feet to 30 feet at this place. As we go south, however, we find that these sandstones are very irregular in structure. No. 13 is a blood-red limestone, somewhat irregular in structure, but very hard. Although it contains no fossils, I am inclined to consider it, together with beds 9, 10, and 11, as of Jurassic age. Space No. 12 is filled most likely with limestones, while in space No. 8 we have at the top greenish shales passing down into limestones with the gypsum bed, as seen in some of the sections made farther south. The pink calcareous shales (No. 10) pass gradually into the limestones (No. 11) in which there are large flinty pebbles. All the beds covered up in space 8 are probably Jurassic. That these beds from No. 8 down to No. 13, inclusive, should be referred to that age, is, I think, scarcely to be doubted, not only from their position, but also

* The letters given in the sections refer to the illustrations.

from the lithological identity with beds that are undoubtedly Jurassic in the following section made by Dr. Hayden at Box Elder, in 1869. The following is the section made by him in ascending order:*

1. Brick red sandstone, with irregular laminæ, and all the usual signs of currents or shallow water. Some of the layers loosely laminated, causing projections. Thickness, 300 feet to 400 feet.
2. Yellow or reddish yellow massive sandstone, 60 feet.
3. Grayish yellow, rather massive sandstone, 50 feet.
4. Ashen brown nodular, or indurated clay, with deep, dull purple bands; with some layers of brown and yellow fine-grained sandstone, undoubtedly the usual Jurassic beds, with all the lithological characters as seen near Lake Como, on the Union Pacific Railroad. Near the base of these beds are thin layers of a fine-grained grayish calcareous sandstone, with a species of *Ostrea* and fragments of *Pentacrinus astericus*. Scattered through this bed are layers or nodules of impure limestone, 150 feet to 200 feet.
5. Sandstone and laminated arenaceous material varying in color from dirty brown to grayish white, with layers of fine grayish-white sandstone, 200 feet.

Dr. Hayden says, "I do not hesitate to regard the beds described as 4 and 5 as of Jurassic age, and they are better shown here than at any other point between Fort Laramie and the south line of Colorado, on the eastern slope of the Rocky Mountains." Nos. 1, 2, and 3 of this section correspond to Nos. 16 to 14 of the South Platte section, (No. 1.) Beds Nos. 4, 5, 6, and 7 of section No. 1 form the main hog-back which is so conspicuous along the entire extent of the foot-hills. No. 4 forms the summit of the hog-back, and is a rather fine-grained uniform textured siliceous sandstone. All these beds belong to the Dakota group No. 1 Cretaceous. Layer No. 5 contains a large percentage of carbonaceous material, and in it I found fragments of leaves and stems. Among the former, Professor Lesquereux has recognized a *Proteoides* very near *Proteoides acuta*, (Heer.) These shaly sandstones weather of a bluish color in places, and are followed by No. 6, which passes into No. 7. The latter has occasional shaly bands, and in some places instead of being yellow the sandstone becomes reddish. Space No. 3 is filled in with No. 2 Cretaceous, Fort Benton group, and perhaps a portion of No. 3 Niobrara division, to which formation also I refer the layers marked Nos. 1 and 2. No. 2 is somewhat sandy, and in places is very dark colored, and on being fractured has a perceptible bituminous odor. It contains quantities of *Ostrea* and a few *Inocerami*. East of these beds the country is so leveled that the remainder of the Cretaceous formation and the entire extent of the Tertiary beds are concealed, being covered by the local drift from the hills. That the Tertiary layers are not far distant, however, is evident, for along the Platte River are exposures of lignitic sandstones. After passing out through the main hog-back, (Cretaceous No. 1,) the Platte turns to the northward, and its course is about north 7° east. The dip of the main hog-back at the Platte River is north 65° east; angle 55° to 60°. Fig. 2, Plate I, represents a section made at Willow Creek, five miles south of the Platte. The dip here is north 55° east; angle of inclination, 50° at the outside, increasing to 55° as we go down to the red-beds. It is not necessary to give the beds of the section here, as it would be a repetition of the order given in the Platte section, (No. 1.) They are so much alike that I will refer only to those where there has been some change. The thicknesses are about the same. In No. 14 of the Platte section, at this place, we have

* Report for 1869, page 19.

merely indications of the red bands, the prevailing color of the sandstone being a creamy yellow. The lower beds are perhaps deeper in color and not so much mottled as at the point where section No. 1 was made. I was unable to carry the section any farther to the eastward. Willow Creek after leaving the hog-backs turns and flows nearly northward, emptying into the South Platte River five miles below the cañon. As we go south from Willow Creek, the upturned edges of the sedimentary beds are covered up, and between Jackson and Spring Creeks we find resting on them sandstones of Tertiary age, which reach to the edge of the hills. These sandstones contain fossil leaves in which Professor Lesquereux has recognized *Platanus nobilis* and a *Sabal*. The beds are probably lignitic. On Jackson Creek are some well-defined terraces sloping from the mountains. On Spring Creek the sedimentary ridges again show themselves, and on Bear Creek we have them beautifully exposed in Pleasant Park. This beautiful little park is studded with pines. Its western boundary is the range of foot-hills, while on the east the main hog-back (Cretaceous No. 1) separates it from the valley of West Plum Creek. Bear Creek flows through the park, cutting across the ridges at right angles to the strike. Inside the sandstone wall we have ridges of sandstone and limestone, giving the park some most picturesque scenery. Just before reaching the park, Bear Creek flows in a series of cascades through a deep and narrow cañon in the foot-hills. Plate II shows the outline of a section through Pleasant Park eastward across West Plum Creek Valley to one of the mesas between the two branches of Plum Creek. The following is the section:

Section No. 2, through Pleasant Park.

In ascending order:

	a.	1. Granite.	
Carboniferous. (?)	*b.*	2. Very coarse white sandstone, 80 feet.	
		3. Red calcareous sandstone, 4 feet.	
		4. Dark purplish cherty limestone, 3 feet.	
		5. Compact red sandstone in layers of one foot thickness, with cross seams of calcite, 15 feet.	
		6. Red calcareous sandstone, very hard, and with cross cleavage layers of one inch, 3 feet.	
		7. Irregular limestone, with pebbles of greenish chert and limestone, 3 feet.	
		8. Indistinct outcrop of limestone with chert pebbles and fossiliferous: in the upper part of the space we have a purplish sandstone, above which is a gray sandstone passing into the next bed, 6 feet.	
Triassic.	*c.*	9. Coarse white sandstone loosely aggregated. In the upper part of these beds there are bands of red sandstone varying in thickness from one to three feet, 80 feet.	
	d.	10. Space covered up	About 1,500 feet in thickness.
		11. Massive red sandstones	
	e.	12. Mottled yellow and red sandstones.	
Jurassic. (?)	*f.*	13. Space	
		14. Pink arenaceous limestone, 4 feet	
		15. Space	
		16. White limestone, 3 feet	
		17. Space, 48 feet	
		18. Fine sandy limestone shales, 4 feet.	

Jurassic. (?)		19. Pink mottled laminated shales, 9 feet	About 461 feet thick.
	g.	20. White limestone, 2 feet	
		21. Space	
		22. Gypsum, 81 feet	
		23. White sandstone, 22 feet	
		24. White limestone, 2 feet	
	h.	25. Space, 100 feet	

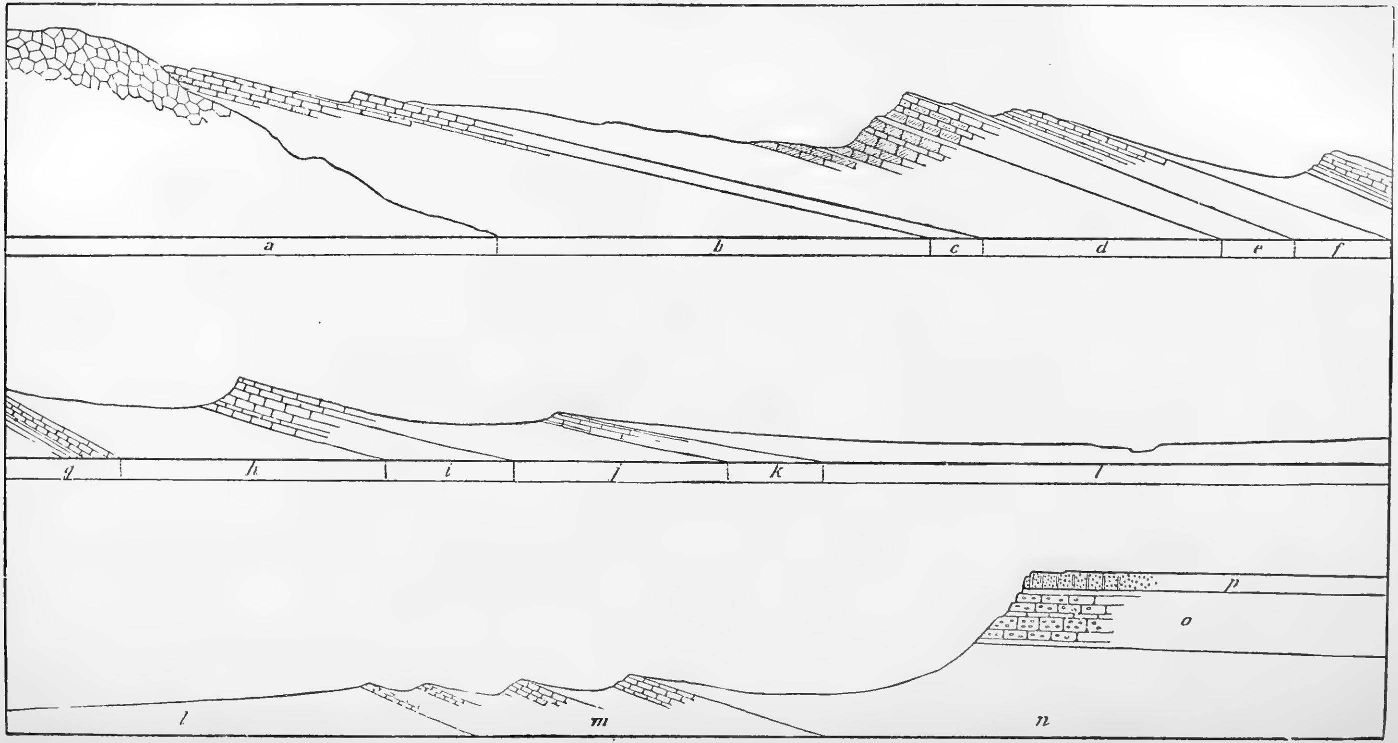
i.—26. Massive siliceous sandstones, yellowish, 213 feet.
j.—27. Space.
k.—28. Limestones, fossiliferous.
l.—29. Space, valley of West Plum Creek.

m.
30. Brown sandstone shales, 2 feet.
31. Space.
32. Yellow sandstone shale, 2 feet.
33. Fine white sandstone, 6 feet.
34. Yellow sandstone, 10 feet.
35. Space.
36. Yellow sandstone, 60 feet.
37. Space.
38. Yellow sandstone, 75 feet.
39. Space.

o.—40. Sandstone conglomerates, 841 feet.
p.—41. Trachyte, 20 to 30 feet.

In this section I am inclined to consider all the beds from No. 2 up to the base of No. 9 as Carboniferous, a total thickness of about 114 feet. None of these lower beds seem to agree with the Silurian layers in Glen Eyrie, nor with those found west of the range on Trout Creek. I have therefore referred them all to the Carboniferous. Future investigation may modify this view. The fossils found in No. 8 (*Terebratula* and *Spiriferina*,) prove it to be Carboniferous beyond doubt. Layer No. 9 is the same as No. 17 in the Platte River section, (No. 1,) and is the lower portion of the Triassic. Nos. 9, 10, 11, and 12, comprehend the beds that we have in Nos. 14, 15, 16, and 17 of the Platte section, (No. 1.) Here, however, they do not appear to be so thick. The difference may be apparent rather than real, as the thicknesses in both cases are only estimated. The red sandstones (No. 11) are massive, and present the same characters we have seen in the same beds all the way from the Platte southward. Space No. 10 is probably filled with an extension of these beds into those of No. 9. The red sandstones in the upper part of No. 9 are of a dark purplish color. The angle of dip of the lower beds (No. 2 to 9 inclusive) is 10°; at No. 12 the dip has increased to 30°. The red sandstones are not abruptly succeeded by the yellow sandstones of No. 12, but there is a gradual change, the upper part of No. 11 being somewhat faded, while in the lower part of No. 12 we find streaks and spots of red. These variations in color give the bluff on which they are exposed a rich and beautiful appearance. In the upper part the sandstones of No. 12 become very light colored. Space 13, as indicated by several indefinite outcrops, must be filled with the continuation of the sandstones of No. 12. The dip on the summit of the ridge is north 65° east. In No. 14 we have the lowest of the beds that I have considered as Jurassic, extending up to space 25. Near the top of No. 19 is a layer having a very irregular structure, and containing cavities lined with crystals of calcite. The lamination is most decided at the bottom. The gypsum bed (No. 22) is well exposed here. As we have it again

Plate 2.



Section near Pleasant Park.

near Colorado City, it probably continues southward uninterruptedly. It can be traced northward as far as Spring Creek, but above that point seems to be covered. Whether or not it is present at the the Platte River I could not determine, as the space where it would be found was covered so that all the beds were totally concealed. The space (No. 21) below the gypsum is probably filled with shales and limestones. That above is filled with the shales just below No. 1 Cretaceous, which is represented in No. 26. The general color of these sandstones is a yellowish white, becoming pink below. No. 27 is filled, in all probability, by the sandy shales of Cretaceous No. 3. Everything is concealed until we reach 28, where we find the same fossiliferous limestone that we have in bed 2 of the Platte section, and outside of it the outcrop of the white, chalky-looking limestone with cross fracture. From this outcrop, which forms a low ridge outside of the hog-backs, we have no exposures until after we have crossed West Plum Creek, a distance of about three-quarters of a mile. This would give us, with the dip at 10°, a thickness of about 700 feet of strata, mostly the shales of No. 4 and the upper part of No. 3, to which No. 28 of the section is referred and of which it forms the lower part. Beds 30 to 38, inclusive, I have referred to No. 5 Cretaceous, although I could find no fossils to prove the correctness of the opinion. Their position and lithological character warrant their being so considered. The dip of these beds is about 20°. The junction between them and the horizontal sandstones in the butte shown in the section could not be seen, as the base of the butte is covered with *debris*. At the base of the butte is a thickness of about 840 feet of rather coarse sandstones. Some of the layers are rusty-colored, and they are nearly, if not quite, horizontal. They are capped with a layer of light purplish trachyte. This capping is about 20 feet in thickness. The area of this mesa or table-like butte is about 30 acres. As we approach the Colorado divide, the Tertiary sandstones reach to the mountains, resting on the upturned edges of the older formations. Plum Creek and its branches have cut their valleys through these sandstones and conglomerates. Throughout the valley of Plum Creek we find numerous mesas, and all that I visited were capped with trachyte. The origin of this volcanic material I was unable to determine. These sandstones probably belong to the Monument Creek group, and once extended to the edge of the mountains along the whole range as we still see them on the divide. The summits of the mesas show us the original surface before the eroding agents had commenced their work. The Colorado divide, or Pinery, is a ridge with a mesa-like top extending eastward from the mountains. It is merely the undisturbed sandstones of the Monument Creek group, capped with the trachyte layer, and forms the water-divide between the branches of Monument Creek, which flow southward to the Arkansas River, and the waters of Plum Creek, which empty to the northward in the South Platte River. The divide is well timbered, and is already the seat of an extensive lumber trade. The shrill whistle of the steam saw-mill echoes and re-echoes among the hills, while the valleys are all being rapidly settled and the capabilities of the land for agricultural pursuits being demonstrated. On the divide close to the mountains, the eroding forces have cut a narrow pass in the Monument Creek group, and the fragments of these sandstones are seen resting immediately on the granites, while to the eastward the beds continue uninterruptedly.

This pass is about half a mile in width, and through it the Denver and Rio Grande Railroad crosses on its way southward. In the sandy *débris* on the divide, and on either side, very good crystals of smoky quartz are found. Crossing the divide, we find ourselves on the branches of Monument Creek. On this side, the overlying sandstones have been subjected to less erosure than on the north side, and with the exception of a few indistinct outcrops of the red-beds a short distance south of the divide, the underlying formations are concealed until we get within a few miles of Colorado City. Between the branches of Monument Creek on the western side we have sloping from the mountains eastward long grassy terraces. Monument Creek flows in a southerly direction, and the general slope of the country from the divide is southward. As we go down the creek the sandstones of the Monument Creek group rise like long lines of fortifications and castle-walls on the eastern side. On the western side also we have remnants left. There are, just south of Beaver Creek, several monument-like forms that are perfectly isolated. The terraces here are about 96 feet above the level of the creek. This height is near the mouth of Deadman's Creek, the first creek south of Beaver Creek. As we go toward the mountain, of course the elevation increases. Thus at the point given above the elevation is 6,592 feet above sea-level. On West Monument Creek, three miles farther south, and about two and a half miles west of the previous station, the elevation is 7,014 feet. In Monument Park we find the sandstones curiously eroded, so that there are monuments and pillars scattered throughout its extent, from which fact it derives its name. The following description is mainly from the notes of Mr. Taggart: The park lies south of West Monument Creek, and is an elliptical basin, about two miles in length from east to west, and three-quarters of a mile in width north and south. It extends from Monument Creek westward, where it is bounded by the ridge of sandstone (Cretaceous No. 1) which forms the main hog-back. The columns and monuments are found in two ridges that run lengthwise through the park. These monuments are from 12 to 25 feet in height, and are composed of sandstones of the Monument Creek group. The lower third of the exposed rock is fine-grained, containing argillaceous layers, and also carbonaceous shales. Above, the sandstone is very coarse, becoming almost conglomeritic. It is from the breaking down of these layers that the local drift, found along the edge of mountains, is derived. The capping of the monuments is a dark ferruginous sandstone conglomerate, very hard, the sand and pebbles being cemented by iron. This layer is about 12 inches thick, and being so much harder than the underlying sandstone, has been more successful in withstanding the eroding influences, and in some places we see it extending continuously over a number of the columns. West of Monument Park, and forming its boundary in that direction, we find the massive sandstone of No. 1 dipping under the Monument Creek group. From this point southward to a point below Colorado City we have this sandstone and the underlying strata well shown. The west section, perhaps, is shown in Glen Eyrie, a beautiful little cañon, which Camp Creek has cut through the granite and superimposed strata at the "Little Garden of the Gods," about two miles above Colorado City. In the cañon the creek flows in an almost easterly direction. After getting outside of the hog-back it turns abruptly and flows due south along the strike of the upturned shales and sandstones.

The following section is made from Glen Eyrie, eastward, to Camp Creek, and is in ascending order corresponding with Fig. 2, Plate III.

Plate 3.

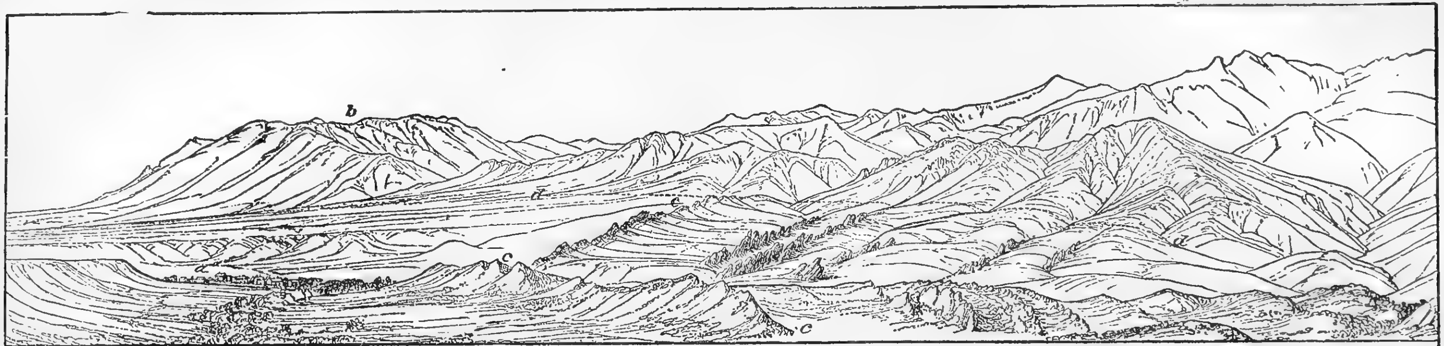


Fig. 1

View showing turn in Beds below the Garden of the Gods

a Colorado Springs
b Cheyenne Mountain
c No. 1 Cretaceous
d-d. Separating line between Granite and Sedimentary Beds

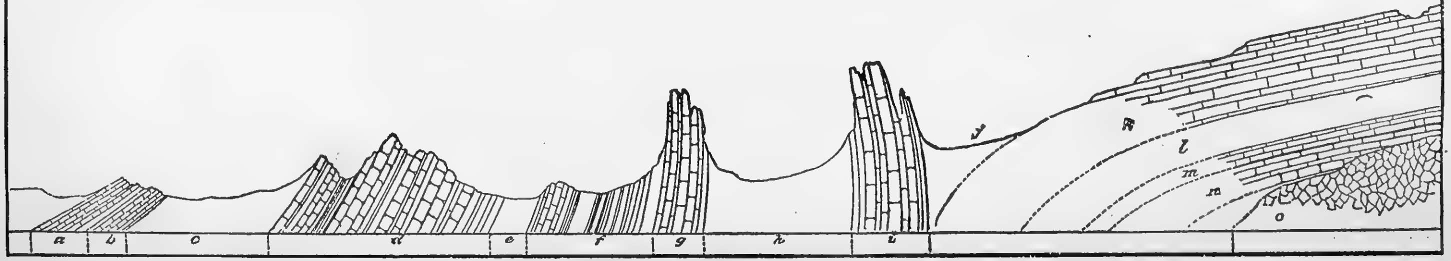


Fig. 2

Section from Glen Eyrie East

Section No. 3.

o. 1. Granite.

Silurian and Carboniferous (?) — *k, l, m,* and *n*.

2. Coarse grayish white sandstone, 20 feet.
3. Coarse dark-green sandstone, 4 feet....
4. Coarse gray sandstone, 6 feet..........
5. Brick-red sandstone, with green layers, 20 feet.............................. } ....40 feet.
6. Red and greenish limestone, 5 feet......
7. Irregularly laminated limestone, 3 feet..
8. Red limestone, 1 foot..................
9. Red shaly limestone, 1 foot............
10. Red limestone, 2 feet..................
11. Red limestone, with flint nodules, 7 feet. } ....19 feet.
12. Limestone, with interlaminated shales, 7 feet.
13. Red shaly limestones, with fragments of fossils, (Silur.,) 4 feet.
14. Gray purplish and yellow limestones, 279 feet.

Triassic.

j. 15. Space..............................
i. 16. Masssive red sandstones............... } about 1,000 feet.
h. 17. Space of 200 feet.
g. 18. White sandstone, becoming pink below 60 feet.

Jurassic. — *f*.

19. Calcareous shales, dark and light red, with green layers, 20 feet.
20. Pink-mottled shales, 1 foot.
21. Light-red sandstone, 2 feet.
22. Red calcareous shales......................
23. Green calcareous shales.................... } ..7 inches.
24. Brick-red shales, 6 inches.
25. Compact sandstone, 3 inches.
26. Fine-red calcareous shales, 6 inches.
27. Sandstone shale, 6 inches.
28. Gray arenaceous limestone, 5 feet.

e. 29. Space, 57 feet.

Cretaceous.

d.
30. Gypsum bed, 57 feet.
31. Soft gray sandstone, 3 feet.
32. Compact limestone, 2 feet.
33. Pebbly limestone, 2 feet.
34. Compact gray limestone, 18 inches.
35. Hard calcareous clay shales, 4 feet.
36. Space, 49 feet.
37. White massive sandstone, 200 feet.
38. White fine-grained sandstone, becoming yellow as we go down; again white near the bottom, we have a layer that is lignitic, containing fragments of stems and leaves. This is just below the yellow layer in which I found fragments of shells (*Lingula*) that were very indistinct.............................. } ...57 feet.

c. 39. Space, 150 feet.

Jurassic. — *a. b.*

40. White shaly limestone.....................
41. Bluish calcareous and argillaceous shales....
42. White shaly limestone, (fossiliferous)........ } ...36 feet.
43. Dark-gray limestone, (fossiliferous)..........
44. White limestone, with cross fracture.......... } ....46 feet.

This section extends over about three-quarters of a mile.

Beds No. 2 to No. 14, inclusive, have a dip of only 10°, and are all older than Triassic. From No. 13 down all is Silurian. Perhaps the limestones of No. 14 should be referred to a higher horizon. Beds Nos. 2 to 5 I have referred to the Potsdam group, while those just above are undoubtedly of the Quebec group, as in beds lithologically the same in the western side of the range I found characteristic fossils. I found in them *Terebratula* and *Crania*. In these beds, also in the Ute Pass, in 1869, Dr. Hayden found *Ophileta complanata*, *Bucanella nana*, (Meek,) and other species, from which Professor Meek referred the beds to the Calciferous division of the Lower Silurian.* The line of junction between No. 14 and No. 16 could not be seen, as it was covered with *débris*. The massive red sandstones of No. 16 (No. 16 of section No. 1, and No. 1 of section No. 3) are here tipped 5° past the vertical, and the weathering of these ridges has given rise to the peculiar forms seen in the "Garden of the Gods," and which have been fully described in previous reports. These sandstones have here the same general characters that we have noticed all along the range. They are still coarse-grained, giving evidence of their deposition in shallow waters. I was unable to get the thickness of the beds, but estimated it, including No. 18 and the space between, at about 1,000 feet. From No. 19 up to the bottom of No. 37, we have the layers that I have considered as Jurassic. In the gypsum bed (No. 30) I found some selenite and some fair pieces of satin spar. Nos. 37 and 38 represent the No. 1 Cretaceous, while the space just above, (No. 39,) which is in all probability filled with shales, belongs to the Fort Benton group. Bed No. 40 is filled with excellent specimens of *Inoceramus*, while in No. 43 we have quantities of *Ostrea*. This bed has the same bituminous odor on breaking that I noticed at points farther north. The dip of these beds is about due east, at an angle of 30°. This angle as we go down increases quite rapidly. At No. 40 it is 55°; at No. 38 it is 60°, and at No. 39, 65° to 70°; below this it decreases to 50°, and at No. 18 the beds are vertical, while the red-beds (No. 16) are tipped past the vertical, as we have already seen. Between Camp Creek and Monument Creek, a distance of about two miles and a half, there is a drift-covered mesa, in which the beds are entirely concealed. They belong probably for the most part to No. 4 Cretaceous, and perhaps the upper portion of No. 3. In the banks of Monument Creek we find the upper portion of the black shales of No. 4. In the bed of the creek, a few miles above Colorado City, we find a bed of hard, bluish limestone, which is in thin layers, and contains *Inoceramus* and other cretaceous fossils. Above this there are brownish and black shales, all more or less fossiliferous. Above the black shales we have a thin layer of sandstone, containing *Baculites* and *Ammonites*. Above this are sandstones. Above the cretaceous layers are the lignitic beds. These have been studied by Professor Lesquereux, and I refer to his report† for the details. I will only insert here a section made by him at Gehrung's coal-mine:

1. Brown laminated fire-clay or chocolate-colored soft shale, a compound of remains of rootlets and leaves and branches of undeterminable conifers	2 feet.
2. Coal, soft, disaggregating under atmospheric influence	2 feet.
3. Chocolate-colored clay-shale, like No. 1, with a still greater proportion of vegetable *débris*	6 feet.
4. Soft yellowish coarse sandstone in bank	8 feet.
5. Clay, shale, and shaly sandstone covered slope	130 feet.

*Report 1870, United States Geological Survey, page 287.
†Report 1872, page 325.

6. Soft laminated clay, interlaid by bands of limonite iron ore, thin lignite seams, and fossil-wood	88 feet.
7. Lignitic black clay, in banks	32 feet.
8. Fine-grained conglomerate	112 feet.
9. Fine-grained sandstone	4 feet.
10. Coarse conglomerate	7 feet.
11. Sandstone	3 feet.
12. Ferruginous hard conglomerate	32 feet.
	426 feet.

The coal found here is of poor quality, and at present I believe the mine is not worked. Professor Lesquereux found the following leaves in the sandstone, No. 4 of the section: *Sabal* leaves, *Platanus Haydenii*, Newb., *Dombeyopsis obtusa*, Lesq., and *Ficus tiliæfolia*, A. Br. Through the kindness of Mr. France, of Colorado Springs, I was taken to an outcrop of coal twelve miles east of Colorado Springs. We could see only the top of the coal-bed, which was exposed in the dry bed of a creek. I was told that the bed was 9 feet in thickness. All the coal I saw was of very poor quality, having been exposed for some time to the weather. Just above the coal, there is a bed of chocolate-colored clay shale filled with fragments of leaves and stems. This bed is about 2 or 3 feet in thickness, and above it is a very soft yellow sandstone, in which I found impressions of leaves, among which Professor Lesquereux has recognized *Rhamnus Cleburni*, Lesq., *Sabal* leaves, *Ficus spectabilis*, Lesq., a *Pali Urus*, and a *Quercus*. These plants characterize the layers as belonging to the lignitic group, as do also the beds at Gehrung's, to which they so closely correspond. The clay shale on top of the coal is precisely like the clay of No. 3, in the section made by Professor Lesquereux, while the yellow sandstone in which I found the fossils is evidently the same as No. 4. A short distance west of this outcrop, there are massive beds of white sandstones and conglomerates corresponding to the sandstones and conglomerates given in the section above the coal. These are the beds that, seen from Colorado Springs looking northward, appear like huge castle-walls. Even out on the plains they stand up in bluffs. Just west of them, at the latter place, I visited an opening that had been made in hopes (not realized) of finding coal. The shaft had been carried a distance of about 50 feet into a lignitic clay, corresponding, I think, to beds 6 and 7 of the Gehrung section. All these beds out in the plains are nearly horizontal, dipping perhaps 3° to the northward.

Returning again to the upturned sedimentary formations near the mountains, both the dip and strike vary considerably. Thus, in the Cretaceous layers on Camp Creek, it is 30° at the point where section No. 3 was made. This dip was taken on bed 44 of section No. 3. It represents a portion of the Fort Benton group. Following this to the southward, we find the dip increases rapidly. On the high ridge of Cretaceous No. 1, beds 37 and 38 of section 3, near Glen Eyrie, it is 65° to 70°. Going south, and crossing the "Fontaine qui boulé," the beds incline past the vertical; and still farther south, on Bear Creek, they are vertical. The dip then decreases after crossing Bear Creek. As we go westward, however, to the older formations, the angle of inclination is very much smaller. Thus in Glen Eyrie it is only 10°, while in the Ute Pass the older sandstones rest upon the granites, inclining at various angles, but never exceeding 20°. Returning again to the hog-back, we observe in Fig. 1, Plate III., that the strike also varies. Opposite

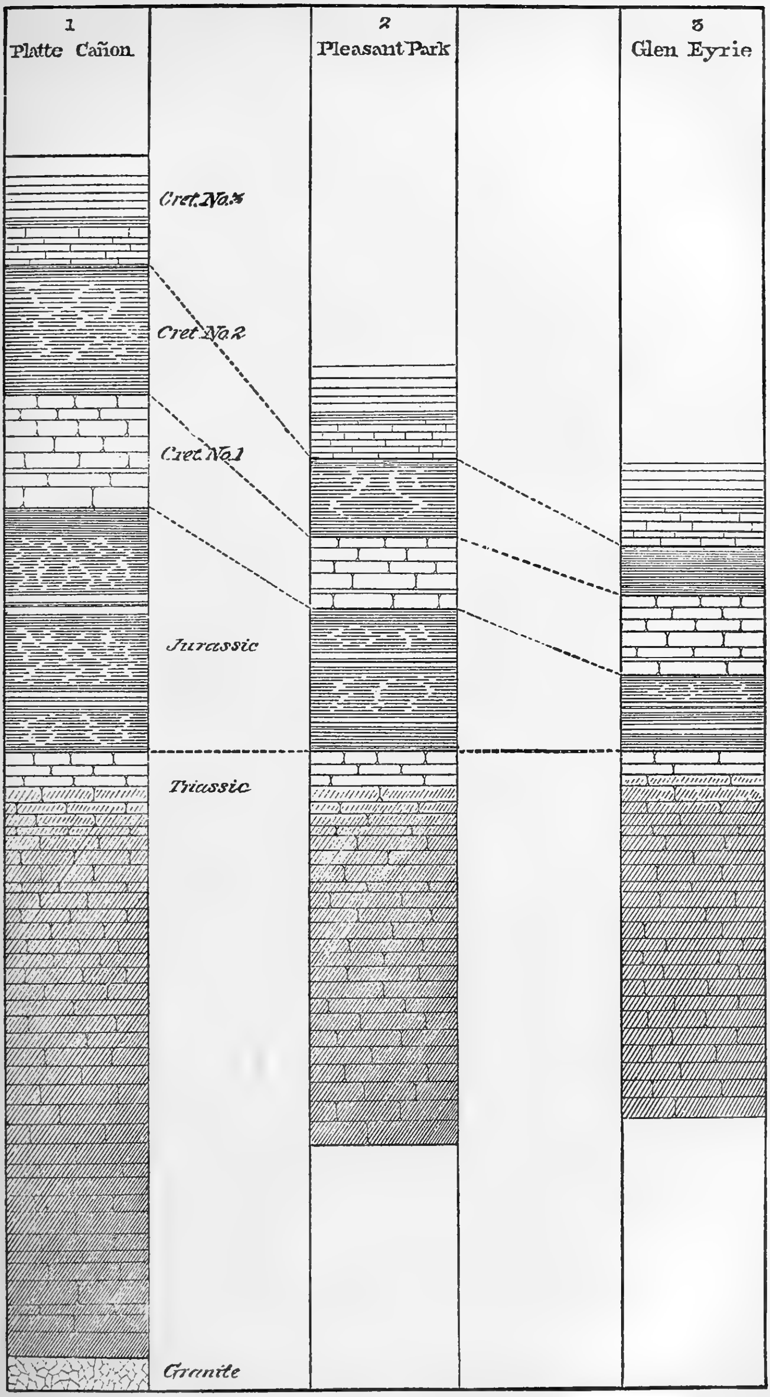
Glen Eyrie it is north and south. This turns slightly to the eastward, until we reach the "Fontaine qui boulé," when there is rather an abrupt turn to the west. Between the "Fontaine" and Bear Creek the strike is N. 40° east to S. 40° west. Where the strata cross the creek is still another turn to the eastward, and the strike here is north 25° east. On the south side of the creek is a more abrupt turn, and the strike is south 15° east. From this point southward the beds are entirely concealed, and do not appear again until we get south of Cheyenne Mountain, where they are in Dr. Endlich's district, and will be considered in his report.

In section No. 3, we have seen that the lower beds (Silurian) dip at an angle of only 10°, while the red-beds (Triassic?) just above are tipped 5° degrees past the vertical, and that the inclination of the succeeding layers becomes less and less as we go eastward, until on Monument Creek it is only 5°. This variation, especially the abrupt change from the Silurian to the Triassic, can, I think, be best explained as follows: After the deposition of the Silurian, and possibly the Carboniferous beds, there was an elevation of the range north of Pike's Peak, the peak itself being the center of elevation. Succeeding this, we have the period during which the red sandstones were deposited. These beds near the Silurian shore had a slight inclination, perhaps only a fraction of a degree. Then, after the deposition of the red sandstones and the succeeding layers, there was a second elevation of comparatively modern date, which tipped up the sedimentary formations as we now find them along the entire range. This force at the foot of Pike's Peak caused the slightly-inclined red-beds to be tipped past the vertical. The following explanation also is possible: It may be that the difference in the angle of inclination is due simply to a fold, and that the red sandstones that we ought to find resting on No. 14 of section No. 3 have from their softness been entirely removed, leaving only the vertical portions. If this be so, we should expect to discover beneath the surface that the lower limestones conform to the Triassic beds, (No. 16, section 3.) The case then would be analagous to that near Golden, which is described in Mr. Marvine's report.

At the foot of Pike's Peak, around the northeast side, during the Silurian age, a bay probably extended in to the westward. That it ever extended across to the west side is exceedingly improbable. The beds extend farther up on the hills here than at any other point north of the peak. At the South Platte River, in section No. 1, the Triassic (?) sandstones rest immediately upon the granite, and it is not until we get some distance south that we have any older beds exposed. At Pleasant Park we have Carboniferous beds beneath the Triassic layers, but it is not until we get to Glen Eyrie that undoubted Silurian shows itself. That both the Silurian and Carboniferous layers are beneath the red-beds (Triassic?) along the entire range is scarcely to be doubted. Their non-appearance to the northward can be readily explained. The force that elevated the range radiating from the center at Pike's Peak, and very likely also from Mount Evans to the northeast from the first point and eastward from the second, caused a general elevation of the plains to the northeast and east. This elevation would enlarge the ancient sea-border, and cause the succeeding deposits to overlap the older ones, and therefore rest immediately on the granite.

The same effect might of course have been produced by a general depression of the country. In this case, however, I think it is improbable that depression has been the cause. All the facts seem to point toward an elevation. The overlapping diminishes as we go southward. The

Plate 4.



Sections giving comparative thickness of sedimentary strata.

difference in dip between the Silurian and the Triassic in section No. 4, also points to an elevation rather than depression. Near Pike's Peak the force was direct enough to elevate the Silurian layers above the sea, and cause them to form part of the shore-line, while the border of the sea retreated to the eastward. To the north and northeast, however, the force was more widely distributed, the elevation more general, and we have the margin of the sea more to the westward. The widening of the sea-borders would, of course, result in a shallower sea, and the character of the red sandstones points to a comparatively shallow sea during their formation, while their structure shows them to have been derived in all probability from the red porphyritic granite found along the margin of the foot-hills from Denver southward.

Pike's Peak is composed of a very fine-grained reddish granite. It is a question whether the rock is eruptive or metamorphic; I incline, however, to the opinion that it is metamorphic. About the base of the peak I found, rather abundantly, good crystals of amazon stone (green feldspar) and smoky quartz.

It is doubtful whether the sedimentary beds ever extended across the range of foot-hills from the east to the west side. There is no positive evidence anywhere along the range that they did. No remnants are to be found on the plateau, and it is scarcely probable that the beds would have continued uninterruptedly across without having left some trace. The nearest approach is near the foot of Pike's Peak, where the older formations extend for some distance up on the hills near the Ute Pass; but this, as I have before said, is due to the existence here, during Silurian times, of a bay extending to the westward. I do not think it reached to the head of West Creek, although, as we will see further on, the Silurian beds on Trout Creek are exactly like those in Glen Eyrie. Taking a general view of the sedimentary formations along the eastern flank of the mountains, we see that the red sandstones have their greatest development near the exit of the South Platte from the mountains, and that as we go southward they become much thinner. This is shown by the sections in Plate IV. In No. 1, the section at the Platte, the red-beds have an approximate thickness of 2,000 feet, which at Pleasant Park, No. 2 in the plate, has decreased to 1,280 feet. At Camp Creek, section No. 3 in the diagram, I was unable to ascertain the exact thickness, as the line of junction between the red-beds and those next below was very obscure. I have, however, estimated the thickness at 1,000 feet. With the exception of No. 1 Cretaceous, the other beds also decrease to the southward, as seen in the diagram.

Considering the strike, we find that north of the divide, or Pinery as it is sometimes called, it is very uniform. Thus, at the Platte, it is north 25° west; at Willow Creek, north 35° west; and at Pleasant Park, north 30° west. Below the divide is a turn to the westward, and east of Glen Eyrie the strike is north and south. From this point, as we have already seen, the strike changes. I have already treated of the dips.

The Garden of the Gods, the springs, and the various beautiful cañons about the foot of Pike's Peak have been so fully described in previous reports that I will but refer to them here. It is to their attraction, perhaps, that Colorado Springs and the village of Manitou owe their prosperity. Within a year the former town has more than doubled, both in size and population. At Manitou is a large hotel for the accommodation of the visitors that every summer resort to the springs. There are also many beautiful cottages about the springs, and the springs themselves are inclosed in tasteful pavilions.

It will be necessary here to give only this year's observations, and for details the reader is referred to the reports of 1869 and 1872.

The water from one of the springs has been devoted to bathing purposes, and is conducted in iron pipes from the spring to bath-houses near by. The following temperatures were taken by Mr. Taggart:

Temperatures June 12, 1873.

Name of spring.	Time of observation.	Temperature, Fahrenheit, of spring.	Temperature, Fahrenheit, of air.
	P. M.	°	°
Shoshone	12.20	60	72
Navajo, or Bathing Spring	12.25	60	72
Manitou, or Doctor Spring	12.30	59	68.5
Little Chief	1.10	48	74
Iron Ute	1.20	54	72

Temperatures June 17, 1873.

Name of spring.	Time of observation.	Temperature of spring.	Temperature of air.
	A. M.	°	°
Shoshone	9.25	59	77
Navajo	9.30	58	78
Manitou	9.35	58	78
Comanche	9.38	60	78
Little Chief	10	45	74
Iron Ute	10.05	48	72
Spring on road near Ute Pass	10.25	53	70

The Shoshone, the Navajo, the Manitou, and the Comanche are on the "Fontaine qui bouilé" all being on the right bank except the Manitou. The Shoshone gives off a great deal of gas, the Navajo a medium quantity, while the Manitou gives out very little. The latter has the best tasting water. The Iron Ute and the Little Chief are on Ruxton's Creek, a short distance above the "Fontaine."

They are distinguished by having a larger percentage of iron than any of the rest. The "Little Chief" gives off a moderate amount of gas irregularly, while the "Iron Ute" is quiescent. The last spring given in the second table is on the bank of the Fontaine, near the Ute Pass road, a short distance below the falls. Its water is very agreeable to the taste, but as the spring is some distance from the others, it is not so generally used. Leaving the eastern side of the mountains, we followed the "Fontaine" to its head, through the beautiful and picturesque cañon which it has cut in the granite. Near the head of the creek we again meet with the sedimentary formations, having a dip to the north and northwest. Following the beds to the northward, the dip turns more and more to the west. The northerly dip is, therefore, the result of the elevation of the mass of which Pike's Peak is the center. Leaving the Fontaine, we cross to the head of Trout Creek, the branches of which drain the country to the northwest of Pike, and, flowing northward through Bergen Park, empty into the South Platte in the cañon. At the extreme head the creek is among granites and schists. Just above Bergen Park the main stream flows through a small cañon, in which we have outcrops of a dark purplish red sandstone, seemingly very much metamorphosed, and having a dip to the east. Just above this is a soft, grayish sandstone, on top of which is a red sandstone like that beneath. These outcrops are indistinct, and the angle of dip could not be ascertained. Emerging from this cañon we come out into an open valley, in which there is a small settlement clustered about a saw-mill. The rocks are all covered with *debris*, and the eastern side is so heavily timbered that little can be seen. As we approach the range to the eastward we will doubtless find the same beds that we see so well exposed to the northward with a westerly dip. At the lower end of the valley the creek enters a cañon, of about a mile and a half in length, in the granites, from which it flows into Bergen Park. The park is about eight miles in length, and will average about three in width. It is, I think, the axis of a synclinal fold, although I cannot be positive, as everything on the western side is so much obscured. The beds seen in the small cañon referred to above dipping to the east, and a few indefinite exposures farther south seeming to dip in the same direction, point toward the existence of a synclinal fold, the center of which is filled with red sandstones, (Triassic.) Through this park the creek flows in a direction a little west of north. At the lower end we have monument-like masses of red standstone resembling those seen east of the mountains. These red-beds have a westerly dip, and incline at very low angles, not exceeding 10° to 15°. At the lower end of the park the creek enters a cañon-like valley, which is about a quarter of a mile in width. At the entrance to this valley there are on either side the massive red sandstones which on the west side rise in high bluffs. On the east side the surface of the country is more rounded and smoothed off, while we have numerous cañons cut by the streams that drain the western side of the Front range. Following up the first small creek that joins the main stream after it enters the valley, we observe that the red-beds become lighter and lighter in color until they are pink. They are also conglomeritic. These lower layers are followed by massive white limestone; this limestone is succeeded by white and pink shaly limestones, which are superimposed on sandstones that rest on the granite.

The following is a section from the red-beds down. The thicknesses are estimated:

1. Red-beds.	
2. Red and pink conglomeritic sandstone	50 feet.
3. White massive limestone	100 feet.
4. Shaly white limestone	
5. Pink limestone, somewhat shaly	30 feet.
6. Green sandstone	4 feet.
7. Brown purplish sandstone	6 feet.
8. Yellow sandstone.	
9. Granite.	

The angle of inclination is 5 to 10°.

As we go down Trout Creek the sedimentary beds are influenced by the mass of mountains to the northward. The strike of the beds crosses the creek, and instead of the bluffs on the west side of the creek being red sandstones, they are first the massive white limestone and then the pink limestones underlaid with sandstone. The creek then enters a granite cañon, which has here and there isolated points capped with remnants of the sandstones under the limestones of the section given above. The dip as we go down the creek changes more and more to the southward until, just above the cañon, it is south 25° west. Still farther below it is south 85° west. The following sections are made across Trout Creek, just above the cañon, the head of which is a few miles below the foot of Bergen Park. Section No. 4 is made through the bluff on the west side, while No. 5 is made on the east side; both are in ascending order:

	No. 4. Feet.	No. 5. Feet.
1. Granitic.		
2. Yellow sandstone	73	65
3. Pinkish sandstone		
4. Dark, purplish-brown sandstone	16	13
5. Green sandstone	4	3
6. Blood-red calcareous sandstone	54	60
7. Pink limestones		

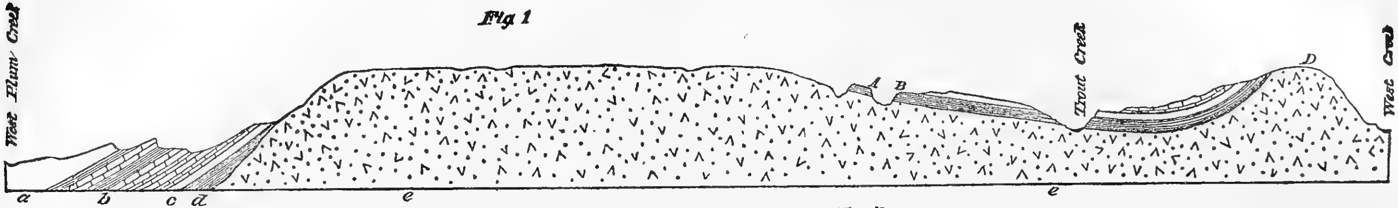
Beds No. 6 and 7 are fossiliferous, and belong in all probability to the Quebec group, while the sandstones below are Potsdam. In No. 6 I found *Lingulepis* and *Obolus*, and in No. 7 an *Orthis*, which Professor Meek says is very much like *O. desmopleura*, Meek. Also, *Euomphalus*, *Asaphus*, (*Megalaspis*,) *Conocoryphe*, *Lingula*, *Bathyurus*, and *Paradoxides* or *Olenus*. On the east side of the creek, in bed No. 2, are several small faults, which are merely local. In the cañon the course of the creek, instead of being north, is about northwest. It is there joined by West Creek, which, for most of its course, is parallel to Trout Creek, from which it is separated by a granite ridge. The cañon at the time of the year we visited it was impassable. Ascending the hills we see all about us patches of sedimentary beds. In some places we have merely portions of the lower yellow sandstone, mostly soft, but often quartzitic, while in other places we will see all the sandstones and portions of the overlying pink limestones. Fig. — is a section from West Creek across Trout Creek and the plateau eastward to Pleasant Park, a distance of about eleven miles. It will be seen that the dip on the west side of the range is very much less than it is on the east side, and that the beds extend farther up on the plateau. This appears to indicate that the beds may have extended across the range. Section No. 6 was made at the point marked C in the Fig. 1, Plate V, and is from below upward.

Section No. 6.

	Thickness in feet.
1. Red limestone, (fossiliferous)	26
2. Light shaly limestone	20
3. Red limestone	34
4. Purplish sandstone	
5. Mottled limestone	3
6. Yellowish-white limestone	20
	103

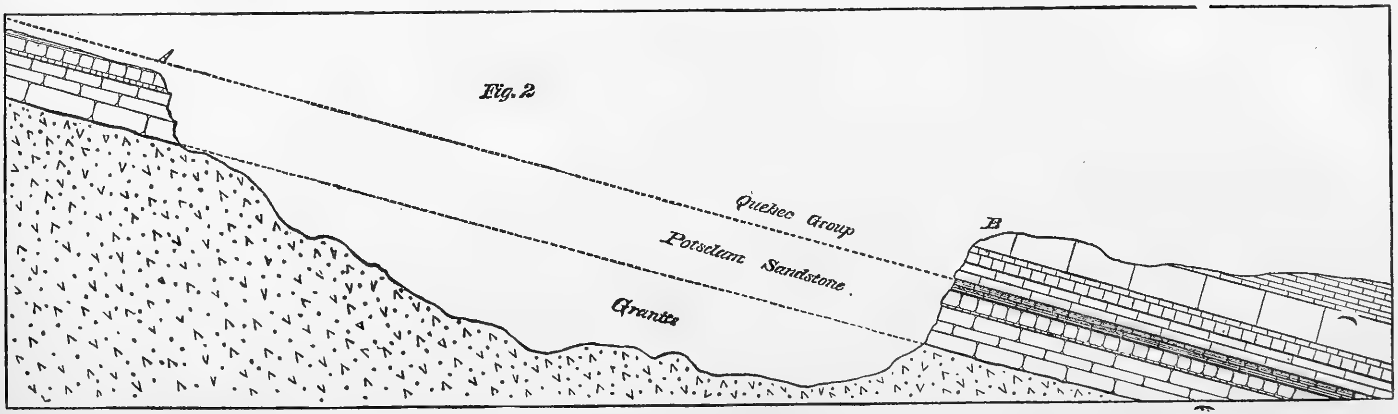
Plate 5.

Fig 1



Section across the Front Range—11 miles

Fig. 2



Section at AB. of Fig. I

The lower part of the bluff is covered with *débris*, but as seen from the other sections made near this locality, is probably composed of the Potsdam sandstone. Bed No. 1 contains *Orthis*, *Bathyurus Saffordi*, (Billings,) and *Lingulepis* or *Lingula*. Whether the yellow limestone, bed 6, belongs to the Silurian or to the Carboniferous is uncertain. Careful search revealed no fossils. I think it probable that it is the equivalent of the Niagara limestone. The angle of inclination of these beds is 15°. Just above we have beds of massive white limestone. Going westward we pass over a rolling country which, as a few outcrops indicate, is underlaid by soft red and gray sandstones, the latter being above the red-beds, and dipping at an angle of from 10° to 12°. We then begin to ascend the hills, and find them so covered with *débris* that very little can be seen. I think, however, that the illustration, Fig. 1, Plate V, presents the correct view of the beds. The ridge above West Creek is granitic, giving a red *débris*. The elevation of the ridge is about 7,556 feet.

Returning to the east side of Trout Creek and following one of the little streams toward its source, we find that only the Silurian layers are to be seen resting on the granite. Section No. 7 is made at the point B in Figs. 1 and 2, Plate V.

Section No. 7.

	Thickness in feet.	
1. Granitic.		
2. White and yellowish sandstone	43	67 ft.
3. Pink sandstone	16	
4. Dark purplish-brown sandstone	5	
5. Green sandstone	3	
6. Brick-red shaly limestone	19	
7. Pale-pink and gray limestones	16	
8. Pink limestones.		

About 6 feet below the top of bed No. 3 is a layer of pink quartzite which, at the point where the section was made, was only 2 feet in width. On following the bed northward, however, it increases to 4 or 5 feet. At the top of No. 3 is a shaly layer 2 feet thick, in red and pink bands. Nos. 4 and 5 are alike except in color. They are very coarse-grained and soft. The red limestones (No. 6) are full of green spots, probably glauconite. In the limestones the same fossils occur that we found on Trout Creek. They cap the hill. Between B and C in the figures on Plate V huge granite boulders are strewn over the surface. The granite is soft, and readily disintegrates. The feldspar is red orthoclase and the mica black. Masses in some places have weathered into forms resembling those found in Monument Park. At the point C we have only the lower sandstone, beds 2 and 3, and those here seem to be much changed. Standing on this hill we see all about us similar monuments capped with fragments of beds. We can also see Platte Mountain, to which we have alluded before. There seems to be a line of these jagged granitic points, the course of which is northwest and southeast, Platte Mountain and the Palisades, near the Platte River, being the most prominent. South of Platte Mountain these detached points show merely the general course. A comparison of the sections given above shows that the Potsdam group is represented by sandstones having a thickness of from 60 to 80 feet, while the beds that represent the Quebec group are a little over 100 feet thick. Comparing with the section (No. 3) made at Glen Eyrie, we see that the beds on the west side of the range are thicker. Thus, instead of 60 to 80 feet of the Potsdam, in Glen Eyrie, we have only 40 feet. The beds correspond, beds 2 to 5 of section No. 4 being the same as 2 to 5 of No. 7. So it is with the limestones above. At Glen Eyrie we have 73 feet where there are over a hundred on Trout Creek. Bed 14, of section No. 3, is, I think, the same as the white limestone above the pink shaly limestones on Trout Creek. Returning again to the head of Trout Creek we cross into Hayden Park. This name has been given to the low rolling country to the west of Pike's Peak. Hayden Park is drained by Trout Creek, West Creek, and Beaver Creek. The latter flows to the northwest, and empties into the South Platte just below the upper cañon. About five miles from its mouth, around the settlement of Florissant, is an irregular basin filled with modern lake deposits. The entire basin is not more than five miles in diameter. The deposits extend up the branches of the creek, which all unite near Florissant. Between the branches are granite islands appearing above the beds, which themselves rest on the granite. Just below Florissant, on the north side of the road, are bluffs not over 50 feet in height, in which are good exposures of the various beds. The following section gives them from the top downward:

1. Coarse conglomeritic sandstone.
2. Fine-grained, soft, yellowish-white sandstone, with bands that are more or less argillaceous, and containing fragments and stems of leaves.
3. Coarse gray and yellow sandstone.
4. Chocolate-colored clay shales with fossil leaves. At the upper part these shales are black and below pass into
5. Whitish clay shales.

These last form the base of the hill. The beds are all horizontal. Scattered around are fragments of a trachyte which probably caps the beds. In one of the valleys, Mr. Taggart discovered, near an old well, pieces of trachyte, which, on looking at the excavation, was found to be the first layer penetrated. The point of overflow from which this material came is probably to the southward, in Dr. Endlich's district. The lake basin may possibly be one of a chain of lakes that extended southward. I had thought it possible that the beds were of Pliocene age. The specimens obtained from bed No. 4, of the section above, were submitted to Professor Lesquereux, who informs me that they are "Upper Tertiary." "But I do not believe, as yet, that the specimens of the Green River group to which your species are referable, authorize the conclusion of Pliocene age. I rather consider it, as yet, as Upper Miocene. The species known of our Upper Tertiary are as yet too few and represented in poor specimens for definitive conclusion. Your specimens have a *Myrica*, a *Cassia*, fragments of *Salix augusta*, (A. Br.,) a *Rhus*, an *Ulmus*, and a fragment of a *Poa* or *Poacites*."

The shales were so soft and friable that it was rather difficult to obtain any specimens.

About one mile south of Florissant, at the base of a small hill of sandstone, capped with conglomerate, are 20 or 30 stumps of silicified wood. This locality has been called "Petrified Stumps" by the people in the vicinity. The specimens of wood are not particularly good.

The upper cañon of the South Platte River is about eight miles in length, and marks the exit of the river from South Park. The range in which it is, if it deserve that name, is the eastern boundary of the park. The rock is all granitic to the northward and to the northeast. South of the cañon is an area of volcanic overflow which extends southward into Dr. Endlich's district, and I will only refer to it again in the next chapter in connection with South Park. The rocks to the north of the cañon were very carefully studied as far as the time would permit by Mr. Taggart, and I will therefore quote largely from his notes. "Going south from the road that leads from Colorado Springs to South Park is a granitic ridge running out into the park, and having a westerly direction. Passing southward we find a light grayish granite standing up in rough, jagged points. They seem, looking at them from one side, to have been thrust up through the coarse beds that lie about it. More conclusive proof of this was found farther along on the southern slope, where I could see the coarse beds tipped up against the lighter-colored and more compact granite, with a dip of about 10°. They then sloped gradually to the bottom of a narrow valley, which is the axis of a synclinal fold, for on the opposite side were the same beds and resting on the same kind of granite. Passing still farther along the ridge I found still another synclinal. The compact granite rises in sharp conical peaks. After passing three of these peaks the ridge becomes flatter and continues to the cañon. As we skirt the base of the ridge we find first a red feldspathic schist bending slightly against the base of the third cone. The dip is west of north, at an angle of not more than 5°. Still farther along we find beds of micaceous gneiss dipping in the same direction, at an angle of 10°. This is followed by a very coarse and then fine, compact granite. The bedding one mile from the cañon shows a dip of 60° to the northwest. As we go toward the cañon it increases. Beyond the cañon the beds continue dipping at about the same angle as in the cañon.

"Going eastward along the cañon, the same beds with the same dip are exposed. The granites are much broken at right angles to the bedding, so much so as to make it somewhat difficult to determine the inclination. To the south of the cañon there is a gradual rise in the ridge until it terminates in a high cone.

"North of the road is a ridge with a series of high points and rather open valleys between. The highest of these points is the one next the opening through which the road to Fair Play passes. This ridge is not a continuation of the one described above, but is parallel with it. The latter is more to the south and west, and the axis of upheaval seems to pass out under the park. The other ridge extends about five miles to the southeast, and presents the same general features as the one first described. The eastern part is low, rising gradually toward the north until within a few miles of the northern extremity, when the greatest height is attained in a conical peak of light gray granite, then gradually sloping to the park, the slope being broken by a few valleys. On station 35, one of the points north of the road about half a mile, the gneiss dips nearly north."

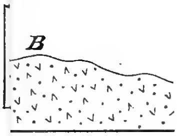
In the irregular triangular space between this range of hills on the east side of the park, which Mr. Taggart refers to above, and the Platte River and Tarryall Creek, is a beautiful rolling park-like country, which, although for the most part covered with *débris*, is plainly seen to be underlaid by granitic rocks. The following is from the notes of Mr. Taggart: "On the northeast side of Tarryall Creek are three high ridges, the general trend being northwest and southeast. There are two main ridges which to the north unite, inclosing a third which has a less elevation. The dip on the southwest side is to the southwest, forming a synclinal with the ridge on the east side of the park. On the summit the beds are horizontal, and then there is a dip to the northeast, and another synclinal is formed with the ridge farthest removed, forming the saddle northwest of the middle ridge. On the southwestern slope of the second main ridge there are very few outcrops to be seen through the trees which cover it. At the northwest end there is a dip to the northwest, while at the opposite end the dip is to the southeast."

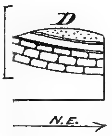
In passing up Tarryall Creek the prevailing dips are to the northeast and southwest. The dip is the same in the country about the North Fork of the Platte, as is shown by the course of the stream, which is about parallel to that of Tarryall Creek. The latter, as far as could be ascertained, flows through a synclinal axis. Along the Platte River are high masses rising in dome-shapes above the cañon. The study of this part of the country would require the work of almost an entire season. The different streams should be followed, and this can be done only in the latter part of the season. We were there in June, and I attempted to follow the Platte River, but found it impossible, not only on account of the rough and difficult traveling, but also because the stream was then at its highest point. The whole country is probably archæan. There may be, and most likely are, points of eruptive material, but, as I have said above, close study will be required to work up this district thoroughly. Our time was too limited to do more than take a general glance at the most salient features. We have seen that on the North Fork and on Tarryall Creek the strike is from northwest to southeast, and that as we go south this changes and becomes northeast and southwest. This change is shown also by the change in the course of the Platte when it enters the upper cañon. Before that it flows from the northwest, but in the cañon its course is toward the northeast.

CHAPTER II.

SOUTH PARK—PARK RANGE.

This chapter will be devoted to the consideration of the remainder of the district lying to the east of the continental divide. This comprises South Park. The park is about forty-five miles in length, and somewhat irregular in shape, being widest at the southern end, where it is about forty miles from east to west. Its surface is very irregular. As the drainage shows, there is a gradual slope from the northwest toward the southeast. At the northwest end, the elevation is from 9,372 to 9,981 feet above sea-level. The elevation of Fair Play is 9,764 feet. As we go east this decreases until we have an elevation of a little over 8,000 feet, and as we go south we notice the same gradual decrease. Thus, at the salt-works the elevation is 8,573 feet. In the southern portion of the park, the elevation is more uniform than in the northern part. Still, the slope is toward the southeast, and where the South Platte enters the cañon the elevation is only 7,991 feet. There are numerous ridges running through the park, generally parallel to each other. Thus, starting at Fair Play and going eastward, the first is a low ridge a couple of hundred feet in height. Crossing this, we descend to Crooked Creek, and then ascend a second ridge that rises 500 feet above the valley. On the east side of this ridge is the valley of Trout Creek, and beyond it a third ridge rising to about the same height, perhaps a few feet higher. East of this is a low rolling country extending for some three or four hundred miles, bounded by a series of rounded hills rising about 600 or 800 feet above the general surface. These hills extend for a few miles, and then there is a space having an almost uniform level





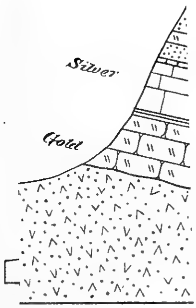
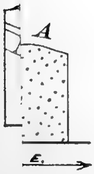


Fig. 6



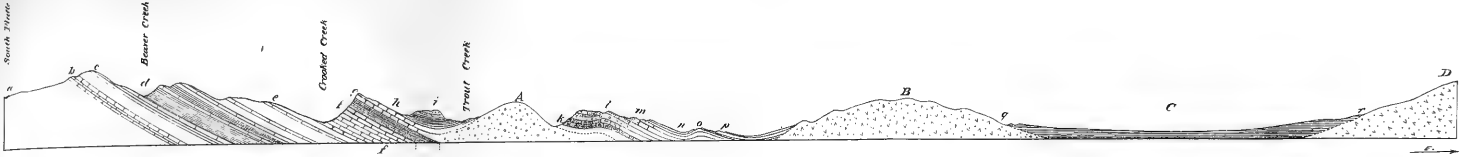


Fig.1 Section across South Park

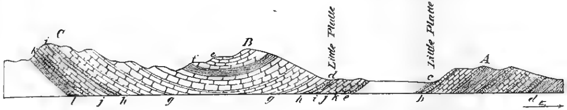


Fig.2 Section across the Little Platte

Fig.3 Section near Hoosier Pass

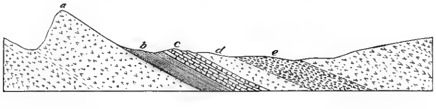


Fig.4 Section from Mt. Guyot, East

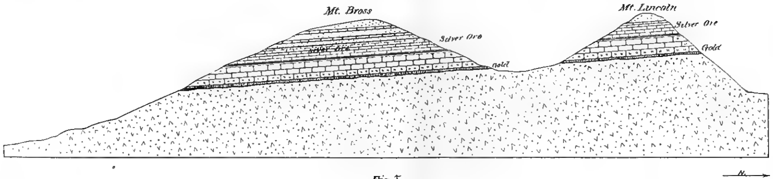


Fig.5

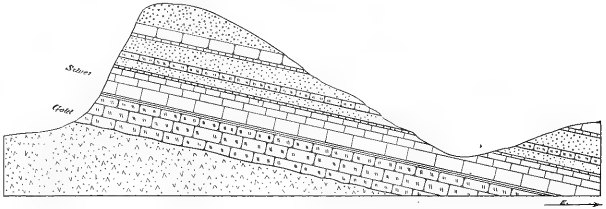


Fig.6 Section though Mt. Bross

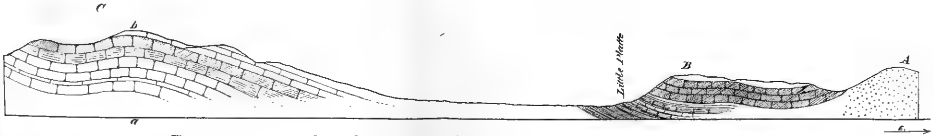


Fig.7 Section across the Little Platte above the Salt Works

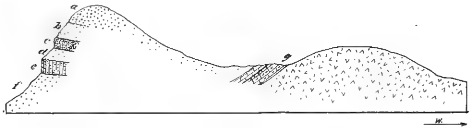


Fig.8 Section through Buffalo Peak

from which the hills bounding the park on the west rise. In the south end of the park are numerous isolated buttes, the majority being of volcanic origin, although some are composed in part of sedimentary formations. They will be referred to again in subsequent portions of the chapter. Almost the entire southern end of the park is volcanic, and the country gradually rises from the South Platte River to the divide, and then slopes to the Arkansas River. The outlet of the lake existing here in early Tertiary times was probably in this direction. The eruptive forces acting after the deposition of the lignitic sandstones elevated this part of the country, and the water had to find an outlet in a new direction. It was then that the present drainage was probably outlined. The lake was most likely drained through the Platte cañon at the southeast end of the park. The lake itself must have extended farther to the southward than the present outlines of South Park would seem to indicate. The mountains on the east side of the park, as we saw in the last chapter, are composed of schistose rocks which extend westward some distance into the Park. The outline is rather irregular, but the general course of the range is northwest and southeast, and, as we have seen, the dips are to the northeast and southwest. The range is therefore an anticlinal axis, which, as we go south, bends to the eastward. The elevation is over 10,000 feet above sea-level and over 1,500 feet above the park. The northeast boundary of the park is a continuation of the schists, identical with those on the east except that here the hills are capped very frequently with eruptive material, mostly trachyte. On the more uniform level of the park, the sandstones are but little disturbed. As we shall see further on they are of Tertiary age. The volcanic rock extends around the northern edge of the park, close to it, not extending far to the northward until we get around to the northwest. It seems to have been an overflow, as I found in several places that it capped hills whose bases were composed of dark micaceous gneiss. The hills that rise above to the northward are also metamorphic. On one of the branches of Michigan Creek, extending some distance up the valley, is a tongue of sandstone, a prolongation from those in the park, probably outlining an old bay. The upper edge of this narrow belt, bounded on one side by trachyte, and on the other by granite, was found by Mr. Gardner to be 500 feet above the general level of the park. A period of elevation in the range north of the park, therefore, must have taken place after the deposition of this sandstone. The granites and schists form the basis of the range north of the park until we get to Mount Guyot, when eruptive rocks are seen at the head of Michigan Creek, near Mount Guyot. This mountain has an elevation of 13,389 feet, and is on the continental divide, which, on the west side of the Arkansas, has a direction nearly north and south, and then turns to the east around the head of the river, and again, beyond Mount Guyot, turns abruptly to the northward toward Gray's Peak. Just east of the mountain is a low saddle, forming the water-divide between Michigan Creek and the waters of Snake River, one of the tributaries of the Blue River.

On this saddle (Georgia Pass) we have the following section, shown in Fig. 4, Plate VI:

(*a.*) 1. Erupture granite forming the peak.
(*b.*) 2. Hard gray slate.
(*c.*) 3. Quartzite.
(*d.*) 4. Coarse gneiss, light colored.
(*e.*) 5. Black micaceous gneiss.

This latter, (No. 5,) as far as could be ascertained, extends eastward for some miles. Bed No. 4 is very coarse, with white feldspar and a silvery mica. The quartzite and slate are both very much changed, and are each about 60 feet in thickness. The slate weathers on the surface a rusty-brown color. The dip is south 55° east; angle of inclination, 50°. I am at a loss as to the position of these beds. They are fragments that have been caught and lifted up, but they are so changed and too few in number to say anything definite of them. They could not be traced to the southward, and our time was too limited to try and follow them to the northward. The mountain itself is composed of a fine-grained granite of a gray color, and, I take it, is eruptive. In it are seams of a dark-green porphyritic rock, in which the matrix is very compact, the crystals being a white feldspar. The mountain has been called Crater Mountain, a name derived from its peculiar crater-like shape. Ascending the eastern side on a slope of about 30° over a mass of shingle-like *débris*, on reaching the summit we are on the edge of a crater-like depression, the walls being perfect, except on the southern side. It is not, however, a true crater, the shape being the result, in all probability, of erosion, due partly, perhaps, to past glacial action. This form is common in the mountains on the west side of the park and in the Sawatch Range on the west side of the Arkansas. In the latter we have abundant evidence of former glacial action in the moraines, which, as we shall see further on, are found along all the streams. Besides the depression below the main peak there are three others, two facing the south and one looking toward the north. Between Tarryall Creek and Michigan Creek are high hills or mountains composed of a porphyritic volcanic rock, approaching the character of a phonolytic trachyte. The summits of these hills are rounded, and their slopes are covered with slab-like masses, which, on the surface, weather to a rusty color, and ring under the blows of the hammer. Following the edge of these hills around to the town of Hamilton, on Tarryall Creek, and then going up stream a short distance above the town, an outcrop of quartzite appears, dipping a few degrees to the south of east under the volcanic (?) rock. At this point is an abrupt turn in the course of the creek. Until it reaches this place it follows the strike of the quartzite, but here breaks through them at right angles. Beneath the quartzite is a soft grayish-white sandstone, and in the banks of the creek are exposures of red sandstone. The quartzite and gray sandstones are, doubtless, Cretaceous No. 1, and a continuation of beds farther southward, between Trout Creek and Crooked Creek. They are in line with them, and the strike corresponds precisely. The red sandstones are Triassic, and have a dip of about 5°. They form the bed-rock upon which the auriferous gravel rests. This gravel is about 10 feet thick, and has yielded a great deal of gold. The mines in this vicinity are treated of in Dr. Endlich's report. About five miles west of Hamilton is the mountain called Silver Heels, having an elevation of 13,731 feet. We ascended it, and on the eastern slope I made a partial section of it, as follows:

Section No. 8.

1. The summit of the peak is made up of an eruptive rock resembling that in the hills above Hamilton. This, with a few layers of coarse micaceous sandstone, sometimes conglomeritic, extends for about 1,500 feet. The slope here is very small, only about 5°, and the beds are so covered with *débris* that it is impossible to define them.
2. Metamorphosed sandstone and volcanic rock. The sandstone contains rather large rounded pebbles. The volcanic rock is beneath

the sandstone, and is probably trachyte. The thickness of both is 117 feet.

3. Green and purplish sandstone shales, very much metamorphosed, 60 feet.
4. Volcanic, (trachyte ?) 4 feet.
5. Purple metamorphosed slates, 5 feet.
6. Volcanic, (trachyte ?) 4 feet.
7. Coarse brown sandstone, very much metamorphosed, but rather uniform in structure, 100 feet.
8. Volcanic, (trachyte ?) about 20 feet.
9. Very hard, dark sandstone, in layers, 6 or 8 inches, 50 feet.
10. Light-brownish sandstone with streaks of dark-brown, 30 feet.
11. Volcanic, (trachyte ?) 20 feet.
12. Dark-gray sandstone, 70 feet.
13. Volcanic, darker than the other layers. The lower portion is covered with *débris*. Thickness, about 80 feet.
14. Red shales very much metamorphosed. These shales break into laminæ of about an inch thickness, and are micaceous. There are mud and rain marks between the laminæ, 8 feet.
15. Greenish-gray quartzitic sandstone, 10 feet.
16. Volcanic: this layer has a wedge-shape, and on the surface its thickness is about 20 feet.
17. Red shales, 10 feet.
18. Pinkish sandstone, very irregular in structure, 8 feet.
19. Red shales, 10 feet.
20. Light-gray conglomeritic sandstone, 4 feet.
21. Red shales, 4 feet.
22. Gray sandstone, becoming coarse toward the bottom, having large pebbles: above, it has a pinkish tinge; 10 feet.
23. Hard-red sandstone in laminæ of 2 to 3 inches, 5 feet.
24. Compact sandstone, with general color gray, but becoming pinkish as we go down, 30 feet.
25. Red shales, 4 feet.
26. Compact sandstone, pinkish and calcareous above, gray below, 5 feet.
27. Dark-blue limestone, containing veins of calcite, and without fossils, 2 feet.
28. Red and purple shales, darker in color than those given above, 3 feet.
29. Compact sandstone, light-gray, 5 feet.
30. Red shales, 2 feet.
31. Volcanic, (trachyte ?) 6 feet.
32. Dark purplish-red sandstone, breaking into blocks, 30 feet.
33. Red and purplish shales, 3 feet.
34. Greenish-gray sandstone, banded and streaked with green in layers from 2 to 3 feet thick, some conglomeritic, 25 feet.
35. Hard, red sandstone shales, 2 feet.
36. Hard, red sandstone, 1 foot.
37. Greenish-gray sandstone, with bands of brown sandstone shale from 1 foot to 2 feet thick, 15 feet.
38. Red shale, 1 foot.
39. Brown-banded sandstone, with bands of volcanic, 50 feet.
40. Red, gray, and purplish sandstones, 20 feet.
41. Greenish conglomeritic sandstone, 6 feet.
42. Brown sandstone, 8 feet.
43. Very hard greenish sandstone, 6 feet.
44. Light-gray sandstone, 10 feet.
45. Volcanic; could not get thickness.

From this point, there is a slope with occasional outcrops of red shales and greenish sandstones, all rather coarse. These no doubt continue to the red-beds (Triassic ?), above which is Cretaceous No. 1, to which I referred above as crossing Tarryall Creek above Hamilton. Beyond this is a hill of the same material as that resting on the same bed (Cretaceous No. 1) on the north side of the creek. This slopes to the park, where the Tertiary sandstones appear. The distances in the section given above are all estimated. For want of time, I was unable to carry the section any farther to the eastward, but the sections made in the park at points farther southward comprehend it. Silver Heels is drained on the south by the branches of the South Platte, and is hollowed out, leaving the high ridge on which the section is made standing out prominently. The volcanic layers seem to be intruded masses which have so changed the sedimentary beds and hardened them that they have been able to resist the eroding influences, and the result is this prominent ridge. Leaving Hamilton, and still keeping close to the edge of the mountains, in going around the northwest rim of the park, we notice after crossing Tarryall Creek that the Tertiary formations extend to the edge of the mountains, which here are volcanic. Near McLaughlin's ranch is a coal-mine. This was visited by Dr. Hayden, and will no doubt be fully treated of by him. The Tertiary beds here are so covered with drift that they are almost entirely concealed. Following the road southward we pass around the edge of a trachytic hill, and come across cretaceous shales belonging in all probability to the Fort Pierre group, (No. 4.) They are found in a valley between the hill just referred to and a low volcanic ridge that runs out into the park. Crossing this ridge we again pass over the shales. Here is a well-marked terrace on a small branch of Tarryall Creek. It is about 100 feet in height. Terraces are to be seen on almost all of the branches of Tarryall in the northwestern part of the park. Just south of the terrace referred to is a long volcanic ridge, the course of which is almost due north and south. I have already spoken of this ridge, which is shown in the profile across the northern end of the park. The following section was made from the Platte River eastward to Trout Creek, about five miles north of Fair Play, and is shown in Fig. 1, Plate VI. The length of the section No. 9, given below, is about six miles. The distances and thicknesses are estimated, the average dip being about 30° toward the eastward.

Section No. 9.

a. 1. Starting from the Platte River, the point *a* in the illustration, we have the valley covered with drift to the edge of the hills, a distance of about a mile. We then begin to ascend the hills, which are well timbered, concealing the beds. From the character of the *débris*, I think there is volcanic rock beneath. The first exposure we met with furnished—

b. 2. Red sandstone shales: thickness, 400 to 500 feet.
Then followed:
3. Gray shaly sandstone.
4. Brownish limestone.
5. Red shales.
6. Very coarse white micaceous sandstone. These beds are indicated by very indistinct outcrops, and are from 500 to 600 feet.
Then we have next—

c. 7. Limestone mostly of a grayish color or grayish-blue, in some places brownish, compact in some layers, and then again irregular, with seams of calcite. Thickness, 6 feet.

d. 8. Space: this is marked by the letter *d* in the illustration, and is the valley of Beaver Creek. The beds are covered up. Probably a thickness of 700 or 800 feet.
9. Very coarse and somewhat massive red sandstones, about 100 feet.
10. Space of about 400 feet.
11. Dark-blue limestone, 5 feet.
12. Space with a few indistinct outcrops of sandstone and limestone, about 700 feet.
13. Coarse red sandstones in massive layers, 300 feet.
14. Space probably filled with sandstone at bottom, shale above, 300 feet.
15. Deep-red shales, 90 to 100 feet.
16. Blue limestone, 4 to 6 feet.
17. Red sandstone, coarse and shaly micaceous, 30 feet.
18. Gray micaceous sandstone, about 5 feet.
19. Dark-blue limestone, 2 feet.
20. Space filled with shales, 3 feet.
21. Dark-blue limestone, with irregular structure, 5 feet.
22. Mottled red and white sandstone shales, weathering red, 5 feet.
23. Blue limestone, coarser than below, and in thin layers, 2 feet.
24. Space covered up, but filled in all probability with shales and interlaminated limestones, about 120 feet.
25. Dark-blue limestone, 2 feet.
26. Very coarse soft shaly sandstones, below and next to the limestone, having rounded pebbles of quartz. At the top they are finer grained and softer; the color becomes deeper as we get toward the middle, where it is brick-red, and then becomes pink at the top, 10 feet.
27. Blue limestone, 1 to 3 feet.
28. Space probably filled with shales, 40 to 50 feet.
29. White and red micaceous shaly sandstones, 40 feet.
30. Coarse sandstones, 10 feet.
31. Dark-blue limestone, 4 feet.
32. Space covered up, but filled in all probability with sand shales, 4 feet.
33. Blue limestone, 4 feet.
34. Space shales, (?) 90 to 100 feet.
35. Dark-blue limestone, 2 to 3 feet.
36. Red and white sandstone, 16 feet.
37. Dark-blue limestone, 3 feet.
38. Space sandstones, (?) 100 feet.
39. Coarse and somewhat massive brick-red sandstones, 50 feet.
40. Space sandstone, (?) 20 feet.
41. Coarse red sandstone like No. 39, 50 feet.
42. Space sandstone, (?) 15 feet.
43. Dark-blue limestone, 3 feet.
44. Space covered up; indications are that sandstones and shales entered through it, 60 to 70 feet.
45. Dark-blue limestone, 4 feet.
46. Space sandstones, (?) 32 feet.
47. Blue limestone, 5 feet.
48. Space sandstones, (?) 150 feet.
49. Blue limestone, 3 feet.
50. Space sandstone, 350 feet.

e. 51. Blue limestone, 3 feet.

52. Space, the valley of Crooked Creek. On the east side of the valley we have the massive red sandstones (Triassic ?) with all the characteristics of the same beds east of the foot-hills, and on Trout Creek west of them. It is probable they extend down to bed 51. Their softness has allowed them to be worn down, and they have been covered with *débris*. The total thickness is from 1,300 to 1,500 feet.

53. Coarse pink sandstones, 25 feet.

53. Fine-grained rose-colored sandstone, 8 feet.

These two beds are the upper part of the red-beds.

f. 54. Rather coarse calcareous sandstones, shales mottled red and gray, 5 feet.

55. Space probably filled with a continuation of 54 grading into the next bed, 30 feet.

56. Gray compact limestone. This limestone has cross cleavage, and becomes harder as we go up, 10 feet.

57. Hard fine-grained limestone, light gray, 15 feet.

58. Space probably filled with limestones and shales, 75 feet.

59. Outcrop of green shales, 10 feet.

60. Space filled with shales and sandstones, 60 feet.

61. Rusty yellow sandstone, 5 feet.

62. Fine-grained white sandstone with fragments of stems and leaves, 5 feet.

g. 63. Space sandstones, (?) 20 feet.

64. Yellow sandstone, 40 feet.

65. Space sandstone, 80 feet.

66. Space filled with shales, (?) 500 to 600 feet.

67. Dark-gray fossiliferous limestone, 2 feet.

h. 68. Space, probably limestone, 20 feet.

69. Black argillaceous shales, 2 feet.

70. Space shales, (?) about 700 feet.

71. Calcareous sandstone shales, 60 feet.

72. Space shales, (?) 300 to 400 feet.

73. Black and green shales, fossiliferous with interlaminated limestone bands, 400 feet.

i. From this point to Trout Creek, a distance of about half a mile, are no exposures, the beds being covered with drift. When we reach Trout Creek it is evident that we have crossed a synclinal axis, for the dip now is toward the westward instead of east as before. On the bluff the beds are as follows:

74. Black argillaceous shales, outcrop 2 to 3 feet.

75. Bluish-black limestone, 1 foot.

76. Black shales, about 180 feet.

This brings us to the bed of Trout Creek, and crossing it black shales prevail until we reach the volcanic ridge which doubtless caused the fold just referred to. This ridge, A in the figure, is about 400 or 500 feet high, and extends north and south. It is trachytic. A low hill between the two branches of Trout Creek south of the hill marked *i* is of the same rock. Whether the eastern side of the fold extends along the ridge to the southward or not I could not determine, as the valley was covered with *débris*, and there were no exposures on the east side until we came to the volcanic rock itself. The line of the section given above is from the northwest to southeast, and with the exception of the beds from No. 18 to No. 51 is a continuous section. The portion of the section between these points was made farther southward, but connects with the others. At the point where the greater part of the section was made these beds were entirely concealed. All the beds below No. 52 are probably to be referred to the Carboniferous and Permian systems, although I cannot so refer them positively as there were no fossils found to prove it. The red-beds (Triassic?) have a thickness of about 1,500 feet, which is about the same as we found east of the mountains. Cretaceous No. 1 (Dakota group) is somewhat thinner, while the Jurassic (?) between has about the same thickness as seen heretofore. The entire thickness of the Cretaceous as shown here (beds 61 to 73 inclusive) is over 2,000 feet. The beds have about the same characters as the analogous beds east of the mountains. The illustration Fig. 1, Plate VI, carries the section still farther to the eastward. Around the northern end of the ridge "A" (trachyte) are, as indicated by the *débris*, Cretaceous shales. No definite exposure was observed, and it was impossible to tell whether or not the shales extended around to the eastern side, and if they did, in what direction they inclined. On the east of the ridge is a grass-covered valley (*k*) about a mile in width, from which, going eastward, we ascend a low hill rising about 200 feet above the valley. On the west side of this hill are outcrops of trachyte, seemingly stratified and dipping toward the east. On reaching the summit we find that it is plateau-like, cut into low hills by small gullies. Crossing toward the eastward in one of these gullies, the following beds are exposed (the point *l* in the illustration) from below upward:

1. Volcanic breccia.
2. Sandstone.
3. Volcanic breccia.
4. Breccia looking very sandy.

The entire thickness is not more than 50 or 60 feet. The dip here, however, is not to the east, but west. The angle of inclination is only 20°. Between the points *k* and *l* is, therefore, a synclinal fold. The sandstone is a dark greenish brown, very much metamorphosed; some of the layers look like a volcanic sandstone. The breccia seems to be interstratified in places, but is probably, in part, intruded, as in some places the sandstones on both sides are much changed. Still farther east, at the point *m*, are similar beds, with the dip once more to the eastward. From this point we descend into a broad valley, in which the beds are, for the most part, covered up. Here are a few small lakes, with no outlet, and the ground about them is covered with alkali. The valley is somewhat rolling in character, not uniformly level, but having a gradual slope to the east. It is underlaid by sandstones, and is a mile in width. On the eastern side, on ascending a low ridge rising about 40 feet above the valley, an outcrop of white shaly sandstones is seen, below which is volcanic breccia. The dip here is south 80° west; so the valley we have just crossed (*n*) is another synclinal. The angle of dip is about 25° or 30°. There are three or four of these low ridges that are parallel to each other; the general strike being north 10° west. The first two, at *o*, in the section, form an anticlinal. From *m* to *n* are exposures of light-gray sandstones, somewhat fine grained, with interlaminated coarser sandstones of a dark-brownish color. The outcrops are not very decided. At *o*, in a bed of rather coarse sandstone, I found fossil leaves, among which Professor Lesquereux has recognized *Rhamnus Poldianus*, *Platanus Haydenii*, and a fragment of a leaf of a *Quercus* new to this country, and related to *Quercus Heerii*, Al. Br. The flora, he says, is Lower Tertiary, and represents the lignitic group. From *o* to *p* is a distance of about an eighth of a mile. From the latter point we have a meadow-like valley about a mile in width, from which we ascend granitic hills. This valley is another synclinal axis. The hills are at B in the section, and are about 500 feet high, rounded in outline, and extending about three miles in width. On the east we descend into another valley, C, in which all the rocks are concealed by the drift. I have little doubt, however, that it is underlaid by Tertiary sandstones. This valley is somewhat irregular in shape; but in the section it is represented at C as about six miles in width. From *q* to *r* the line on which the section is made is changed, and has a course of south 45° east. The Tertiary sandstones, which we have just spoken of, are the same that we noticed extending to the edge of the trachytic hills in the northern and northwestern part of the park. We have seen that they extend across the park in a wave-like manner, occasioned, no doubt, by volcanic action that was contemporaneous with the elevation of the volcanic ridge on the east side of Trout Creek. Returning to this ridge, and following it southward, we observe that it turns more and more to the eastward; and this fact is also rendered evident when we notice the course of the streams that are parallel to it. At Station No. 92, a high point to the southeast, which seems to mark the termination of the ridge, we have, on the south side and dipping toward the south, as I learn from the notes of Mr. Taggart, an outcrop of sandstone, somewhat metamorphosed. This I take to be the bed of sandstone so characteristically marked as Cretaceous No. 1. It evidently belongs to the western side of the synclinal fold, to which I have already referred as existing at the head of Trout Creek. Still farther down the river, and on the eastern or rather northeastern side, is another butte, in which I found exposures of beds belonging to the Dakota group. The sandstone here, being very much metamorphosed, is quartzitic. Just above it are the same shales that we saw in other places, and the limestone, with Cretaceous fossils, (bed No. 2, in section No. 1, and No. 67, in section No. 9.) These beds all dip to the southwest at an angle of 50° to 60°, and are, I take it, a prolongation of the eastern side of the fold on Trout Creek, and at the butte (Station No. 92) referred to by Mr. Taggart. The volcanic ridge, which is the cause of the uplift on the eastern side, making a turn to the eastward, of course, the strike of the sedimentary beds is also to be found turning in that direction. At the base of the butte just referred to are remnants of a soft sandstone, which I consider to be of Tertiary age, whether Eocene or more modern I could not determine. Before leaving this butte I will describe the springs that are at the south end. They are all saline. There are four principal springs, although there are beside a number of places where the water bubbles up. Spring No. 1 is about two feet in diameter and three feet in depth, and has no doubt been artificially enlarged. At intervals of a few seconds there is a slight escape of gas, probably all carbonic acid. The water has rather a pleasant taste, though by no means as agreeable as that in the springs at Manitou. It is saline, somewhat pungent, tasting slightly also of sulphur. The temperature of the water was 58° Fahrenheit; the air being 78° Fahrenheit.

Spring No. 2 is about 6 feet below No. 1, and about a foot in diameter and 6 inches deep. The water tastes very much like that of No. 1, although not quite so pungent, nor is there as large an escape of gas. The temperature was the same as that of No. 1.

Spring No. 3 is very little different from the other two. It is about 4 feet from No. 2, and has a greater evolution of gas. The temperature is still 58°.

Spring No. 4 is about 30 feet from No. 3, and about a foot in diameter and 6 inches deep. It is a very quiet spring, the water tasting strongly of salt, and also slightly of sulphur. Between No. 3 and No. 4 is a marshy space, in which, by a little digging, a spring could be formed.

At this place is a considerable deposit of iron not noticed in the springs. For some distance about the springs there is an efflorescence of salt and alkali. The principal constituents of the water are common salt, sulphur, iron, and carbonates. Southeast of the butte, at the base of which we find these springs, is a double-topped butte, which I found to be composed entirely of granite. The rock was somewhat covered, but I consider it to be a remnant of a line that once extended northward, and that the rocks probably incline to the southwest or to the northeast. The whole southern end of the park, as I learn from the notes of Mr. Taggart, is volcanic. The Platte River for some distance follows a course very near the line between the trachyte and the sedimentary formations. On this line are several buttes, on the northern end of which are granite outcrops, while the rest of the butte is either trachytic or basaltic.

Following the river up from the cañon we find that it flows through schists for about five or six miles. We then meet with trachyte, which at this point is found on the south side of the river. As we near the salt-works we find numerous isolated buttes of trachyte, many of them having a conical shape. A line of these buttes extends from the Little Platte, about eight miles above its mouth, toward the southwest. They mark the limit of the volcanic rock in this direction. The Little Platte forms the boundary from the mouth up for eight miles. The main river for about eight or ten miles above the mouth of the Little Platte flows in the axis of a synclinal fold, the same to which I have several times already referred. The fold is here much broader than at the head of Trout Creek, where we first observed it. Above the mouth of Trout Creek, the Platte River cuts through the beds after being for some distance on a monoclinal valley in the red-beds. Above, at Fair Play, its course is again across the strike of the beds. Here it has cut deeply into deposits of gravel, which are probably the result of glacial action. This may also account for the course of the stream at this point, as its bed may have been determined by a glacier. Near Fair Play, the gravel, which is auriferous, is from 70 to 100 feet thick, composed of rather large rounded boulders. Between the Platte River and the mountains that form the western boundary of the park, the country is rather uniformly level, and so covered with drift that we have very few exposures of rocks. It is not until we reach the Little Platte, about ten miles south of Fair Play, that we have any definite exposures. At this point, near a bend in the creek, I made the following sections, section No. 10 being made at the point A in Fig. 2, Plate VI, and section No. 11 from the point B to C. The dip of the beds on the bluff where section No. 10 was made is about south 75° west; angle of inclination, 25° to 30°.

Section No. 10.

In ascending order:

a.	1. Pink sandstone	52 feet.
	2. Space covered up	
	3. Blue limestone, 3 to 4 feet	21 feet.
	4. Space covered up	
	5. Reddish sandstones	120 feet.
	6. Space probably filled with alternation of sandstones and limestones	120 feet.
	7. Blue limestone 4 to 5 feet	69 feet.
	8. Space covered up	

9.	Red sandstone	70 feet.
10.	Space covered up	
11.	Light-gray sandstone	52 feet.
12.	Red sandstone	
13.	Blue limestone	10 feet.
14.	Red sandstone shales	8 feet.
15.	Dark-gray argillaceous sandy shales, breaking into fine layers, between which are crystals of *pseudo-malachite*	10 feet.
16.	Red sandstone shales	25 feet.
17.	Light-gray sandstone	8 feet.
b. 18.	Very dark blue, almost black, limestone	5 feet.

These beds are, I think, a portion of those just below the red-beds included in section No. 9, between beds 17 and 51. I am inclined to refer them all to the Permian or Permo-Carboniferous. At any rate, if not Permian, they are high up in the Carboniferous. I shall refer to them again in a subsequent chapter, when I have occasion to speak of similar rocks found on the Eagle River, a branch of the Grand River.

Between the points A and B in Fig. 2, Plate VI, the Little Platte makes a bend, as is seen on the map. The section in the illustration crosses the stream twice, therefore, as shown at the points *c* and *d*. We then ascend the hill B, which, from the exposures of bright-red sandstones where the river had cut through, is conspicuous from a long distance. It is from the summit of this hill westward that section No. 11 is made.

Section No. 11.

Made in descending order:

e. to *f.*	1.	Red sandstone shales outcropping on the summit of the hill dipping south 50° west, at an angle of about 30°	
	2.	Very compact sandstones, generally of a mottled character, in rather thin layers; general color, brick red	40 feet.
	3.	Very soft red sandstone, the first outcrop dipping as No. 2. Proceeding a very short distance we find that these sandstones form the center of a small synclinal fold, the dip of the western side being to the northeast, at an angle of about 35° to 40°. We then have beds No. 2 and 1 the same as given above; below which we have—	
	4.	Bright red shales	
	5.	Coarse pink sandstone	10 feet.
	6.	Red sandstones and shales	80 feet.
	7.	White sandstone with greenish tinge	3 feet.
	8.	Very hard light-gray sandstones with bands of red shaly sandstone, varying from 4 inches to 3 feet	40 feet.
	9.	Hard gray sandstone, very similar to No. 8, with bands of soft red shales. The gray sandstone is in bands from 6 inches to a foot	20 feet.
	10.	Brick-red sandstones with pinkish layers	31 feet.
	11.	Bands of hard gray sandstone with interlaminated shales, very fine and dark red. The lower band is about 2 feet thick, middle 6 inches, and top 1 foot	33 feet.

g.	12. Coarse light-red sandstone	6 feet.
	13. Maroon-colored sandstone, shales streaked with red. Near the top there are lighter-colored bands showing a gradual change toward No. 12	107 feet.
	14. White sandstone	13 feet.
	15. Maroon-colored shales	400 feet.
	16. Pink sandstone with red bands	110 feet.
	17. Fine maroon-colored shales	220 feet.
	18. Light-maroon red sandstone shales	108 feet.
	19. Dark-maroon red sandstone shales, very fine-grained	108 feet.
	20. Reddish maroon-colored sandstone	20 feet.
	21. Gray micaceous sandstone with green spots, very closely resembling those found in bed 15 of section No. 10. I think this is a higher bed, however	15 feet.
	22. Sandstones of a general greenish-gray color extending for about a quarter of a mile. These are probably a few beds of interlaminated limestone. The beds were too much covered up, however, except to show that the sandstones are micaceous	660 feet.
h.	23. Dull reddish sandstone, rather light colored. This bed is on the summit of the bluffs at C in the figure	16 feet.
i.	24. Fine black and gray shales	22 feet.
j.	25. Yellowish-white sandstone	15 feet.
k.	26. Brownish-red sandstone	26 feet.
l.	27. Space reaching to the bottom of the hill, probably filled with sandstone, but so covered with *débris* that the rocks are entirely concealed.	38 feet.

All the beds given in this section are probably above those of section No. 11. They probably came up in the valley of the river between the points A and B, where the river turns, their softness allowing them to yield readily to the action of the water.

My time was too limited to carry the section any farther either to the eastward or to the west. In the latter direction the beds continue down through the Carboniferous and Silurian. In following up the Little Platte we find exposures of red sandstone shales resting on limestones. I did not have time to make any section in the cañon, but in a subsequent portion of the chapter will give a section made a little to the north of the creek. To the eastward, about five miles down the stream, I learn from the notes of Mr. Taggart, is a butte on the northeast side, west of which are exposures of red-beds, as shown in Fig. 7, Plate VI, at B. The dip here is 5° toward the northeast. Therefore, between this point and the bend of the stream where section No. 10 was made, is an anticlinal axis increasing from north to south, for there is no indication of it due east of Fair Play. This is probably the only fold, there scarcely being room for more. The axis is about north and south. The butte itself is volcanic, and the red-beds tipped up against a dip from 8° to 10° to the westward, as shown in the illustration. Crossing Four Mile Creek the dip is again east or northeast. Returning to the road, which keeps close to the low hills, a short distance below the point where sections Nos. 10 and 11 were made, is an outcrop of gray sandstone, dipping a few degrees north of west. Still farther down the road we pass over the upturned edges of the same sandstone now dipping in the opposite direction. Just above it is an outcrop of dark-blue limestone only a few feet in thickness. This is the same fold that we find in section No. 11, at the point B in Fig. 2, Plate VI. The axis has a direction nearly north and south. The fold continues southward, and is shown again in a low hill above the salt-works at the point C in Fig. 7, Plate VI. It is not so decided here, however, and seems to be dying out. Fig. 7, Plate VI, represents a section running from the west side of the park eastward to the volcanic butte on the west side of Four Mile Creek. The following section is made on the bluff shown in Fig. 7 at the point C. It is in ascending order on the line *a b*:

Section No. 12.

a. 1. The beds at the base of the bluff are entirely concealed for some distance, and then we have—
2. Red shaly sandstones breaking into very irregular pieces, 18 feet.
3. Light red shaly sandstones in bands of varying structure. The general color is of a brick red; some of the bands are very soft, and in fine laminæ, while others are very hard. The latter are very dark, almost brown. The top of the bed is especially shaly, and has lighter-colored bands, 68 feet.
4. Rather coarse, grayish-white sandstone, 8 feet.
5. Reddish and greenish-gray sandstone, with interlaminated shales. Near the top there are very fine red shales, 45 feet.
6. Greenish-gray sandstone with bands of shale, 5 feet.
7. Brownish-red sandstone with interlaminated pink shales, 56 feet.
8. Coarse, light-pink sandstone, 12 feet.
9. Shaly sandstones, dark-red and very compact, at top lighter colored and more shaly below, 8 feet.
10. Conglomerate sandstone with irregular pebbles of limestone, 38 feet.
11. Coarse yellowish sandstone, 10 feet.
12. Coarse irregular sandstone, 10 feet.
13. Compact dark-red sandstone, with interlaminated shales, 125 feet.
14. Soft light-red shaly sandstone, 15 feet.
15. Soft and rather fine gray sandstone shales, 15 feet.
16. Gray sandstone, 10 feet.
17. Brownish-red shales, 28 feet.
18. Light-red shales, 77 feet.
19. Coarse white sandstone. } 42 feet.
20. Red shales .... }

This last bed crowns the bluff. The dip of the beds is from 15° to 20°. They are, without doubt, of the same age as the beds of sections 10 and 11, which I thought were Permean. Near the salt-works we have three isolated buttes. The most southern, the one on the east of the salt-works, is trachytic, and is about 580 feet high. The rock is of a liver-color, and jaspers are scattered over it in abundance. The base of the butte is covered up, but from the occurrence of gypsum in considerable quantity I take the rocks to be either of Cretaceous or Jurassic age. There are, however, no well-defined outcrops. To the east of this butte are two others, which Mr. Taggart determined to be volcanic, and of the same character. One of these buttes has two cone-like projections. The plain around them is covered with an alkaline efflorescence. This is especially seen in the valley in which the salt-works are situated. All the water in the streams in this region has an alkaline taste. At the works are two springs and two wells that have been sunk by the company. The works, which have been quite extensive, are now entirely deserted. Crossing the stream to the butte north of the works, we discover at the base exposures of gray sandstones laminated, and containing gypsum. These sandstones seem to dip toward the north. In some places the gypsum seems to be interbedded, and in others occurs only in pockets. Ascending the butte, we find on the top trachyte, very much like that on the butte east of the works. The slope for some distance is covered with *débris* from this rock. It is probably a portion of an overflow that was once continuous toward Buffalo Peaks, for to the west, on a line between it and the peaks, is a third butte capped in the same manner, having gypsiferous beds at the base. The gypsum is very impure compared with that found in the hog-backs outside the mountains. East of the salt-works the line of the volcanic material has a direction toward the southwest, to the divide between South Park and the Arkansas River, where we shall speak of it again in a subsequent portion of this chapter. The range on the west side of the park, the Park range, is for the most part composed of sedimentary formations, which have been thrown up, and dip toward the park. There are a number of extensive faults, the down-throw being always on the west side. This, however, will be rendered clear as we proceed. We will return to the northwest part of the park and commence the consideration of this range with Mount Lincoln, one of its highest peaks. Mount Lincoln and Mount Bross have both become widely known since the discovery on them of extensive deposits of silver-bearing galena. The mines here will be described in the mining report of Dr. Endlich. Mr. Taggart ascended Mount Lincoln from the town of Montgomery, and in speaking of the geological structure I will quote frequently from his notes. On the west side of the Platte River, below Montgomery, he made the following section:

Section No. 13.

Ascending order:

1. A light-colored quartzite, very much broken up. The weathered surface is greenish. The dip is 12° to north of east, 20 feet.
2. Gray crystalline limestone, conformable to No. 1. It has bands of laminated gray limestone, varying from a foot to a foot and a half each, 12 feet.
3. Limestone very much like that of No. 2, only darker in color, 15 feet.
4. Cherty limestone, 12 feet.

Mount Lincoln is 14,121 feet above sea-level. It is capped with a trachytic rock, as seen in Fig. 5, Plate VI. This is probably the result of a flow from a dike; erosion has carried away so much material that it is isolated, and it resembles a bed that is contemporary. At one point on the northeast spur of the mountain Mr. Taggart says he found a well-defined dike, about 10 feet in width, which seemed to extend through the beds.

On the ridge running toward Mount Bross Mr. Taggart made the following partial section:

Section No. 14.

1. Soft and brittle carbonaceous shale, 6 feet.
2. Gray quartzite, with bands of a dark ferruginous quartzite one to two feet each, 78 feet.
3. Laminated micaceous sandstone, 2 feet.

4. Gray crystalline limestone, with cross cleavage, breaking into small irregular pieces, 10 feet.
5. White quartzite, 3 feet.
6. Dark quartzite, 6 feet.
7. Gray limestone, with shaly bands and cross-cleavage, harder and lighter colored in the upper part of the bed, 20 feet.
8. White quartzite, gradually becoming darker until it is red, 80 feet.
9. Very hard brownish limestone becoming laminated and dark-colored towards the top, 125 feet.
10. Light-colored quartzite, 50 feet.
11. Brown volcanic rock like that on the summit of Mount Lincoln, only darker in color.

"Below No. 11 is the limestone in which the mines are situated. After about 100 feet of this is a gray crystalline limestone, very hard and compact. This continues for several hundred feet. It is very irregular and much broken up, and is followed by a brown crystalline limestone, from which there is a great deal of *débris*."

Fig. 5, Plate VI, represents a section through Mount Lincoln and Mount Bross, in a direction north and south. Mount Bross is nearly two miles south of Mount Lincoln. Between the two there is therefore a portion hollowed out, probably by glacial action. A semicircular ridge connects the two mountains, which were once probably continuous. On this ridge Mr. Holmes made the following section from below up:

1. Gneiss.
2. Quartzite.
3. Blue limestone.
4. Yellow limestone.
5. Limestone, (ore-bearing.)
6. Volcanic.

I learn from Mr. Gardner and Mr. Holmes that the quartzites are faulted on Mount Lincoln. The quartzites are probably the equivalent of the Potsdam sandstone, and the limestones, which are mostly magnesian, should be referred to the Quebec group. In the latter, in Four Mile Creek Cañon, I found fossils that point toward such a conclusion. Fig. 6, Plate VI, is a section through Mount Bross from west to east. The beds of the section will be found in Doctor Endlich's report. Further notes in regard to Mount Lincoln will be found also in Doctor Hayden's report. West of Mount Lincoln is Buckskin Mountain, which heads three streams, viz: the South Platte River, Buckskin Creek, and a branch of the Arkansas River. The first flows to the northeast, and turning to the east around Mount Lincoln, flows southeast. The second flows to the southeast into the South Platte, while the third flows to the northwest for about five or six miles, and then turns to the southwest and empties into the Arkansas. Above the town of Montgomery, between the South Plate and the Blue Rivers, on the main divide, is a pass called Hoosier Pass. Its elevation is 11,364. In regard to the geology here, I refer again to the notes of Mr. Taggart, who says: "The pass shows no outcrop, but is covered with granite boulders. East of it is a point, (A in Fig. 3, Plate VI,) the sides of which show no outcrop. The summit, which is flat, is covered with volcanic rock, and holes dug by prospectors show the same material. There is a slope to the eastward. In the depression or saddle between this point and the next one, which is higher, the surface is covered with a *debris* of fine-grained gray granite. As we ascend the higher summit we meet first with an outcrop of volcanic rock, and then higher up an outcrop of coarse conglomeritic sandstone, which continues only a short distance, and then we have volcanic again, which continues over the summit until we again find on the opposite slope the sandstone. There is another rise. Then we have volcanic again, and then sandstone and volcanic rock alternately for about half a mile, when, in a greater depression than the previous ones, we meet with, first, a coarse sandstone, which becomes fine-grained, somewhat shaly toward the top. It is followed by a red micaceous laminated sandstone at the point B. These beds all dip east at an angle of about 15°. They all seem to lie in the lap, as it were, of the volcanic rock which is pushed up through them. This is shown in the illustration Fig. 3, Plate VI. On the northern slope of one of the higher points (D) are fragments of a blue limestone. Above it is volcanic rock, but I could not determine the order of superposition. On the opposite side is a cliff-like wall about 6 feet high. The volcanic rock seemed to overlie it, and at one point there was a distinct dike about 2 feet in width, running through the limestone. The volcanic rock seems to have been thrust up and spread out over the limestone. On the next slope are some coarse sandstones, dipping toward the west. From this point the ridge continues to rise gradually, and we have a long saddle-like depression connecting it with Silver Heels Mountain. On the side of the next high point, in addition to the beds already named, are—

"1. Coarse sandstone.
"2. Red shale sandstone.
"3. Conglomerate.
"4. Sandstone.

"These beds lie against the side of the hill, and dip to the northeast."

The following section was made by Mr. Taggart on the ridge east of Mount Lincoln, on the east side of the South Platte River, and is in ascending order:

Section No. 15.

1. Volcanic rock, which seems to reach to the timber-line, although there are no distinct outcrops. The whole surface, however, is covered with fragments of the rock.
2. Coarse gray conglomeritic sandstone.

On the summit of the next ridge we have—

3. Volcanic rock in blocks. Then—
4. Gray shaly sandstone, dipping to the ———, at an angle of about 15°. This is about 3 feet thick.
5. Red shaly sandstone, about 6 feet.
6. Fine gray sandstone, with small gray quartz pebbles.
7. Volcanic rock in blocks as before. This exposure is on a higher point.

This section made by Mr. Taggart fills the gap between Mount Lincoln and section No. 9, made across the park, the profile of which is shown in Fig. 1, Plate VI. This volcanic rock, to which reference has been frequently made, is mostly trachytic, and although in many places it has very much the appearance of being contemporary, I am of the opinion that it is all intrusive. We find that where it is conformable to the sandstones and limestones the latter beds are always changed on both sides of the volcanic material. We have already seen this in the section made on Silver Heels, and we shall see it again in sections made farther south. There are also, as we shall see in Buckskin Gulch and in the cañon of Four-Mile Creek, a number of faults and dikes, in which everything points to the intrusive origin of the volcanic rock.

This will be more clearly shown as we progress. First, we will speak of Buckskin Gulch. Buckskin Creek, like all the streams heading in the Park range, has cut profoundly into the rocks, giving us an excellent opportunity to study the geological structure. As I have said before, the creek rises on the southeast side of Triaqua, or Buckskin Mountain, and flows toward the southeast, around the west side of Mount Bross, and empties into the South Platte. Passing through the deserted town, which was once a mining center, we soon find ourselves in the cañon. On the top of the wall-like bluff on either side, capping it, are quartzites and limestones dipping a little south of east, at an angle of about 10° to 15°.

Approaching more closely, we see that the quartzites resting on the granite are faulted. The appearance of the bluff-like wall is shown in Fg. . This is on the south side of the cañon. The following section in ascending order is made on the line *a f*, in Fig. 3, Plate VII:

Section No. 16.

a. 1. Granites, coarse and rose-colored. They extend to the bed of the creek covered with *debris*.

b. 2. Very hard white quartzite, 20 to 30 feet.

3. Greenish volcanic rock, growing wider as we go toward the west and thinning out to the eastward, 15 feet.

c. 4. White quartzite, 10 feet.

5. Greenish volcanic rock, terminating in a wedge-like point. It has split No. 4 from the bed above, (No. 6,) 12 feet.

d. { 6. White quartzite, really a part of No. 4, 6 feet.
7. Brownish snuff-colored quartzite, 2 feet.
8. Light-colored quartzite, with dark bands, 14 feet. }

9. Greenish volcanic rock, terminating in a wedge-like point, the point this time being to the westward, while before, in No. 5, it was toward the east, 12 feet.

e. { 10. Dark-colored quartzites, 6 feet.
11. Light-colored quartzites, 8 feet.
12. Banded quartzite, in layers about a foot thick each, gray and rust-colored, 12 feet.
13. Light pinkish quartzite, 4 feet.
14. Dark reddish quartzite, 15 feet.
15. Banded quartzites, about 100 feet. }

These beds correspond to the quartzites on the side of Mount Lincoln, and are undoubtedly only their southern prolongation. As we go up the creek we find that there is a large fault, and that we again come to these beds dipping in the same direction. The line of this fault if prolonged would pass to the west of Mount Lincoln near Triaqua Mountain. It probably extends into Mr. Marvine's district. It also continues to the southward, where we shall refer to it again; the down-throw is to the west. In Mosquito Gulch, the next one south of Buckskin, the same beds occur with the same great fault, and with smaller local faults in the quartzites. Mr. Taggart made the following section on the south side of the creek. It is made to the right of the fault (AB, CD, EF,) shown in Figs. 1, 2, and 3, Plate VIII.

Section No. 17.

1. Reddish volcanic rock.
2. Dark quartzite, (reddish,) 3 feet.
3. Light quartzite, dipping 20° toward east, 8 feet.

Plate 8.

Fig. 34.

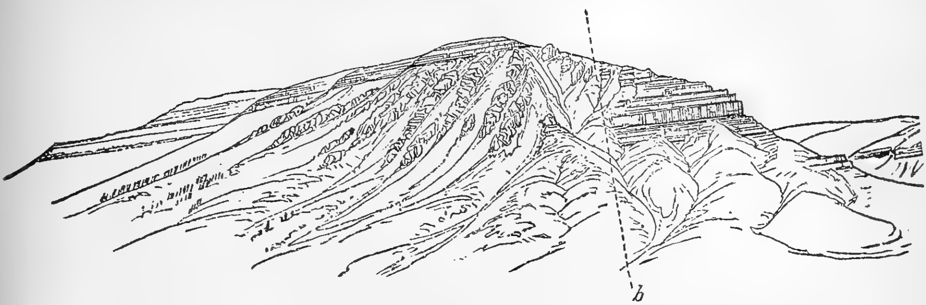


Fig. 1 Fault in Musquito Gulch Looking South

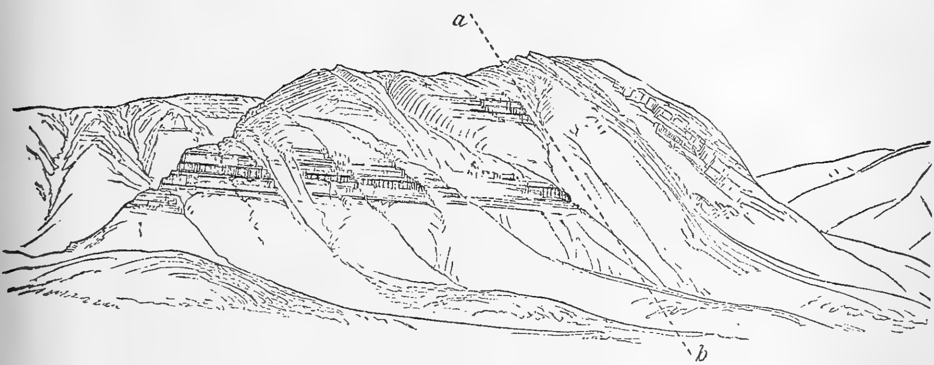


Fig. 2 Looking North

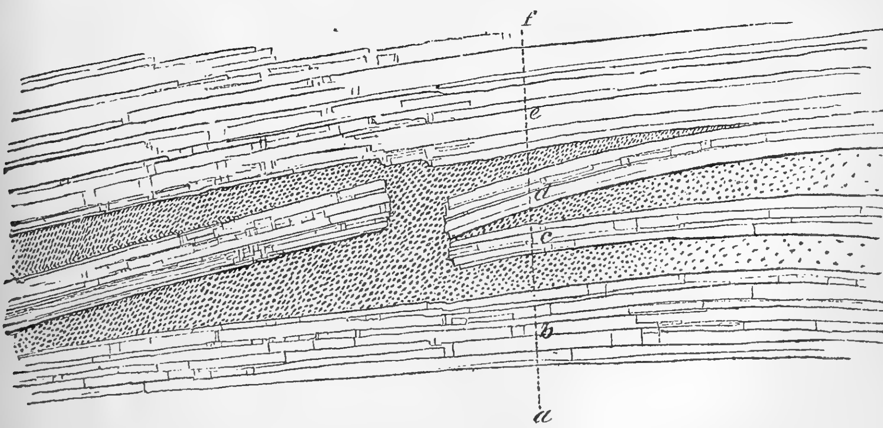


Fig. 3 Fault in Buckskin Gulch S. side

Plate 7.

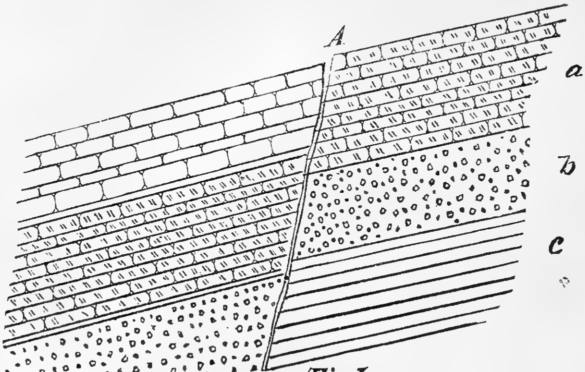


Fig. 1

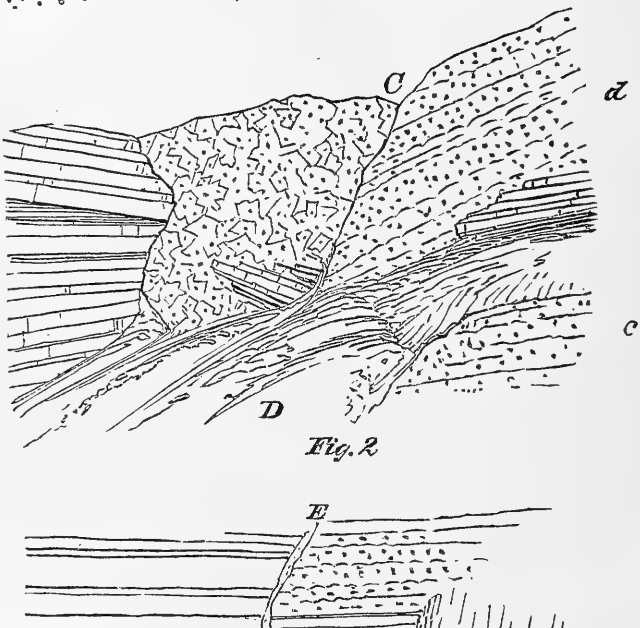


Fig. 2

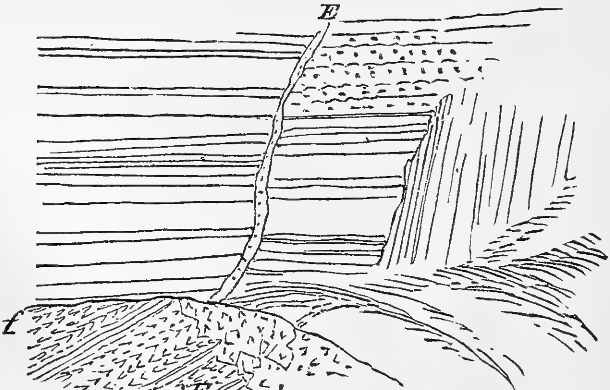


Fig. 3

Faults on Mosquito Gulch S. side

4. Reddish volcanic rock, 12 feet.
5. Light quartzite banded with dark, 5 feet.
6. Gray quartzite.

Fig. 2, Plate VIII. { *e.* 8. Greenish volcanic rock, 10 feet.
9. Light quartzite; unable to get thickness.
10. Micaceous sandstone, 4 feet.
11. White quartzite, 8 feet.
d. 12. Reddish volcanic rock, 15 feet. }

Fig. 1, Plate VIII. { *c.* 13. White quartzite opposite volcanic rock.
b. 14. Greenish volcanic rock, 8 feet.
a. 15. Gray quartzite, 6 feet. }

16. Micaceous sandstone, 4 feet.
17. Gray quartzite, with bands of brown sandstone, 20 feet.
18. Pink sandstone, with bands of pink shales 2 to 6 inches thick, 3 feet.
19. Gray quartzitic sandstone, 40 feet.
20. Compact gray limestone, 15 feet.

From Mr. Taggart's notes I take the following: "Below bed No. 2 there is gneiss on the same plane with a gray quartzite, *f*, in Fig. 3, Plate VIII. From diagram No. 2 to 3 the line of the fault is continuous. The fault is filled with volcanic rock, which can be very readily traced. The diagrams had to be made in sections. The line is not uniform. The volcanic rock at the bottom of diagram No. 2 is probably continuous with that at the top of No. 2, but there was so much *débris* that I was not able to ascertain definitely if it was or not."

The quartzites in Mosquito Gulch dip more nearly to the east than they do in Buckskin. The angle is about 15°. Going up creek we find the same fault we saw in Buckskin, and after passing the gneiss we find a small patch of quartzites, still dipping east but at a less angle. The gneiss has seams of volcanic rock. Then we have another fault, the line *a b* in Fig. 1, Plate VII, which shows the appearance on the south side of Mosquito Creek. A short distance farther up, between the forks of the creek, is an isolated hill. (Fig. 2, Plate VII, shows this hill looking north.) The eastern end is gneiss, then follows volcanic rock, and at the western end the same beds of quartzite outcrop that we saw at the mouth of the cañon. When we cross to the Arkansas side of the range we find them again, while between is a layer of very massive volcanic rock. In addition to the quartzites on the Arkansas side are very dark, almost black, limestones, which probably belong to the Quebec group. These rocks are all highly metamorphosed. The divide itself is composed of a volcanic rock with Silurian strata above. Between the divide, which has an elevation over 12,000 feet, and the hills to which we have just referred, and which are shown in the illustrations, there is a low pass, the direction of which is north and south. On the branches of Sacramento Creek—the next south of Mosquito—the same beds are lifted up on the granites. I did not go up the creek, but doubtless the same faults exist that are seen on the other streams. It was on Horseshoe or Four-Mile Creek that we were able to make the most complete sections. The following section was made from the mouth of the cañon of Four-Mile Creek westward to Horseshoe Mountain. It is in descending order:

Section No. 18.

a. 1. Brown metamorphosed sandstone, 3 feet.

2. Blue limestone, 30 feet.
3. Laminated limestone, bluish-gray, 10 feet.
4. Coarse brownish quartzite, 3 feet.
5. Light-bluish limestone, with cross cleavage, and containing in places grades with quartz crystals, 20 feet.
6. Light grayish-blue limestone, on weathered surfaces light gray; in the middle there is a band of blue limestone with white seams, 70 feet.
7. Blue limestone, the upper layers very hard and compact. The lower layers are fossiliferous, and contain on the weathered surface fragments of an *Orthis* like *O. desmopleura*, Meek, and *Euomphalus*, 50 feet.
8. Light-gray magnesian limestones, 30 feet.
9. Quartzite, 10 feet.
10. Bluish magnesian limestone, 4 feet.
11. Very hard, reddish quartzite, with interlaminated black shales, the latter about 6 inches in width, and the quartzite varying from 8 inches to 2 feet, 10 feet.
12. Red and green hard shales, in fine laminæ, and breaking into small pieces, 2 feet.
13. Reddish-brown quartzitic sandstones. About 3 feet from the bottom there is a layer 6 inches thick of red shale, with mud-marks in layers of a few inches each. The surfaces between the layers are brightest in color; 40 feet.
14. Fine brownish-gray sandstone shale, in laminæ one-fourth of an inch thickness, 2 feet.
15. Brown quartzitic sandstone, in laminæ from 2 to 4 inches thick; at the top the surfaces are coated with green, 30 feet.
16. Reddish quartzitic sandstone, 20 feet.
17. Dark-purplish quartzitic sandstone, containing near the top irregular layers of soft, dark-purple sandstone, with green glauconitic (?) grains, 15 feet.
18. Reddish quartzitic sandstone, somewhat irregular in structure, and containing layers of quartzite each a few inches in thickness, 15 feet.
19. Quartzite, white below and pink above, in beds of 2 or 3 feet thickness, 15 feet.

b. 20. Gneiss reaching to the bed of the creek. On the summit of the hill we have some of these beds folded in, as shown at the point *k* in Fig. 1, Plate IX, between the gneiss and the next bed.

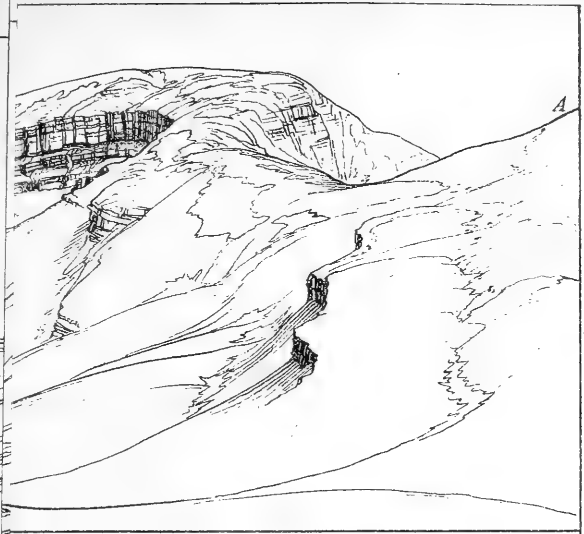
21. Volcanic rock, causing the great fault between the points *k* and *c* in the section. In this volcanic rock there are included fragments of the stratified beds of the section given above. The thickness of the rock is about 300 feet.

c. 22. Sandstones somewhat coarse and conglomeritic, dipping at an angle of about 25° to 30°.

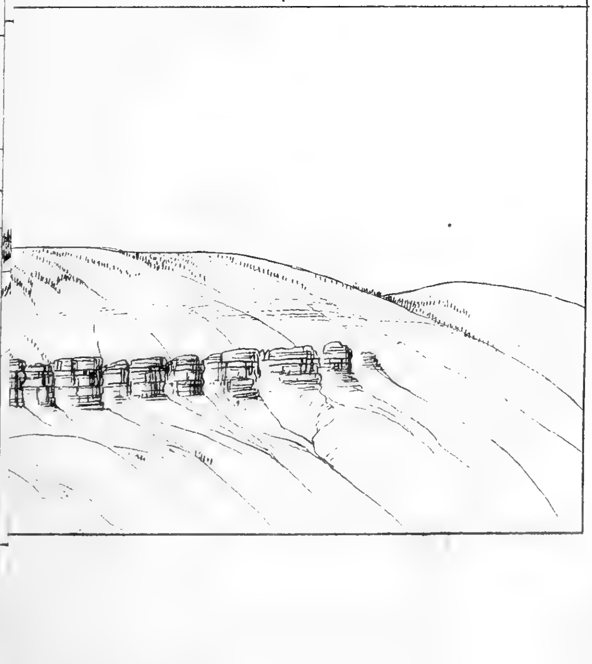
d. 23. Volcanic rock, like 21. This forms the cap of the hill, marked *d* in the illustration. At the bottom it appears to be about 300 feet thick, and at the top must be nearly 1,000 feet. The rock is porphyritic, and the lower layer next to beds of No. 24 have a somewhat regular jointage at right angles to the dip. The color below is a gray, becoming rusty in places and lighter in color above.

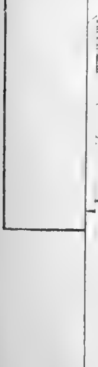
24. Sandstones, for the most part coarse and conglomeritic, with interlaminated black argillaceous shales, especially near the top; below we have a few bands of limestone, reaching 3 or 4 feet in thick-

PLATE. XIII.



South […]e Divide





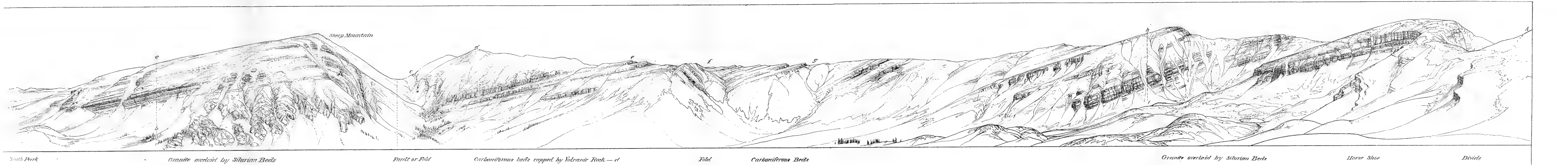
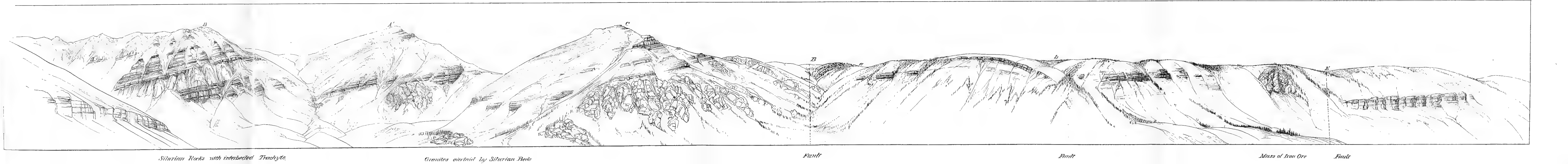


Fig. 1 Natural Section S. Side of 4 Mile Creek



Continuation of Fig. 1 down Iowa Gulch

ness. These sandstones extend from *e* to *g* in the illustration. At the point *f* there is a small fold. The general dip is to the eastward, at an angle of from 10° to 20°. The angle is greater on the west side of the fold. The thickness of the sandstones is about 903 feet.

25. Black and greenish-gray sandstones, shales micaceous, 6 feet.
26. Sandstone, 51 feet.
27. Blue limestone, very dark, and weathering of a reddish brown color, 20 feet.
28. Sandstones, conglomeritic, generally of a gray color, about 600 to 800 feet.
29. Fine black shales, 6 feet.
30. Greenish-gray micaceous, sandstone-shale. The mica is silvery and especially distinct between the laminæ. They become quartzitic above, 34 feet.
31. Bluish and brownish limestone, with interlaminated shales, 10 feet.
32. Sandstone, 2 feet.
33. Limestone, 4 feet.
34. Fine black argillaceous shales, 9 feet.
35. Coarse grayish sandstone, 10 feet.
36. Limestones and shales, 6 feet.
37. Greenish-gray micaceous sandstones. Toward the top the beds become very coarse, 15 feet.
38. Limestones and bluish argillaceous shales with sandstones. The upper portion of the bed contains in blue shaly limestones fine specimens of *Productus semireticularis*, *P. nebrascensis*, *Spirifer opimus*, *Productus prattenanus*, and a *Pleurotomaria*,* 57 feet.
39. Black shaly limestones, in the lower part of which we find the following fossils, *Productus Spirifer*, and fragments of *Trilobites*, 34 feet.
40. Quartzite sandstone laminated and micaceous, 15 feet.
41. Space covered with the *débris* of a porphyritic volcanic rock, 5 feet.
42. Shaly limestone, 3 feet.
43. Space covered with *débris* of volcanic rock, limestone, and sandstone, 27 feet.
44. Porphyritic volcanic rock, about 10 to 20 feet.
45. Blue laminated limestone, 10 feet.
46. Quartzitic sandstone, lighter colored and laminated above general color, steel gray to brown, 6 feet.

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* PLEUROTOMARIA TAGGARTI, Meek.

Shell attaining a large size, turbinate, very thin, slightly longer than wide; spire depressed, conical, a little shorter than the length of the aperture; volutions five to five and a half, flattened above to the slope of the spire, last one very prominent and angular around the middle, with the under side slightly convex and sloping inward nearly at right angles to the flattened slope of the upper side above the peripheral angle; suture merely linear; umbilical region but very slightly excavated and imperforated; aperture rather large, subquarate, with height and breadth apparently nearly equal; spiral band extremely narrow, occupying the peripheral angle of the body volution, and passing around only about its own breadth above the suture on those of the spire; surface nearly smooth, or showing only obscure lines of growth, with apparently merely the faintest possible traces of revolving striæ. Height about 2.60 inches; breadth about 2.49 inches.

In size and general appearance this fine species somewhat resembles *P. missouriensis*, (*Trochus missouriensis*, Swallow,) but it may be at once distinguished by having its body volution below the periphery longer than the height of the spire above it, instead of flattened, as well as by wanting the distinct revolving lines of that species. The specific name is given in honor of William R. Taggart, esq., of Dr. Hayden's survey, who discovered the type specimen.

47. Porphyritic volcanic rock, 20 feet.
48. Brownish-gray arenaceous limestone, 15 feet.
49. Blue laminated limestone, 15 feet.
50. Shales, 5 feet.
51. Porphyritic volcanic rock, 20 feet.
52. Blue laminated limestones, 6 feet.
53. Bluish-gray limestone, fossiliferous, 10 feet.
54. Volcanic rock, 8 feet.
55. Blue shaly limestone, 15 feet.
56. Sandstone, 10 feet.
57. Blue shaly limestone, 15 feet.
58. Sandstone, 6 feet.
59. Bluish black limestone, 5 feet.
60. Brownish quartzitic sandstone, 21 feet.
61. Bluish black limestone, 11 feet.
62. Sandstone, light colored and soft above, becoming darker and quartzitic as we go down, 10 feet.
63. White laminated volcanic rock, 17 feet.
64. Indistinct outcrops of a black shaly limestone, 12 feet.
65. White quartzite of a rusty color on weathered surfaces. Just above it there are indications of bluish limestone, probably a continuation of bed 64, 75 feet.
66. A very dark-blue limestone, weathering black crystalline, and containing nests of calcite distributed through it, 8 feet.
*h.*67. Light colored laminated porphyritic volcanic rock, very similar to No. 63, about 10 to 20 feet.
68. Dark bluish-black limestone, very irregular in structure, especially near the top; at top is pink on weathered surfaces, 60 feet.
69. Sandstone and limestone conglomerate, 10 feet.
70. Dark-blue limestone, 2 feet.
71. Rusty-brown quartzite, 2 feet.
72. Blue limestone, 50 feet.
73. Light-gray quartzite, 4 feet.
74. Light-blue limestone, with irregular cross-fracture weathering of a lighter color, for the most part fine grained, becoming coarse in some places. In the upper part it becomes laminated and somewhat darker. On weathered surfaces there are crinoidal fragments. Thickness estimated, 10–15 feet.
75. Light brownish quartzite, passing into sandstone near the top; a few feet from the bottom there is a layer, a few inches in thickness, of greenish sandstone, 20 feet.
76. Magnesian limestone, light colored, with seams of dolomite. The beds become darker from the bottom up; 50 feet.
77. Light-bluish magnesian limestone, weathering of a yellowish color, becoming siliceous as we go down, 15 feet.
78. Brown quartzite, 10 feet.
79. Laminated sandstones, general color a pinkish gray; about half way down there is a layer of shales. The lamination is most distinct in the lower part of the bed, the laminæ having a red coating, 15 feet.
80. Massive gray sandstone, 10 feet.
81. Pinkish-gray sandstone, laminated, laminæ 1 to 3 inches in thickness, with green coatings between, 10 feet.
82. Light-gray laminated sandstone, somewhat shaly in places, laminæ from 1 to 3 inches in thickness, 6 feet.

Fig. 1

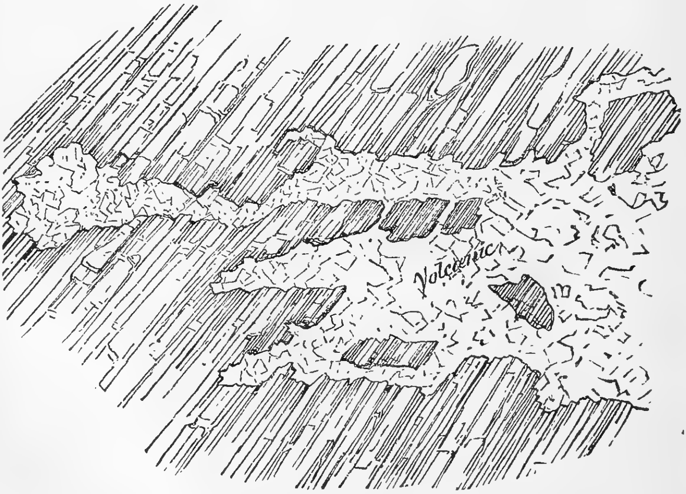


Fig. 2

Intrusion of Volcanic Rock
East of Horseshoe Mountain

83. Light reddish-gray sandstone, with red shaly bands. At the top there is about one foot of pink sandstone; 6 feet.
84. Sandstone with brown and red lines, general color reddish brown, dark below, 6 feet.
85. Yellowish-brown laminated sandstone, very hard and compact, almost quartzitic, breaking into laminæ from one-eighth of an inch to 2 or 3 inches in thickness, 6 feet.
86. Gray sandstone, somewhat laminated at the top; weathering of a rusty brown; 20 feet.
87. Brown laminated sandstone, with green coating between the laminæ, 2 feet.
88. Light brown sandstone, with bands of white quartzite varying in thickness from four inches to a foot; the thickest at the top; 6 feet.
89. Brown quartzitic sandstone in laminæ of about 18 inches each, 6 feet.
90. White quartzite, 4 feet.
91. Brown quartzitic sandstone, 2 feet.
92. White quartzite, (about 2 feet from the bottom there is a layer of brown sandstone 6 inches thick,) 5 feet.
93. Brown quartzitic sandstone, 2 feet.
94. White quartzite, 5 feet.
95. Brown quartzitic sandstone, 5 feet.
96. White quartzite, 20 feet.
97. Brown quartzite, 10 feet.
i 98. Granite, coarse, and rose-colored.

This bed (98) reaches to the bottom of the cañon at the head of the creek under Horseshoe Mountain. The section from bed 1 to 20 is made on the line *a b*, Fig. 1., Plate IX. From bed 24 to bed 67, inclusive, it is made between the points *e* and *h* in the illustration; while the remainder of the section (68 to 98) is made on the line marked *h i*. In the top of bed 23 of the section given above we have fragments of the sandstone of No. 22 caught in the mass; and again we see the volcanic rock penetrating the sandstones, and their interlaminated shales changing their character very much. Mr. Holmes sketched several of these intrusive masses, which are beautifully shown in Figs. 1 and 2, Plate X. The lower beds in the section given above dip at an angle of about 10 to 15 degrees. The quartzites and magnesian limestones in the last part of the section are the same that are given in the first part on the east side of the fault.

It is a question whether or not the sandstones of No. 22 of this section (No. 18) are the same as No. 24, or whether they belong to a higher horizon, and have been merely separated by the intrusion of No. 23. I incline to the latter. The character of the sandstone in both places is similar, but in No. 24 there is very little difference between the top and the bottom layers. The difference is no greater than between No. 22 and the top of 24. If 22 is merely the continuation of 24 folded, the ends of the two probably connect below the surface. The rock of No. 23 is peculiar. It is trachytic, and very highly siliceous. It is very white, and might, if seen alone and not very carefully examined, be mistaken for a highly-metamorphosed sandstone. A closer examination reveals the presence of crystals of feldspar. The large proportion of silica is due, perhaps, to the intrusion among the sandstones, from which it was, in great measure, derived.

As seen in the illustration, Plate IX, Fig. 1 at *c*, bed 22 dips about 30°, while No. 24, at *e* in the illustration, dips about 15°.

At the head of Four-Mile Creek are two branches which head in Horseshoe Mountain. Each of these small streams heads in an amphitheater, the center of which is granite, upon which rest the quartzite and limestone given in the section above at the lower part. They form an arch, as is seen in the illustration, and it is this that gives the name to the mountain. Between the two amphitheaters is a point which is capped in the same manner. The limestone and quartzite extend up on the divide, and it is in them that the silver-bearing galena is found. They are very much metamorphosed and somewhat broken up by veins of volcanic material. In Empire Gulch, which, with Iowa Gulch, heads directly opposite Four-Mile Creek, these beds outcrop again. Iowa Gulch affords the best exposure, however. Fig. 2, Plate IX, represents the outline along the south side of Iowa Gulch, continuing the section that we made on Four-Mile Creek. We see, then, that at the head of the gulch another fault, as great as the one noticed on the divide as the head of Mosquito Creek. It is in fact a continuation of the same fault. A section through the hill, marked B in Fig. 2, Plate IX, is represented in Fig. 3, Plate XI, the figures corresponding with those in the following section:

Section A.

1. Volcanic, capping the hill.
2. Black limestone, very much metamorphosed.
3. Thin layer of quartzite.
4. Volcanic rock, columnar.
5. Bed of quartzite.
6. Volcanic, columnar.
7. Quartzite.
8. Volcanic, columnar.
9. Fragment of quartzite bed.
10. Quartzite.
11. Volcanic, columnar.
12. Fragment of quartzite.

The quartzite from a distance has a yellow color. The base of the hill is covered with *débris*, but underneath I think we would find gneiss. The beds of volcanic rock (which is a variety of trachyte) are beautifully columnar. Beds 7, 9, 10, and 12 are fragments that seem to have been caught in the flow of volcanic material. Figure 2, Plate XI, represents a section through a hill about half a mile west of the hill B, on the north side of the creek, between the main creek and a small branch. Here we have the following section:

Section B.

1. Volcanic.
2. Blackish limestone, very much metamorphosed.
3. Yellowish quartzite.
4. Volcanic, in fine columns.
5. Gneiss.
6. Volcanic.

The rest of the hill is covered to the base. In the gneiss, layer 5, there are seams of the volcanic rock. A section through the hill A, which is the same hill as A in Fig. 1, Plate IX, is shown in Fig. 1, Plate XI, corresponds to the following:

Sections at Head of Iowa Gulch

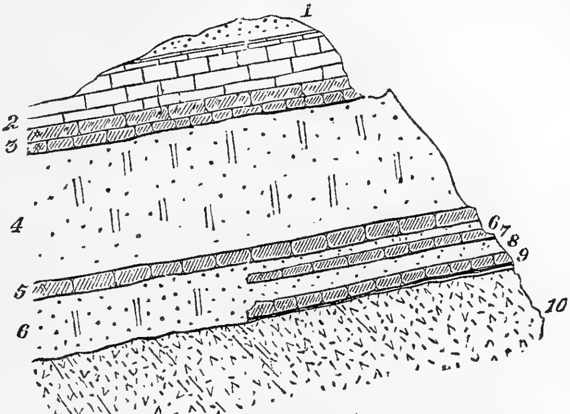


Fig. 1

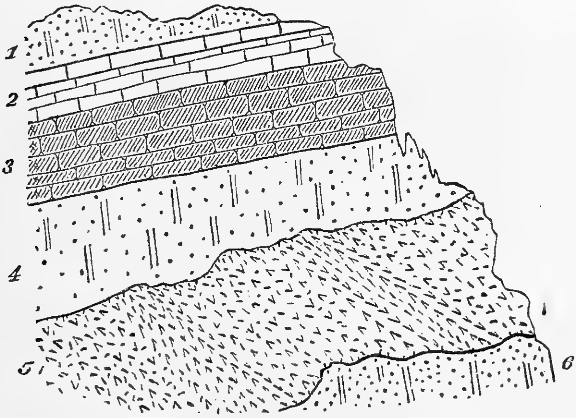


Fig. 2

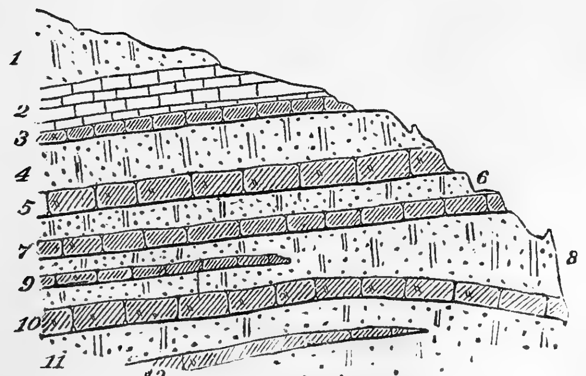


Fig. 3

Section C.

1. Volcanic, capping the hill.
2. Black limestone, very much metamorphosed.
3. Yellow quartzite.
4. Volcanic, in columns.
5. Quartzite.
6. Volcanic.
7. Quartzite.
8. Volcanic.
9. Quartzite.
10. Gneiss.

In these three sections just given the bed marked No. 1 is the same in all. So is the bed of limestone marked No. 2 in all the sections. No. 3 of the second section, (*b*,) in the third (*c*) has been split up into four beds, Nos. 3, 5, 7, and 9. In the first, (*a*,) it has been split into six beds, viz, 3, 5, 7, 9, 10, and 12.

No. 4 of section (*b*) which is represented in the first (*a*) by Nos. 4, 6, 8, and 11. In the third section (*c*) the volcanic rock is much thicker, and is represented by Nos. 4, 6, and 8. It has thrown the fragments of quartzite, Nos. 5, 7, and 9, lower down. The bed, No. 10, corresponds with No. 5 of the second section. The hill marked C in the illustration (Fig. 2, Plate IX) is capped with volcanic, and below are sedimentary beds again which have dropped down. The center is gneissic. Still farther down the creek, at the point D, is another fault, and then a fold which is merely local in the quartzite between *a* and *b*. At the latter place there is a break again, and then the quartzites are almost, if not quite, horizontal. At E is another fault, and beyond the quartzites dip about 12°. It will be seen that in all these faults the down-throw is on the west side. In California Gulch, which is the one next north of Iowa, the rocks are more covered up, but there is probably the same condition of affairs as we see here. We have seen, then, that there are two main lines of faulting running north and south, which we have traced from Mount Lincoln southward to Horseshoe Mountain, a distance of about ten or eleven miles. In Plate XII is represented a section made through stations 56 and 57, about five miles south of Four-Mile Creek. The section is as follows:

Section No. 19, *made by Mr. Gardner.*

a. 1. Conglomerate.
2. Soft white limestone.
3. Gray limestone.
4. Nodular limestone.
5. Blue limestone.
6. Quartzite, white.

b. 7. Schists with veins of granite.
8. Quartzite.
9. Nodular limestone and shales.
10. White quartzite.

c. 11. Gneiss and schists.
12. Limestones.
13. Quartzite.

d. 14. Gneiss.

The faulting in the center of the diagram is evidently the second or western fault at Horseshoe. That is the one observed on the divide.

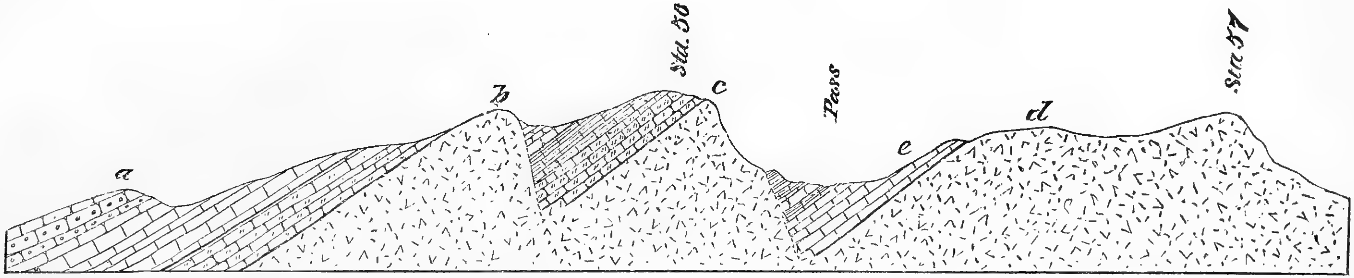
The first one probably dies out to the southward of Station 45, or Sheep Mountain. The country slopes off in that direction, and from station 45 there is a long ridge on the east side of a branch of the Little Platte, which slopes toward the park. In following up the Little Platte to Weston's Pass, I saw no indication of the first fault. The trend of the fault at the point *b* in the illustration is about south 10° east. How much farther it extends to the southward I was unable to determine for want of time. The dip of the schists at the point *d* in the diagram is toward the east. They are of a rusty-red color, with micaceous layers in some places, and in others quartzitic beds with light-colored granites below. These schists extend to the Arkansas River, and it is through them that the river cuts the cañon, to which I will refer further on. On leaving the mouth of the cañon on Four-Mile Creek and going eastward, we find that all the underlying beds are covered. From a few indications of volcanic rock, however, I am inclined to believe that there is a fault running toward the north, the line of which would pass east of Mount Lincoln. We have seen (section No. 16) that on the ridge east of Lincoln there is a line of volcanic rock. This probably represents a line of faulting. On looking at the map we see that there is an abrupt turn in the course of Four-Mile Creek directly on the prolongation of this line, the course for a short distance being in a line with that of the Platte west of the ridge where section No. 15 was made.

In section No. 18, we have the Potsdam group in beds No. 11 to 19, a thickness of 119 feet. This is repeated again in beds 78 to 79. The estimated thickness here is greater, being 156 feet. In section No. 18, made by Mr. Taggart, in Mosquito Gulch, the thickness is 160 feet. In Buckskin Gulch it was estimated at over 200 feet in section No. 16. This last is probably exaggerated, as the upper bed in the section was estimated from a point some distance below it. The thickness of the Potsdam group along this range probably averages about 150 feet. The remainder of the Silurian layers will probably average about 200 feet in thickness. It is probably all referable to the Quebec group. The lower layers are so beyond doubt. A comparison with the same layers already treated of in the first chapter is given below:

Locality.	Thickness in feet of Potsdam.	Thickness in feet of remains of Silurian.
Glen Eyrie	40	73
Trout Creek	60 to 80	100 to 150
Range between South Park and Arkansas Valley	150	200

There has, therefore, been an increase in thickness as we have come westward. The line between the Carboniferous beds and the Silurian is in all probability the bed No. 68 or 69 of section 18. The lower part of the Carboniferous contains a number of beds of limestone, with interlaminated black shales, more or less argillaceous. In no case do these beds attain a great thickness, and between them are beds of micaceous sandstones, which are laminated. Their general color is a greenish gray, with the mica especially noticeable between the laminæ.

Plate 12.



Section through Weston's Pass

As we go up the limestones gradually thin out, and the sandstones become coarser and coarser, pointing to the existence of shallower waters during their deposition. I was unable to define the line between the Carboniferous and the beds that I consider to be of Permian age.

Going south from Weston's Pass we find that the range ends rather abruptly in Buffalo Peaks. South of this the divide between South Park and the Arkansas is comparatively low. Buffalo Peaks consist of two high conical points of about equal elevation, viz, 13,365 feet. Between the two there is a ridge bounding an amphitheater, which faces to the northeast. On the face of this we find, going from the top toward the base, the following beds:

Section No. 20.

a. 1. Trachyte, weathering very dark from the amount of iron it contains. There are crystals of hornblende and sanidine. On fracturing the rock the matrix is seen to be light-colored. This is found on the western summit of the peak, and extends across along the ridge to the eastern summit. Below we have—

b. 2. Trachyte. The upper part of the bed has a bluish color, which becomes red below. This is also hornblendic, and contains crystals of sanidine. The rock is more compact and finer-grained than that on the summit; 100 feet.

c. 3. Reddish breccia. The included masses are highly porphyritic, 100 feet.

d. 4. Light gray tufa. I could not see the line between it and the one above. There are light-yellow pebbles in this rock. In the lower part there is a soft black layer, thin; 5 feet.

e. 5. Columnar layer of very hard black rock, containing a large quantity of hornblende and obsidian. There are, also, a few included pebbles. The columnar form is quite distinct in places; 50 feet.

f. { 6. Light tufacious rock, very soft, mostly of a white color, but pink in some places and yellow in others, 150 feet.
7. Gray breccia, which reaches to the base of the peak as far as can be seen; 200 feet.

This section corresponds with Fig. 8, Plate VI.

I was extremely sorry that I was unable to work to the eastward of the peak. Until that is done the opinions in regard to these rocks must be to a great extent conjectural. On the west side of the west cone, *g* in Fig. 8, Plate VI, resting on the granite, is a bed of white and rusty-looking quartzite, dipping toward the east at an angle of about 10°. Going toward the north we find above the quartzite, and dipping in the same direction, a bed of limestone very much changed. In one place there is a flinty layer, over which I found coatings of chalcedony. These beds are probably a continuation of those seen in Weston's Pass at the point *e* in Fig. 1, Plate XII. They seem to have been caught here by the volcanic rock. As we go south the beds continue uninterruptedly, as we shall see on Trout Creek. The rock on the summit of Buffalo, although lighter in color, is very nearly like that found on the tops of the buttes near the salt-works. They are probably identiical, the differences being caused, perhaps, by the difference in length of time of cooling. In both places the trachyte is micaceous. The peaks are evidently a center of eruption, and the overflow was probably toward the southeast in the direction of the salt-works. Fig. represents an ideal section through the peaks from east to west, the dotted lines representing the planes of deposition of the various beds given in the section above.

There has been so much erosion, preceded by glacial action, that the greater part of the beds has been removed. That the section represents the actual condition of affairs is rendered the more probable by the fact that Dr. Endlich found in his district just south of our line the same succession of beds at Promontory Point. Here the succession and order of superposition was more clearly demonstrable. Trout Creek is the second large creek flowing into the Arkansas from the east below Buffalo Peaks. Crossing the low divide southeast of the salt-works, we find exposures of black shales and conglomerate sandstones dipping a few degrees east of north, and inclining 35° to 40°. Below the black shales we have sandstones and green shales; then we have blue limestone; then there is a space in which all the beds are covered up. The next outcrop is a gray limestone, below which there is a blue limestone. I was unable to get the dip, but it is probably the same as we saw in the beds above. After leaving these outcrops we come into a small park, about five miles in length and over a mile in width. It is a beautiful meadow-like park, in which the underlying beds are almost entirely concealed. At the upper end, however, I was able to make the following section:

Section No. 21.

In descending order:

1. Light-reddish gray micaceous sandstone, 50 feet.
2. Blue limestone, 3 feet.
3. Yellow sandstone shales, 13 feet.
4. Light-red micaceous sandstone, 10 feet.
5. Hard reddish brown sandstone, 6 feet.
6. Gray shales, 4 feet.
7. Red shaly sandstones, 6 feet.
8. Fine bluish shale, 5 feet.
9. Yellowish-brown sandstone, 3 feet.
10. Bluish shales, 6 feet.
11. Red shales, 9 feet.
12. Brown and red shaly sandstone, 13 feet.

These beds all dip toward the northeast at an angle of 40°. They correspond closely to the limestones and sandstones seen in sections Nos. 10 and 11, and to those east of Fair Play below the red beds, and which I have already referred to the Permian. Farther down the creek we find outcrops of greenish micaceous sandstone. These beds are laminated, and between we have fine black shales. The dip is still in the same direction. Below these are blue limestones, and still farther gray limestone. These beds are undoubtedly Carboniferous, and a closer search than I had the time to make would doubtless reveal fossils in some of the layers. At the lower end of the park the creek has cut its way through the beds at right angles to the strike, and the beds stand on either side as a high wall, dipping northeast at an angle of 15°. Resting immediately on the granite there is a bed of quartzite. Above this there is a bed of dark-gray limestone, about 200 feet in thickness. Next follows 10 to 20 feet of brown quartzite and then limestone. Above this the beds are covered until we reach the Carboniferous layers already referred to. The quartzite and limestone resting on the granite are evidently the direct prolongation of the beds noticed west of Buffalo Peaks. Farther south and southeast, in Dr. Endlich's district, these beds are more distinctly shown, and will be fully treated of by him. Trout Creek, for the rest of its course, flows through granitic rocks. About two or three miles below the park we find on the east several high hills of trachyte. There is a small branch coming in here which seems to form the boundary between the trachyte and the granite. This is a portion of the same eruptive material seen east of the salt-works, of which it is the continuation southward. I shall reserve the consideration of the Arkansas Valley to the next chapter.

CHAPTER III.

ARKANSAS VALLEY—EAGLE RIVER—SAWATCH RANGE.

The Arkansas River, in our district, has a course a few degrees east of south. On the east side we have the Park range, separating the valley from South Park, while on the west is the Sawatch, or main range of the Rocky Mountains, forming the continental divide. It has here, perhaps, its culmination. The range to the southward of Mount Bowles falls off, as it also does north of the mountain of the Holy Cross, which is the last peak in the range in this direction. Before reaching this point the water-divide sweeps around the head of the Arkansas to the eastward. In the Sawatch range we have first Mount Bowles, rising 14,106 feet above sea-level. About twelve miles farther north is Mount Harvard, having an elevation of 14,208 feet. The next high point measured was La Plata Mount, which is eleven miles northeast of Harvard: its height is 14,126 feet. Grizzly Peak, at the head of Lake Creek, is about seven miles from La Plata, and a little north of east from it. Its elevation is 13,786 feet. Six miles east of north from La Plata is Mount Elbert, named in honor of the governor of Colorado: its elevation is 14,150 feet. Six miles farther north is Massive Mountain, having an elevation of 14,192. North of Massive Mountain the range is comparatively low until we near the mountain of the Holy Cross, when it rises again. The elevation of the Holy Cross is 13,478: it is about eighteen miles north of Massive Mountain. Beyond it, the range dies out, and we have Eagle River sweeping around to reach the Grand River. As we have seen in the latter part of the last chapter, Trout Creek flows through granitic rocks, which continue to the valley of the Arkansas and are the prolongation of those seen west of Buffalo Peaks. The granite is generally coarse and of a reddish color, with seams of white quartz. The bedding is probably the same as we saw at the peaks, that is, to the northeast. The eruptive rock that is seen near the head of the creek extends to the southward and southeast, and will be fully treated of in Dr. Endlich's report. I did not go farther down the Arkansas Valley than opposite the mouth of Trout Creek. Here we have a beautiful broad valley, with streams coming in from either side, and cutting deep terraces in the deposits of drift. There is a gradual slope from either side to the river. The main part of the valley lies on the west side, and it is here that the terraces are most conspicuous. The valley is park-like, and is about six miles wide: it extends southward into Dr. Endlich's district. I found nothing but drift as far as I had time to examine the deposits. I was unable to determine whether the drift is of glacial origin or not. It is probable, however, that it is, for in the cañons in the range farther north we have abundant evidence of glacial action.

Below the mouth of Trout Creek, Dr. Hayden, in 1869, found Tertiary beds. He refers to them as follows:* "On the west side of the Arkan-

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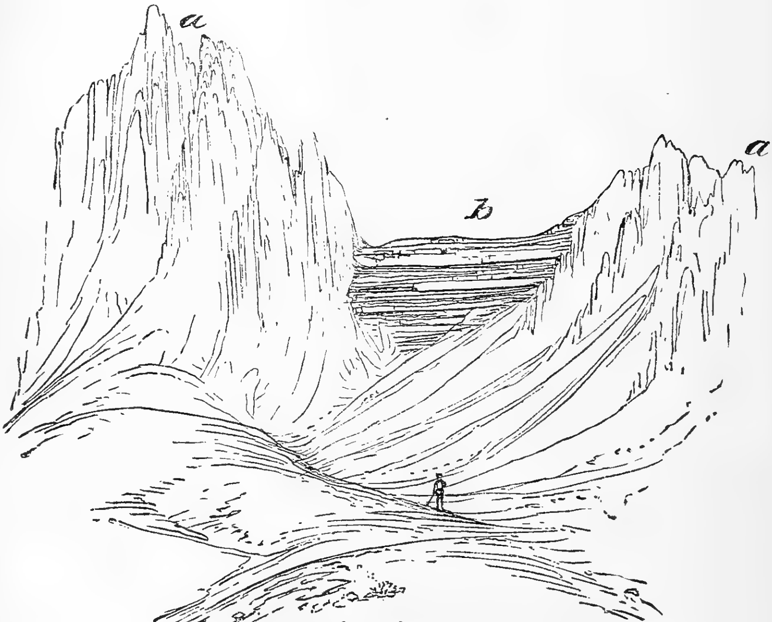
* Report, 1869, page 177.

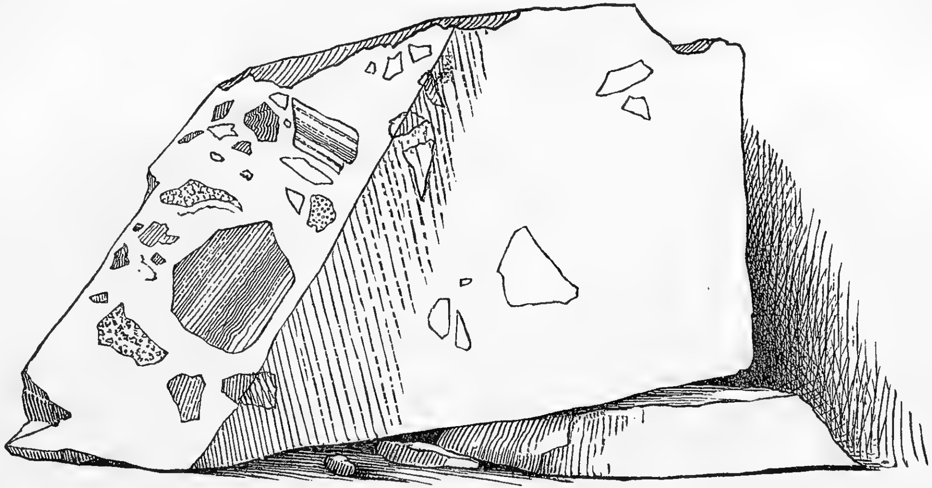
sas Valley the recent Tertiary beds run up to and overlap the margins of the mountains. They are composed mostly of fine sands, arenaceous clays, and pudding-stones, cream-colored arenaceous clays, and rusty yellow marls, fine sand predominating. These beds weather into peculiar architectural forms, somewhat like the 'Bad Lands of Dakota.' Indeed they are very nearly the same as the Santa Fé marls, and were doubtless contemporaneous, and dip at the same angle, three to five degrees a little west of north. The tops of the hills have all been planed down as if smoothed by a roller. I have called this group the Arkansas Marls."

Above this valley the river is in a cañon, or rather a cañon-like valley, until we get above Twin Lakes, when we have another valley reaching almost to the head of the stream. It is about sixteen to twenty miles in length, and about ten miles in width at the lower end. The whole valley, as far as could be determined, is underlaid by granite. At the lower end, back of Weston's ranch, in the terraces, there are modern Tertiary deposits, soft conglomerate sandstones. The whole valley is terraced, especially on the eastern side. These terraces are covered with drift, no under-lying beds being exposed until we get to the lower end of the valley. On almost all the streams coming into the Arkansas from the west above the lower valley we have morainal benches. Between the two broad valleys mentioned above, the river flows through a monoclinal rift in the granites and schists, the eastern side of the cañon remaining intact, while the west is somewhat broken down by the streams coming from the mountain on that side. The cañon is plainly one of erosion, and in some places is from 1,000 to 1,500 feet in depth. The bed of the stream is strewn with enormous boulders, in some of which there are pot-holes. The river while in the cañon falls at the rate of about 60 feet to the mile. The first large creek coming in from the mountains above the mouth of the cañon is Pine Creek. There are along this creek well-defined lateral moraines. I did not, however, go up the creek, but waited until I reached La Plata, which is much larger, being about fourteen miles in length. The valley is about half a mile in width, with beautiful meadows in the lower portion through which the stream gracefully winds. On either side bordering this meadow-like valley are two morainal benches extending from the edge of the mountains to the river, a distance of about 800 to 1,000 feet in height; they are at the edge of the mountains, gradually falling off as we approached the river. I could find no evidence of any terminal moraine. The southern bench is well timbered on top with pines and aspens, while the sides of both are overgrown with sage-brush. Entering the cañon, which is cut profoundly into the granites, and is quite picturesque, we find that the rocks scattered over the bottom are rounded and polished. There were very few evidences of striation and groovings on the rocks on the sides, and these were all very indistinct. In the center of the cañon the stream has cut a deep, narrow, secondary cañon in the granites, some 50 feet below the general level of the valley, which once formed the floor over which the glacier passed. The next creek to the north is Lake Creek, which is by far the most extensive branch of the Arkansas; it is about sixteen miles in length, and flows almost due east, one branch draining the country between La Plata Mountain and Grizzly Peak, while another branch, the North Fork, comes from the north, draining the country southwest of Massive Mountain. Before reaching the river, the creek passes through the Twin Lakes, two beautiful lakes, probably of glacial origin: they are separated by morainal material. There are moraines on both sides of the creek, as well as along all the main branches,



Schist included in Volcanic Rock.

Plate 14.



Block of Breccia; Grizzly Pk.

which are somewhat concealed in many places by the timber. The granites in the cañon are beautifully polished, and rounded even more noticeably than in the cañon of La Plata Creek. The rock exposed in these cañons is granitic—a granitic porphyry of a light color, with crystals of feldspar, (orthoclase,) rather large and conspicuous, in a fine-grained matrix: on weathered surfaces the crystals are of a purplish color.

On La Plata Mountain Dr. Hayden found evidence of volcanic intrusion. At a point in the cañon below the junction of the North Fork there are also evidences of a trachytic dike. Following up the creek that rises immediately west of La Plata Mountain, and ascending the ridge opposite, we find trachyte. The western slope of the ridge is covered with *débris*, which weathers of a bright red color. The exposures are limited. We find an obsidian rock, which seems to rest on the granite: above this there is a gray layer; then a light-colored trachyte; and the summit of the hill is capped with a quartzitic-looking layer, the weathered surfaces of which are bright crimson: from a distance this color is very noticeable. There is a similar spot at the head of a small creek rising southeast of Grizzly Mountain. This was visited by Mr. Taggart, who reported as follows: "In Red Rock Pass we have first the quartzitic layer, the *débris* of which is bright red, and from which the pass takes its name. Above this, as we pass eastward along the ridge, we meet with varieties of trachyte. Over the first point, lying apparently on the surface, there is granite and mica schist; next trachyte, and again mica schist, having an easterly dip, and an inclination of about 30°. Then we have more volcanic rock, followed by a coarse conglomeritic layer, somewhat like the quartzitic layer first mentioned. It contains pebbles of quartz. This continues for some distance, and is succeeded by a green schist, (chloritic?) Above this there is trachyte again. Finally, we meet with a fine-grained granitic rock which continues for quite a distance, alternating with a volcanic breccia, above which we have an obsidian rock, which is porphyritic." At the head of the other branch we find granites and schists, having a dip a little north of east. The schists are dark and micaceous, with seams of quartz. The bedding is quite distinct in places, inclining at an angle of 40° to 50°. In the smoothed rocks at the head of the cañon, we have abundant evidence of glacial action.

On the north side of the creek, high up on the ridge separating it from the one next to the north, on which Mr. Taggart reported, there is a capping of trachyte in columns. The rock is of a reddish color, and at one point seems to have included a portion of a bed of gneiss, as shown at *b*, in Fig. —, Plate XIII, *a a*, being the trachyte. Grizzly Peak, which was visited and ascended by several members of the party, was also found to be volcanic.

The figure in Plate XIV represents a block of volcanic breccia from this peak. I was unable to follow the line of the eruptive rock so as to define it accurately. In going up the creek, about a mile and a half above the mouth of the North Fork, we first meet with it crossing the creek in a direction south of east. The western line has a direction of about north 25° west, and south 25° east; on the north side it curves more to the westward, while I think that not very far southward the western line joins the eastern. The North Fork probably flows partly along the line of juncture, between the volcanic on the west and the gneiss on the east. The extent of the outflow will have to be determined by closer investigation in the future; I do not think that it extends very far to the north of Grizzly Peak. On Massive Mountain the rocks are mainly gneissic, with alternations of a porphyritic granite, or rather granitic porphyry, with seams in places of quartzite and a hornblendic volcanic rock. The general dip seems to be toward the northeast. To the southwest of the peak the dip seems to be toward the north and northwest. At the head of Roaring Fork, opposite the head of the Gunnison, the dip is to the northwest, and the angle of inclination about 50°. Between the two there is a continuation of the eruptive rock of Grizzly Peak, but to what extent I am unable to say. The gneiss is mostly dark and micaceous, with alternating beds of coarse white granite, in layers from four to eight feet in thickness. The country all about is very rough and rugged, making traveling very difficult.

Between the head of the Arkansas and the head of Eagle River there is a low pass—Tennessee Pass—the elevation of which is 10,242 feet. The upper part of the river flows through granitic rocks, in which there are occasional dikes of volcanic rock. The river flows through a cañon for about three miles, when it emerges into a broad, open valley about four miles in length and three wide. Here the sedimentary beds again make their appearance, dipping a little north of east at an angle of 5° to 10° Resting on the gneiss there are quartzites about 200 feet in thickness, above which there are limestones, succeeded by shales and brownish sandstones. Mr. Holmes obtained some fossils here—*Spirifer*, *Productus*, *Crinoids*, &c. On the western side of the creek we have the lower quartzites capping the granites—the continuation of the same beds on the eastern side of the valley. At the head of the valley a large branch comes in from the east. Toward the head of this creek there seems to be a slight change in the dip. The beds which before were horizontal, or nearly so, and having a dip on the main stream to the eastward or northeast, now are slightly inclined to the westward, influenced probably by the Blue River range. On the west edge of that range I am inclined to think there is a fault, the continuation of one of the faults west of Mount Lincoln. I hope to be able to study this region more closely next season, so that it may be determined.

Just below the meadow, the creek enters a cañon, and the line of the sedimentary beds crosses the creek. The trail here leaves the branch coming from Tennessee Pass, and crosses to a large branch coming from the west. For about four miles of its course, it is parallel to the other stream, and on the low ridge between them capping the schists there is a layer of quartzite, and on the east side of the cañon of the main branch we have all the layers from the Silurian upward at least to the Upper Carboniferous. At the mouth of the Western Fork, a high hill stands between it and the other fork, capped with the Silurian quartzites. Here the main river enters a deep and rough inaccessible cañon. The trail keeps high up on the hills overlooking it. Sedimentary beds are shown on both sides. On the west are only the quartzites which I have referred to—the Potsdam group. On the eastern side, however, we have beds at least as far as the Permian, and if we could have gone far enough to the eastward I am satisfied I would have found the Triassic sandstones on top, and perhaps even the Jurassic layers. Mr. Holmes says that farther north, on Eagle River, not only is the Jurassic present, but also the Cretaceous. This was west of Mr. Marvine's district, and will be the subject of future investigation. The creek rising just north and west of the Holy Cross Mountain, and flowing to the northeast into Eagle River, was once the seat of intense glacial action, and the valley now presents us with the most beautiful example of what is on the Alps known as *Roches moutonnés* that is perhaps to be seen anywhere in this country. These *Roches moutonnés* are immense rounded masses of rock scattered through the valley, and from a distance look like a large flock of recumbent sheep. These rocks have all been polished by the glacier. In this valley are also groovings and striations; these striæ and grooves have the same direction as the valley.

On the eastern side of the valley of Eagle River we have high bluffs, from which I made the following section:

Section No. 22.

In ascending order:

1. Gneiss.
2. White quartzite.
3. Fine-grained, rather compact sandstone in laminæ, having greenish grains, (glauconitic?) 10 feet.
4. Sandstones somewhat like those of No. 3, but grayish-brown in color; the laminæ have a greenish coating on which there are mud-marks; 98 feet 6 inches.
5. Space probably filled with sandstone, 22 feet 8 inches.
6. White quartzite, like No. 2, 4 feet 9 inches.
7. Space, in the upper portion of which there is an outcrop of a metamorphosed conglomerate, seemingly made up of pieces of white quartzite and brown sandstone. The masses are irregularly shaped. The lower part of the space is probably filled with sandstone; 68 feet 4 inches.
8. Light-bluish limestones, weathering on the surface white and yellow, non-fossiliferous. It is in bands of from 3 to 8 inches, and has a cross-fracture. At the top it is crystalline. Part of the limestone is probably magnesian; 219 feet 6 inches.
9. Very hard black flinty limestone, with fragments of fossils and pieces of pyrite, 273 feet 9 inches.
10. Space probably filled with limestone, 1,400 feet.
11. Laminated volcanic rock, 15 feet.
12. Blue limestone with fossils; could not define limits above.
13. Space, lower part of which is probably filled with a continuation of limestones of No. 12, and the upper part with gray micaceous sandstones and shales, 408 feet 2 inches.
14. Greenish-gray micaceous sandstones, conglomeritic in places, 352 feet.
15. White granular sandstone, with brown spots, 8 feet.
16. Brownish sandstone, 99 feet 8 inches.
17. Red sandstone, 11 feet 4 inches.
18. Soft greenish sandstone in fine layers, with a few hard bands each a few inches in thickness, 99 feet 3 inches.
19. Coarse white sandstone, with grains of quartz; becomes finer grained above, 71 feet 3 inches.
20. Red sandstone, 57 feet.

The fossils in No. 9 are very indistinct, some resembling *Spirifer* or *Spiriferina;* the layer is probably Carboniferous. In No. 12, I found the following, identified by Professor Meek: *Aviculopecten*, *Pleurophorus*, and *Avicula* or *Bakevellia;* these indicate Carboniferous age for the layer.

The section above (No. 22) was made north of Roches moutonnés Creek, and could not be continued farther because the bluffs became perpendicular. Section No. 23 was made below the mouth of Roches moutonnés Creek, and completes section 22.

Section No. 23.

Ascending order:

1. Light-red conglomerate sandstone alternating with fine-grained sandstone shales. The latter have a greenish tinge, and are micaceous, and are from a foot to 2 feet in thickness. The conglomerate beds are about 2½ feet thick. The upper beds of shales are darker in color and break into thin lamina, while the conglomerate becomes lighter-colored; while in the middle they are dark-red. Near the top there is a layer of green shales about 8 feet in thickness; 231 feet.
2. Silvery-gray micaceous sandstone shales, breaking into thin laminæ, 1 foot.
3. Coarse white sandstone, with grains of quartz and some decomposed feldspar. This layer is the same as No. 19 in section 22; 3 feet.
4. Fine-grained sandstone—white; becoming pink in places, with two or three layers of gray micaceous shale, from two to four inches thickness each, 4 feet.
5. Brownish-red sandstone, somewhat conglomeritic in places, 30 feet, 10 inches.
6. Dark-red micaceous shaly sandstones, 6 feet 8 inches.
7. Red conglomeritic sandstone, 38 feet 8 inches.
8. White conglomeritic sandstone, 5 feet.
9. Coarse white sandstone. Near the top there is a band of very hard fine-grained red sandstone. All the beds seem to be micaceous; more marked between the layers; 40 feet.
10. White and greenish-gray conglomerates and shales. First we have conglomerate and then green micaceous shales, with black carbonaceous layers; then conglomeritic layers, above which we have about 15 feet of hard sandstone, with interlaminated shales that are soft; then 5 feet of gray compact micaceous sandstone. Next there are very soft greenish-gray micaceous shales for about 10 feet, followed by from 10 to 12 feet of alternate beds of shale and sandstone, (some of the latter conglomeritic,) varying from 2 to 4 feet in thickness. Above these we have first conglomerates, then shales, and last of all, conglomerates; 511 feet 7 inches.
11. Coarse-grained gray sandstone, very hard, with greenish spots, 4 feet.
12. Fine-grained reddish-brown sandstone, 27 feet 4 inches.
13. Coarse grayish sandstone, with interlaminated shales near the top; there is a layer of red sandstone, above which there is a conglomerate layer; 25 feet 1 inch.
14. Sandstone conglomerate below, with pebbles of quartz, 2 inches in diameter. This bed is the base of a bluff, and is about 10 feet thick. Above there are alternate beds of shale and coarse sandstone. On top of all there is greenish micaceous sandstone; 252 feet.
15. Sandstone and shales, 251 feet 7 inches.
16. Sandstone conglomerate, 5 feet.
17. Shales, 20 feet.
18. Coarse sandstone and fine micaceous shales, 86 feet 10 inches.
19. Conglomeritic sandstone, 3 feet 9 inches.
20. Blackish micaceous shales, 3 feet 9 inches.
21. Light gray shales, with hard sandstone bands, 3 feet 9 inches.
22. Conglomerate and gray shales, 92 feet 9 inches.
23. Pink conglomeritic sandstones, 37 feet 5 inches.

24. Coarse white conglomerate, 27 feet 3 inches.
25. Greenish-gray micaceous sandstone shale, with hard sandstone bands; 45 feet 11 inches.
26. Very hard blue limestone, irregular in structure; brown on weathered surfaces. This limestone has the same character as the limestone in the shaly sandstone in section No. 10; 10 feet.
27. Coarse gray sandstones with shales, 145 feet.
28. Massive sandstones of a greenish tinge. Mostly fine-grained and micaceous. Some beds are pebbly, and near the bottom there is from 6 to 8 feet of black shale with carbonaceous material. The upper part of the bluff on which these exposures are is conglomeritic, where the color is darker than below; 205 feet 10 inches.
29. Rather coarse gray sandstones in these beds, weathering of a rusty color, fossiliferous; 342 feet 4 inches.
30. Space reaching to the summit of the hill, and filled, in all probability, with sandstones; 500 feet.

All the beds in this section have a dip toward the northeast, the angle of inclination varying from 10° to 25°. As we go down Eagle River, we find that the beds above gradually make their appearance, and that the dip becomes more and more toward the north, until the beds curve around the end of the range of which the mountain of the Holy Cross is the last high point. Going eastward from the mouth of Roche Moutonnés Creek the dip gradually decreases toward the Blue River range, where there is, as I already mentioned, no doubt a fault. There is also, I think, a very small synclinal fold between Eagle River and the Blue River range.

In bed No. 29 of section No. 22 I found fossils which were submitted to Professor Lesquereux, who has found the following species: *Calamites Suckovii*, Brgt., *Calamites gigas*, Brgt., *Stigmaria fucoides*: of the first he says: "This species is perhaps more abundant in the coal-measures; but it ascends to the base of the Permian, where, in Europe at least, it has been found in plenty." The same species, however, was associated with *Calamites gigas*, which, Professor Lesquereux says, is exclusively Permian, or has as yet never been found in the Carboniferous measures. Of *Stigmaria fucoides* he says: "It is a universal species of the coal-measures, also ascending, rarely however, to the Permian. I am inclined to consider it as Permian merely by the lithological relations to the other specimens, but it is not possible to decide positively from this." The latter specimens were found somewhat lower (a few feet) than the other specimens. The layer in which these specimens were found probably lies near the line between the Carboniferous and Permian formations. All below probably belongs to the Carboniferous. Two things are especially noticeable here, namely, the small amount of limestone when compared with the section made at Horseshoe, (section No. 18,) and again the presence of so much carbonaceous material in the shales and sandstones. We have seen in the section above that there are numerous black shaly layers, but besides there are also in the sandstones at various places patches of black carbonaceous material. When these layers were being deposited there must have been low, marshy ground bordering this part of the Sawatch range. This range must therefore have been partly above water, or at least not very far below the surface. There may have been oscillations of the surface.

The sandstones at the upper portion of the bluff, those in the latter part of the section, are very much like those below the first fault on Four-Mile Creek, (No. 24 of section No. 18.) I think they are of the same age. Another season we may study these beds again, and above them I hope to discover the limestones and interlaminated red shales that we found east of Fair Play, (No. 18 to 51 in section No. 9.)

The Sawatch range is, therefore, probably a true anticlinal axis, the sedimentary beds on the east side, where the Arkansas Valley now is, having been removed and carried down the Arkansas to help in forming the plains. The beds spoken of in the last chapter as being faulted in the range on the west side of the park, are the remnants of these beds that once extended uninterruptedly to the Sawatch range, forming the eastern side of the anticlinal. We have seen that the range dies out both toward the north and toward the south, its highest portion being just opposite the park. Not only is the evidence of the anticlinal shown at the northern end, but also on the south, as will be seen in Dr. Endlich's report. The western side will be treated of in the next chapter. The elevation of the park range, in which Mount Lincoln and Buffalo Peaks are situated, probably took place in the Cretaceous or early in the Eocene times. It is probable, also, that at the same time the main range west of the Arkansas attained its greatest elevation. It was doubtless above water before this, the sedimentary beds dipping slightly from it toward the eastward. This may have resulted from a more gradual action, while the later elevation was due in part, at least, to volcanic action. Crossing the range at the head of Lake Creek, we descend on the west side to the waters of the Gunnison River, which at this point flows through a meadow-like park called Taylor Park. This park is bounded on the west by gneissic rocks. The basis of the park is also granitic and gneissic, but it is for the most part covered with drift, probably all of glacial origin. All the creeks coming into the Gunnison from the east, rising on the western slope of the Sawatch range, in the park, present evidence of glacial action. On Texas Creek, the second creek from the lower end of the park, there are well-marked lateral moraines, reaching from the edge of the mountains almost to the main river and gradually decreasing in height. Almost all the curves of these moraines correspond with those of the streams upon which they are found. In the limited time which I had I found no evidence of terminal moraines. The main portion of the park lies on the east side of the Gunnison River, which keeps close along the edge of comparatively low granite or gneissic hills. Several outcrops of granite are found throughout the park, but they are mostly covered either with the glacial drift, or, close to the streams, by alluvium. The park has its greatest width at the southern portion, where it is about six miles wide. At the northern end, on some of the branches coming in from the northeast, volcanic material is seen, which is probably connected with that on Grizzly Peak and that in the pass at the head of Lake Creek. At the southwest corner of the park the Gunnison enters a cañon in the granites. Dr. Endlich went through this cañon, and for an account of it I refer to his report. East of the cañon and south of Taylor Park, from which it is separated by a low ridge of granitic hills, is a smaller park called Union Park. Here we found some men working in the drift on the branches of a small creek and getting out a little gold. The two principal gulches are named Cotton and Lotus Gulches. Placer-mining was carried on here and in Taylor Park in 1860, but it was broken up by the Indians. Both Taylor and Union Parks are partially timbered, and in the valleys of the streams we have a growth of sage-brush, (artemisia.) The remainder of our district, including the Elk Mountains and the head-waters of Roaring Fork, I will reserve for the next chapter.

CHAPTER IV.

GUNNISON RIVER—ELK MOUNTAINS—ROARING FORK.

Leaving Taylor Park, we followed to its source one of the western branches of the Gunnison, which for the greater part of its course flows through gneissic rocks of the same character that we saw on the west side of the Gunnison, and of which they are really the continuation. The course of the stream is about northeast. Near the head of the creek we found the first sedimentary beds we saw west of the Sawatch range, in an outcrop of blue limestone containing *Zaphrentis* and *Spirifer*. The layer in which the fossils occur is very dark in color, and has above it lighter-colored layers that are non-fossiliferous. The strike of these beds is north and south, and they incline about 10° to the west. As we follow them southward, the strike gradually turns toward the westward. A few miles south of this outcrop, between the Gunnison and the east branch of Taylor River, I ascended a high point, which I found capped with the same limestone. I named it the Triangle, from the shape of this capping, which was triangular. It seemed to be the center of these ridges, one running toward the west, one toward the north, and the third toward the south. Its height is 12,830 feet above sea-level. Beneath the limestones are quartzites, probably Silurian. The northern side of the hill heads a small creek that joins the east branch of Taylor's Creek just above a deep gorge. The course of this small creek is at first toward the north, and then west. It rises in an amphitheater, recalling the form of Horseshoe Mountain. The dip here was toward the northwest, there being a sharp turn to the west in the strike, which on the ridge to the north is almost north and south. As we follow the ridge to the west, however, the strike turns still more until its direction is north of west. Toward the south, however, the dip is toward the southwest, and on the next high point, about a mile south of the Triangle, on the northern part, it is toward the northeast. Between these points, therefore, there is a fold. The more southern point was visited by Dr. Endlich, and I learn from him that the summit is granitic, and that the beds dip away from it in all directions. I think that the cause of this folding is to be referred to eruptive agencies, the evidence of which is to be seen in the dikes that we find to the westward, and which will be referred to presently. Before this disturbing element was present the general dip was probably to the westward. The east branch of Taylor Creek cuts its way at right angles to the strike across the strata that continue west from the Triangle, and flows through a narrow rocky gorge, in which I made the following section from north to south:

1. Volcanic.
2. Limestone.
3. Quartzite.
4. Volcanic.
5. Sandstone and conglomerate.
6. Limestone.

The first layers are very indistinct, but enough is seen to show that the dip is toward the northeast in Nos. 2 and 3. The first layer is a dark-green porphyritic rock, probably trachytic. Nos. 2 and 3 are probably Silurian, and are the direct prolongation of some of the lower layers seen on the Triangle. We see that the dip has changed. Layer No. 4 is a highly siliceous rock (Rhyolite?) and is in laminæ which incline toward the southwest. There are included fragments of limestone and quartzite noticed in some places. The last bed of limestone has a dip to the southwest and inclines at an angle of 65°. About two miles farther down the river, at the mouth of Dead Man's Gulch, the dip is again north, or a few degrees west of north. At the head of Dead Man's Gulch, and between Taylor River and Cement Creek, are two points, stations 72 and 73, which we ascended from the valley of East River. On the ridge running southwest from Station 72, which is the most western of the two, the first rocks met with were sandstones dipping north 75° west, beneath which was a bed of limestone dipping in the same direction at an angle of from 5° to 10°. We next passed over a saddle, beyond which are irregular structured pink and white mottled limestone, containing fragments of fossils like those we found in the Silurian layers in Glen Eyrie, east of the foot-hills. Indeed, the beds bear a very close resemblance to them, and I have but little doubt that they are of the same age. The dip here is north 55° west, at an angle of from 5° to 10°. Below the beds just given are quartzites which rest on reddish granites. On the station itself we have limestones and quartzites, in too much confusion, however, to make a very complete section. The lowest exposure is a coarse quartzite, above which is a band of very black limestone, flinty and containing pebbles. This is from 3 to 4 feet thick. Next is a light yellowish limestone, followed by a brownish-gray limestone, above which we find dark-blue limestone. The dip on the western side is toward the northwest. This changes toward the north until it becomes northeast: the angle is 10°. There is also a change to the south and southeast, where we find the dip to be south and southwest, and the angle 25°. The station has a broad top, and is 11,862 feet above the sea-level. On the ridge, between stations 72 and 73, the dip of the beds is east of north, and the angle 15° to 20°. We have here about 60 feet of white limestone and then about 40 feet of reddish quartzitic sandstone. These beds, I think, belong immediately below those seen on station 72 and above those seen on the ridge we ascended.

At Station 73 we have the following beds:

1. Irregular spotted limestone; general color, gray. The lower portion is very compact, and full of purple spots. It contains, also, on the weathered surfaces, fragments of crinoidal stems and corals. The thickness I estimated at about 20 feet.
2. Soft white-purple spotted sandstone, about 8 or 10 feet in thickness.
3. Light-gray limestone; very compact, especially above, where it is also somewhat laminated; and on the surface, weathers red. Its thickness is from 30 to 40 feet.
4. Irregular gray limestone, with large flint nodules and pebbles. This is at the upper part of the bed; could not get at the lower part, which is probably like that I have referred to above on the first ridge we ascended; could not give the thickness.
5. Quartzites and sandstone; thickness not estimated.
6. Mica schist; below this bed we have rose-colored granites.

These are the extension of the granites in the cañon of the Gunnison River, and they reach to the westward and southwest toward East River to a line of trachyte rock. Along the creek heading under Station 73 and flowing into East River, there were several exposures showing the bedding of the granite very distinctly. The dip was about north 75° west, at an angle of from 55° to 60°. From the station we could overlook the cañon of Taylor River, which seems to be very rugged and cut through the granites. From Station 93 the line of outcrop of the sedimentary beds curves in toward the northward, and then back toward the south, and crossing Taylor River turns gradually toward the north around the granite point just south of the Triangle. The general dip seems to be north and northwest. This entire region is one of great interest, and to be worked up in detail will require some time. I can hope to give only the most prominent features.

Below the mouth of Cement Creek, East River flows through a beautiful broad valley, in which it has cut well-defined terraces in the drift. On the south side, some distance back from the river, are two mountains, with mesa-like summits. They were not visited, but they are undoubtedly capped with trachyte, as is a high hill on the north side, which was ascended by Mr. Taggart. It is composed of a light purplish trachyte. This rock extends to the eastward and southeastward, and is probably continuous into Dr. Endlich's district. Above Cement Creek the river flows through a broad open valley, on either side of which the Cretaceous formations are exposed. I will refer to this valley again further on. Leaving the valley of East River we proceeded up Cement Creek, which, near the mouth, is in a cañon. The first exposure of sedimentary rocks is on the west side, near the mouth of the cañon. Here are white and rusty sandstones, dipping about south 65° west, inclination 15°. These sandstones probably belong to the Cretaceous No. 1. Farther up the creek we meet with dark and rusty-colored limestones, which I think are unconformable to the sandstones near the mouth, and belong to a lower horizon. They will have to be traced to the westward before their exact relation can be determined. The dip here is about north 45° west. Farther up stream, below these limestones, are beds of quartzite, which rest immediately on the granite. They are probably Potsdam. The dip gradually changes, and about three-quarters of a mile up the cañon it is north 5° west, angle 10°. The course of the creek here is south of west. The cañon for about two miles has a comparatively wide valley, reaching to the base of cliffs on either side. Above this point the cañon narrows, and the trail has to make a wide detour. Just at the point where the creek enters this cañon the sedimentary beds cross almost at right angles to the course of the stream. The dip here is about north 15° east, angle 20°. Above this point the creek flows through a beautiful grassy valley, in which all the beds are covered until we have gone about a mile and a half up stream, when we come to beds of conglomerate with a red matrix containing pebbles of limestone and granite. These seem to be somewhere near the line between the Carboniferous and the Triassic (?) formations. Above it are red sandstones. The dip of these beds is, toward the northeast angle, 10° to 15°. Leaving Cement Creek at this point, we crossed to Deadman's Gulch, striking one of the northern branches, down which we proceeded until we reached a fork coming in from the north. At the head of this the red-beds are tipped up, and dip about south 35° west, at an angle of 25°. This change in the dip seems to have been caused by the upheaval of a high point to the eastward, which I took to be volcanic, judging from the *débris* in the creek heading under it. I was unable to visit it for want of time. Following up the main Taylor Creek we find that the layers we saw crossing the east branch of the creek still continue, the strike being toward the northwest. One of the dikes (Layer No. 4 in the section) is very prominent. Whether the other continues or not I could not determine. At the head of the creek there is some confusion in the beds. On the west side of the creek are high bluffs of limestone, on top of which there is a conglomerate sandstone. Below these beds, near the creek, is a series of limestone shales. These beds on top of the bluff dip toward the northeast at an angle of 60° to 65°. Following the ridge to the north we find that a red feldspathic granite makes its appearance, and on a high rounded hill on the east side of the amphitheater at the head of the creek, resting on the granite, is a bed of white quartzite, above which are bluish and yellow limestones. These beds, I take it, are Silurian. At the southwest side of the hill the dip is toward the southwest. This gradually changes to the west, and finally to the northwest as we go toward the northern end of the hill, where the angle of inclination is 25°. Between these beds and those referred to above as appearing in the cliffs farther down the creek, there seems to be a break. In the amphitheater are beds of blue limestone with shales, all dipping toward the southwest; but when we ascend the ridge on the northern side we find limestones, black shales, and sandstones, followed by thick beds of limestone, all dipping to the northeast. When we ascend Italian Mountain the confusion of these beds is explained. The mountain is named from the colors it shows at a distance, red, white, and green, the Italian national colors. The white is due to the granite, of which the peak is mainly composed; the red is seen on the weathered surface of included beds of quartzite, and the green is seen in the grassy slopes on the eastern side of the mountain. Its elevation is 13,255 feet.

The peak is made up in part of a light-gray granite, which I consider to be eruption, and rusty quartzites very much metamorphosed. These quartzites in places stand on end, and in others dip southwest and northeast, at angles from 80° to 85°. Between some of the beds are long narrow seams of the granite. This is beautifully shown in the accompanying illustration made by Mr. Holmes, Fig.

This shows, also, how the quartzite has been broken up by the granite. The illustration shows the northern face of the peak. On the west side there is a fault of about 400 feet in the quartzite. This fault extends to the northwest, and I shall refer to it again. Extending from the peak toward the southeast is a line of eruptive granite gradually thinning out. Close to Italian Mountain is a high point at the commencement of a ridge, which forms the western side of the amphitheater heading Taylor Creek. Italian is the most eastern high peak in the Elk Mountains. The name Elk Mountains is applied to the mass of mountains between the Gunnison River and the waters of the Roaring Fork of Grand River. The trend of the range, at first, is almost at right angles to the trend of the Sawatch range. Afterward, however, it turns to the northwest. The nucleus of the range is composed of eruptive granite, of which that on Italian Mountain is a part. The general trend of this granite, which shows itself in three island-like patches, entirely isolated from each other, is northwest and southeast. This is also indicated by the courses of the principal streams. The course of Roaring Fork and its branches is toward the northwest, while East River flows to the southeast, its course being parallel to that of Roaring Fork, although it flows in exactly the opposite direction.

To the north of Italian Peak, between it and the divide between the Gunnison and Roaring Fork, there are remnants of the sedimentary beds. To the west we have a grand view from the summit. The island of eruption is distinctly shown, the white or light-gray color of the granite being contrasted with the dark colors of the older stratified rocks, above which are the bright-red sandstones of Triassic age, and resting on them, in a few isolated places, patches of lighter-colored beds that are of Jurassic and Cretaceous age. The sedimentary beds are beautifully shown dipping away from the granite nucleus. They are lifted high up, and form some of the most prominent peaks in the range, the stratification of the rocks giving the mountains a peculiar architectural form. The pyramidal form is frequent. Southeast of the peak I made the following section in ascending order:

Section No. 24.

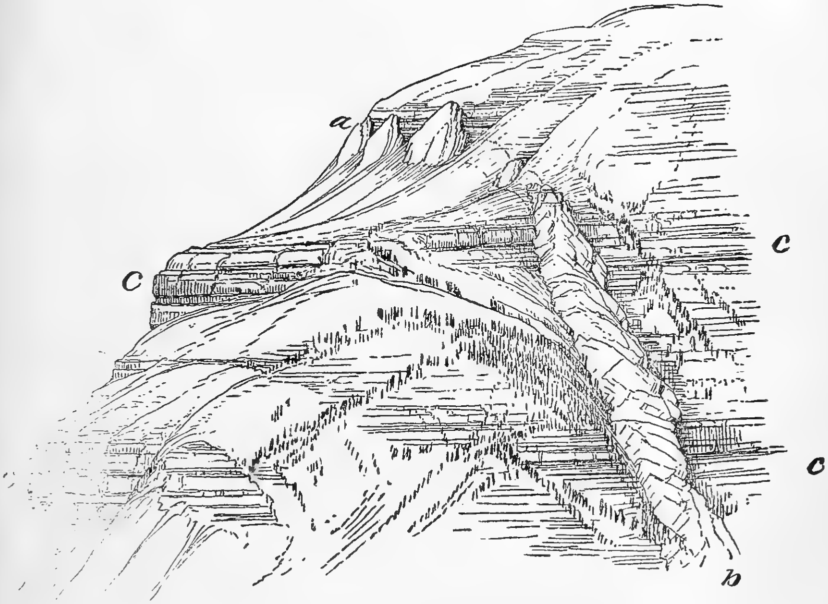
1. From the pass at the head of a small western branch of Taylor River we have a space reaching about 400 feet up the hill, in which the beds are covered. Occasional outcrops indicate that this space is filled with red sandstones below, above which there are limestones, with interlaminated shales and conglomerates. Above we have as follows:
2. Hard gray laminated sandstone, becoming coarse near the top; dip 50°; 50 feet.
3. Conglomerate; pebbles of blue limestone and granite, from 1 to 4 inches in diameter, in a coarse red sandy matrix, 30 feet.
4. Brownish red sandstone, 20 feet.
5. Space probably filled with continuation of No. 4, 20 feet.
6. Dark, compact, grayish-blue limestone, fossiliferous, with veins of calcite, becoming laminated, and somewhat laminated as we go up, 12 feet.
7. Yellowish-gray standstone, becoming conglomeritic above, with pebbles of limestone and granite. The dip here is about 40°; 4 feet.
8. Coarse yellow sandstone, 5 feet.
9. Fine yellowish sandstone, in laminæ of about $\frac{1}{8}$ of an inch. The lower layers have a reddish tinge, while those above become more gray; 3 feet.
10. Sandstone shales; some of the layers are conglomeritic, with pebbles of limestone. Below they are gray, in the middle red, and above yellow; 60 feet.
11. Compact blue limestone, very dark and laminated below, lighter-colored above, and fossiliferous, 4 feet.
12. Bluish-gray calcareous shales, 8 feet.
13. Yellowish sandstones, somewhat shaly, graduating toward the top into fine calcareous shales, 50 feet.
14. Bluish calcareous shales, 3 feet.
15. Snuff-colored sandstone, loose textured and porous, 4 feet.
16. Bluish-gray calcareous shales, 25 feet.
17. Blue laminated limestone, weathering light gray, 5 feet.
18. Sandstone, weathering dark yellow, with interlaminated soft gray sandy shales, all calcareous, in layers from 1 to 2 feet thickness, 50 feet.
19. Coarse reddish yellow sandstone, followed by an alternation of sandstones and shales, 60 to 70 feet.
20. Purplish-red sandstone, 5 feet.
21. Reddish-yellow sandstone, 30 feet.
22. Yellow sandstone, 10 feet.
23. Reddish sandstone, 5 feet.
24. Sandstones and shales, 30 feet.
25. Space probably filled with sandstone, 70 feet.
26. Blue laminated sandstone, 25 feet.
27. Gray sandstone, 8 feet.
28. Coarse reddish sandstone, becoming gray toward the top, 65 feet.
29. Blue fossiliferous limestone, 5 feet.

30. Micaceous sandstones and shales, general color gray and yellowish, greenish gray at top, 40 to 50 feet.
31. Greenish-gray micaceous sandstones, all laminated and having a few thin beds of limestone near the top. They extend a distance of about a quarter of a mile, dipping at an angle of about 30° toward the northeast.
32. Hard irregular black limestone, 10 feet.
33. Rusty-brown quartzetic sandstone.
34. Brown crystalline limestone.

I was unable to get the thickness of these last two beds, as they were somewhat confused by the presence of the eruptive granite, which rises here toward the high point just south of Italian Mountain. The quartzites seen on the peak evidently belong to this section, of which they are probably the lower portion, for the upper layers here are really the older or lower if the beds were in their proper position. There has been a complete inversion. The dip on the top of the ridge is about north 40° to 50° east.

In bed No. 1 of the section No. 24, some distance below No. 2, in a red limestone, I found a specimen of *Loxonemia.* It was below the conglomerates given in the upper part of the bed. It is probably Carboniferous. In layer No. 6 I found *Productus muricatus*, *Spirifer*, and other indistinct fossils. In No. 11 there was a profusion; among the specimens collected, Professor Meek has identified *Productus muricatus*, N. & P.; *Athyris subtilita*, Hall; *Rhynchonella osagensis*, Swallow; *Hemipronites crassus*, M. &. H.; *Terebratula bovidens*, and *Retzia punctulifera.* In No. 29 I found some fragments, among which *Productus muricatus* was identified.

Descending to Cement Creek we again find conglomerates and red sandstones, dipping to the southwest, the angle being only a few degrees, (5° to 8°.) As we go up creek this increases gradually until the beds are suddenly turned up and stand almost on end. Mr. Holmes tells me that beyond this point the beds dip to the northeast. There is therefore running across the creek here a line of fracture, the direction of which is northwest and southeast. On the south side of this line, which is probably connected with the fault in the quartzites on Italian Mountain, fragments of the Cretaceous beds cap the hill. Some distance down the creek, as we have already seen, the dip is toward the northeast, inclining from 6° to 15°. Between the two points there must be a synclinal fold, the axis of which crosses Cement Creek with a direction a little west of north. From Cement Creek we crossed to the head of a small branch of Cascade Creek, the east branch of East River. This small creek rises on the broad divide, and has cut its way through the red sandstones, which are capped here with lighter-colored beds, probably of Jurassic age. Below the red sandstones are thick beds of red conglomerates like those seen on Cement Creek. The dip is west, or perhaps, in some places, a few degrees south of west. For a short distance the creek flows through a grassy valley, that gradually deepens until it ends on the edge of steep bluffs, over which the creek flows to join the main stream, which is about 600 feet lower down. From here we have an excellent view down the river. The cañon walls of Cascade Creek are bright-red sandstones and conglomerates, in which, on the west side near the forks of the two streams, is a broad trachytic dike. (*a b* in Plate XV.) It is about 50 feet wide, and crosses the creek. Its direction is about south 65° west. The dip of the beds seems to have been but little affected by the dike. As we go down stream the dip



Dyke on Cascade Creek

ab Dyke of Trachyte

cccc Red Sandstones and Conglomerates

becomes more and more toward the south, and we pass over red sandstones and conglomerates. The matrix of these conglomerates is a coarse red sand, in which are large pebbles of limestone. The angle of the dip to the southwest is 25°. This is at a point about a mile below the forks. A number of beautiful falls and cascades diversify the course of the stream. Below these the dip changes, and it is toward the north and northeast. This corresponds exactly with what we saw on Cement Creek. Below, in all probability the Silurian layers may be discovered, although I did not have time enough here to identify them.

About two miles below the forks a large creek comes in from the northwest. It rises under Castle Peak, and I will have occasion to refer to it again when I speak of the peak. From its mouth a broad open valley reaches almost, without interruption, to East River. Just above the mouth, on the east side, in the bed of the creek, there is an outcrop of quartzite, below which are shales. On the west side, reaching up for 400 or 500 feet, are limestones, above which we find the red-beds. I cannot say with certainty of what age these beds are, but they are probably Carboniferous. A little less than a mile farther down the stream we find, on the west side, outcrops of Cretaceous rocks, consisting mainly of calcareous clay shales, with interlaminated limestones. In one of the upper layers I discovered fossils agreeing with those I found east of the mountains in bed No. 2 of section No. 1. The bed has the same characteristics, including even the bituminous odor on fracture.

Above we find from 25 to 30 feet of rough conglomeritic sandstone of a rusty yellow color; next are thick beds of laminated limestone. All these beds dip toward the northeast. Crowning the hill are red-beds. There is, I think, a fault running through here. Its direction is probably northwest and southeast. It extends across Teocalli Creek also. Here, however, the beds are very much confused, seeming to have been crushed together. Mr. Holmes has made a very excellent drawing of the appearance of the beds on the west side of Teocalli Creek in Plate XVI. The following section was made here, the letters being the same as those in the illustration:

Section No. 25.

A	1. Conglomerate of large limestone pebbles in a red siliceous matrix. 2. Fine red sandstone shales, with bands containing nodules.	Thickness not accurately taken; about 10 to 15 feet.
B.	3. Very hard, compact, dark and blue, almost black, limestone; 8 inches to 1 foot.	
C	4. Purplish blue limestone; weathering, reddish on surfaces; 1 to 2 feet. 5. Steel-gray quartzitic sandstone, 1 foot. 6. Soft light-gray calcareous sandstone, shaly below, 10 feet. 7. Red sandstone, fine grained, and somewhat soft, 2 feet.	
D	8. Gray sandstone, 3 feet. 9. Soft gray sandstone shale, 2 feet.	
E	10. Conglomerate, 6 feet.	

Below the beds given in this section we have as follows:
Red sandstones, 10 feet.
White sandstones, 15 feet.
Red sandstone, 8 feet.
Mottled sandstone shales, 10 feet.

The beds are very irregular in structure, and also in color. The same bed may be conglomeritic at one place, and then gradually become fine, while the color will shade from a deep red into white or gray. Not only are the beds crushed together, but they are also broken, as seen in the illustration. The line F G represents the fracture. As we go up Teocalli Creek the beds on the west side dip at first at a very small angle, not more than 5°, to the south or southwest. Farther up it is 45°, and this soon increases to 80°. As we go west, along the ridge, we find that the beds are completely turned over past the vertical. Mr. Taggart was on the ridge, and found Carboniferous fossils in beds that were inverted. On the east side of the creek is a high pyramidal mountain, (Teocalli,) which I ascended. Its height is 13,098 feet, and it rises over 3,000 feet above the bed of the creek. The stratification of the rocks composing it is almost horizontal, and they have weathered into curious forms. On the east and south is a series of enormous steps, while the north face presents castellated forms. The rocks are all very much metamorphosed, and are of a dark maroon-red color. At the base on the southern side Mr. Taggart found the following beds from below upward:

1. Yellow conglomerate.
2. Purplish limestone.
3. Yellow limestone and purple shales.
4. Purple shaly limestone.
5. Compact brownish-red sandstone.
6. Green cherty limestone.
7. Purple sandstone.
8. Sandstones.

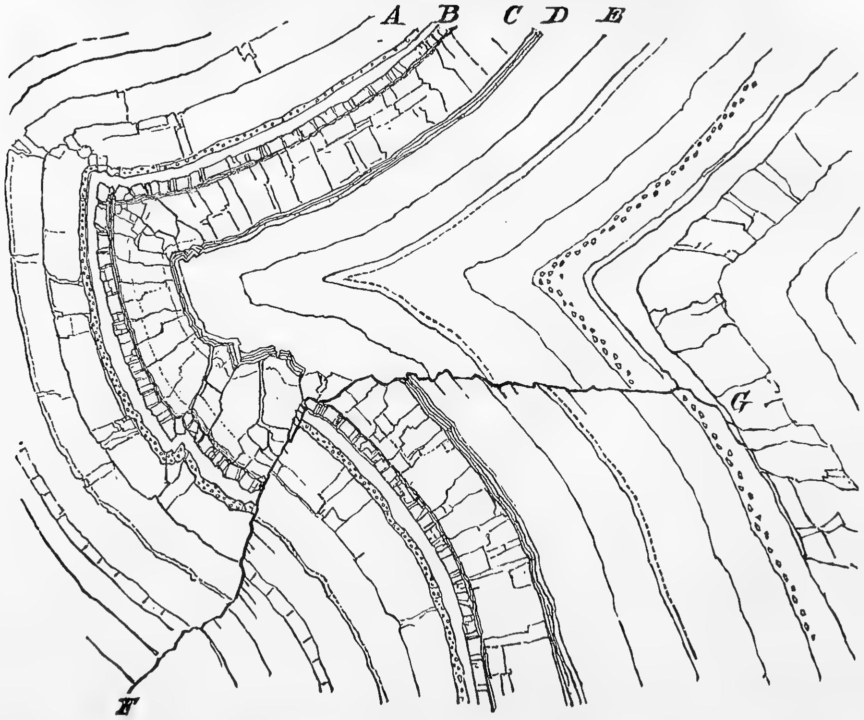
These beds all dip about north 45° east, at an angle of about 55°. He was unable to carry the section any higher, as the slopes were grassed over. The mountain stands on the southern edge of the eruptive island of which Italian Mountain is the most eastern high point. Here it is rather narrow; but to the east, south of Castle Peak, it widens, as it also does around White Rock Mountain, to the northwest of which it again narrows and ends, the sedimentary beds not having been broken through.

The following section was made from the summit of Teocalli Mountain in descending order:

Section No. 26.

1. Very fine textured laminated sandstone, generally of a maroon color, although grayish in some places. They have been very much changed. Thickness about 350 feet.
2. Yellowish metamorphosed sandstone, 50 feet.
3. Metamorphosed conglomerate gray matrix, with large purplish pebbles, 50 feet.
4. Fine-grained sandstone streaked with lines and spots; general color reddish maroon; about 50 feet.
5. Gray conglomerate, with interstratified purplish and gray sandstones, 200 feet.
6. Gray sandstone and conglomerate, 150 feet.
7. Coarse-grained light gray sandstone, greenish in places, 6 to 8 feet.
8. Sandstone conglomerate, 5 feet.
9. Light-grayish brown sandstone, 50 feet.
10. Coarse greenish variegated sandstone, 20 feet.
11. Space probably filled with sandstones that are yellow, judging from the *débris*; 55 feet.

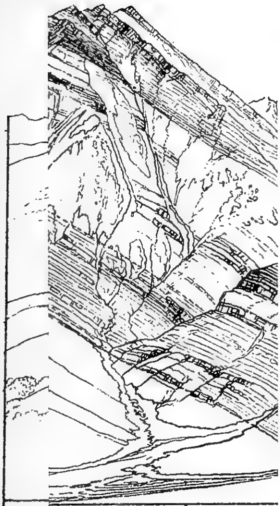
Plate 16.



Folding and Faulting in Cliff on Teocalli Cr.

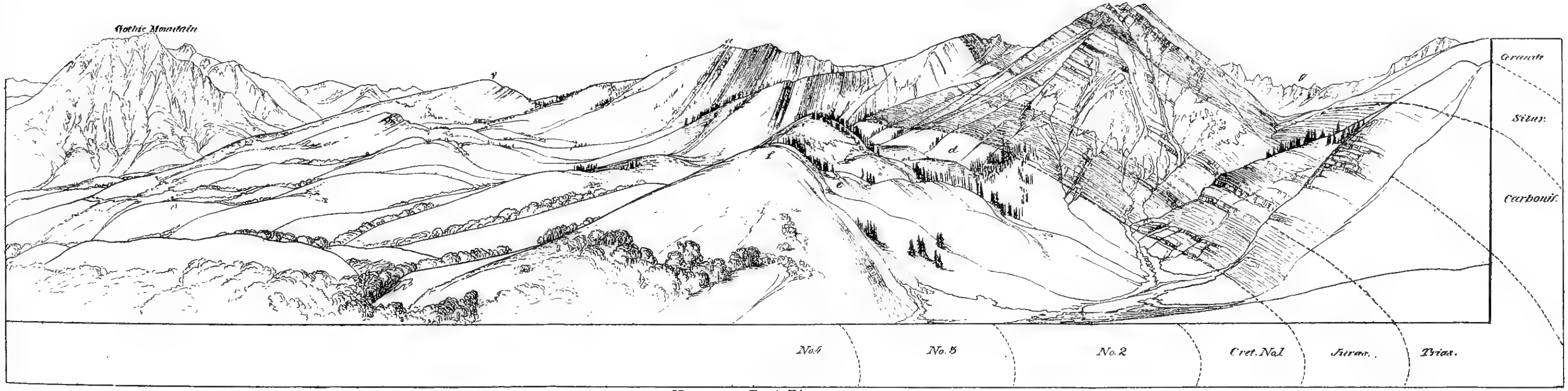
12. Yellowish-white limestone. The upper part grades into a sandstone, and has small crystals of pyrites. Below the bed has an irregular cross-fracture, and is white on the weathered surfaces. Thickness about 20 feet.
13. Rusty yellow quartzite with seams of eruptive rock running through it, which has disturbed the beds very much. The angle of the dip here is about 50°, and seems to be toward the east or north of east. Thickness is about 50 feet.
14. Eruptive granite reaching to the creek, a distance of about 600 feet.

These beds on Teocalli Mountain seem to have been broken off from those on the west side of the creek, and carried up past them. Crossing the ridge from Teocalli Creek to Dike Creek, coming from Castle Peak, we followed the stream up to the foot of the peak. At the foot of Teocalli on the east side, there seems to be a dip to the west or southwest. This gradually changes to the south and southeast, toward the east. The exposures are all of reddish sandstones and coarse conglomerates. As we go up, the strike of the sedimentary beds crosses the creek and has a direction a little north of east, probably joining the line of outcrop of the beds northwest of Italian Mountain. After leaving this line the valley is underlaid by eruptive granite, and near the head of the creek resting on this granite on the summits of the ridges on either side are the sedimentary formations, forming a semicircle around the head of the creek. At the head of the amphitheater thus formed is Castle Peak, a high, black-looking peak, in shape somewhat resembling Teocalli. It is not so regular, however, the outline being very rough and ragged. It is on the north side of the eruptive island, and is composed mostly of sandstones that are very much changed and intersected with dikes. We ascended the mountain, but the weather was so stormy that I did not attempt to make any section. The summit is 13,930 feet above sea-level, and about 2,400 feet above the head of the creek. While on the top we were almost constantly surrounded by clouds, and it was only occasionally and for a very short time that we were able to see any of the surrounding country. From the peak eastward the general strike is a little south of east, with an irregular outline until we reach the head of the Gunnison River, when it turns to the north, and seemingly follows a branch of Roaring Fork, which flows to the northward. On the summit is a very hard metamorphosed laminated sandstone, generally of a somber reddish-brown color, streaked in places with green. Next below is a very handsome sandstone conglomerate, and then a yellowish sandstone, all metamorphosed. Below these we have an alternation of red sandstones and conglomerates until we reach the base of the mountain. The beds are all more or less changed and intersected by dikes, which sometimes cut across the strata, and again lie between different layers. The dip is nearly due north, and the angle of inclination on the ridge below the summit is from 5° to 10°. It is difficult without closer study to determine with exactness to what age these rocks should be referred. I think it probable, however, at that the base we have the Potsdam sandstone or quartzite, and above the Silurian, the Carboniferous, and Permian rocks. Those on the summit are probaably Permian. Perhaps Permo-carboniferous would be the best term to apply to them. White Rock Mountain is at the head of Teocalli Creek. To the south the sedimentary beds are overturned, the strike being northwest and southeast and the dip to the northeast. On the north the dip is to the north and northeast. To the west the sedimentary beds extend across the granite. There is, however, a break, although the granite does not appear through them. Before reaching this point the beds that were turned over beyond the vertical have resumed their original position, and the ends have been dragged in, as shown in Fig. 1, Plate XVIII, which represents a section made west of White Rock. The peak is made up of eruptive granite, and is 13,671 feet high. Near the base I found micaceous hematite coating the surfaces of the granite *débris* in radiating crystals. The rock near the summit is very much broken up, rendering the ascent of the peak a little dangerous in places. North of the peak the summits of the ridges are capped with sedimentary beds, dipping north and northeast. All the mountains in this mass have conspicuous amphitheaters, in which there are snow-banks and small lakes, the latter generally frozen. Returning to the mouth of Teocalli Creek, we find ourselves in the broad valley of East River. East River flows through Cretaceous rocks. Below the mouth of Slate River, the largest western branch, are several beautiful terraces. The Cretaceous area extends southward into Dr. Endlich's district. Below the mouth of Slate River, on the west side of East River, beyond the valley, the Cretaceous rocks are covered by an overflow of trachyte. As we come around from Teocalli Creek to East River, the most striking points are "Crested Butte" and "Gothic Butte," which stand between East River and Slate River. They are both isolated, and rise considerably higher than the surrounding country. Both are surrounded with cretaceous shales. Crested Butte is the more southern of the two, and is 11,838 feet in height. It is composed of eruptive granite, similar to that on Italian Mountain and White Rock. Between the two buttes there is an exposure of trachyte, which is probably continuous with a band that is seen in Gothic Butte. The latter is six miles from Crested Butte. It was visited by Doctor Hayden, and to his report the reader is referred for the details of its structure. The summit is trachytic. Whether this is only a capping or not I cannot say positively. I am inclined to think, however, that it is not merely a capping, but that its relation to the surrounding beds is as shown in Fig. 1, Plate XVII, at *a*. Below the trachyte that is seen on the summit are cretaceous shales on the side of the butte, and below a second layer of trachyte. On the opposite side of the valley Mr. Holmes found in the shales of No. 2 Cretaceous, a bed of trachytic rock. This extends for some miles. I think that this mass is intrusive, and is connected with the trachyte of the butte. Mr. Holmes was unable to determine the line of junction between it and the beds above. I but little doubt that the shales just above will be found changed to a greater or less degree near the trachyte. I have before referred to the inversion of the beds on the northeast side of East River. These inverted beds are seen in Fig. —, Plate XVII, the Silurian being on top. The lower beds are all cretaceous. At the head of a small branch of East River we have bluffs of these beds dipping to the northeast about north 55° east, at an angle of 20° to 25°. First are about 100 feet of very thinly laminated black shales, non-fossiliferous. Next are yellowish sandstones and shales for about 150 or 200 feet. In the lower part of these shales fragments of stems and leaves are found. I saw also some poor specimens of *inoceramus*. Above we have black shales. How far they extend I was unable to determine, the slope being grassed over. On another small creek, the one seen to the right of a hill, the first exposure is a bed of white limestone shown at *f*, Plate XVII. Below, or rather above, as the beds are inverted at the point *e*, Mr. Holmes found fossils of No. 3 Cretaceous. This bed of limestone is, therefore, probably the same white bed that is seen in the Cretaceous all along the foot-hills on the edge of the plains. It is bed No. 1 in section No. 1, and No. 44 in section No.



No. 2

Plate XVII.



View up East River

3. Then there is a space reaching to the bed *d*, which seems to be filled entirely with black shales. At *d* is a bed of white sandstone, quartzitic in places. It is beyond doubt the No. 1 Cretaceous. Above it are variegated shaly beds. The colors are very bright. They are green, purple, yellow, and white. They extend for 300 or 400 feet, and are succeeded by red-beds which extend for nearly 1,000 feet, grading into maroon-colored beds, beyond which are yellow beds, probably representing the Silurian. Above No. 1 Cretaceous, therefore, is a complete series from the top of the Jurassic to the base of the Silurian. At *g* the eruptive granite is seen. The illustration shows also how the beds farther along, at *a*, are in their natural position. On the other side of the valley, just above Crested Butte, the dip is northeast, and at this point, therefore, East River flows in the axis of a synclinal fold. At the base of Gothic Butte the dip is the same as on the opposite side of the valley, viz, toward the southwest. On Slate River the rocks are all Cretaceous, and there are some very fine terraces cut into these rocks. The general dip, I think, is to the northeast or east. I hope to be able to visit this region again in continuing the work westward, and to be able then to determine some points that are as yet somewhat indefinite. The Elk Mountain region is sufficient of itself to furnish several years' work. Slate River formed the western limit of our work for the season at this point, although more to the north we worked considerably farther to the westward. Fig. 1, Plate XVIII, represents a section (partly ideal) through Gothic Mountain and across the granitic area west of White House Mountain. It is an interesting fact that the beds from *b* to *c* are right side up, while a short distance down the river they are inverted, as seen in Plate XVII, and also on Rock Creek, as shown in Fig. 2, Plate XVIII. It is opposite Gothic Mountain that they are in the normal position. It is fair, then, to infer that the presence of Gothic Mountain has something to do with it. Either the force of upheaval of the latter counteracted the force of elevation of the main range, or the egress of the trachyte acted as a relief to the latter force. The two elevations were probably contemporaneous, at least in part. The eruption of Gothic Mountain must have occurred at the same time that the inversion of the beds, both below and above it, took place. At the same time the beds were compressed laterally, and the fold between *c* and *d* was formed. As we look down East River, from Bellevue Mountain, we have a fine view of these beds. They are so folded between *c* and *d* as to form a semi-quaquaversal. As shown in the illustration, subsequent erosion has broken the connection between the beds, and a little beyond the point where the section was made the granite is seen in the center. At *e*, on the north side of the granite area, the sedimentary beds are seen dipping toward the northeast. It is probable that the mass of granite shown at *f* and the trachyte forming Gothic Mountain are connected. It would be interesting if we could trace the trachyte down to that connection and learn whether or not there is a gradual transition into the granite. The Elk Mountains present many complex problems, and it will require years of close and arduous work to master all the geological details. Each stream, with all the numerous small branches, will have to be followed to the very source, and almost every ridge and prominent peak will have to be ascended before all the obscure points can be made clear. It is one of the most interesting regions in the entire extent of the Rocky Mountains. I am confident, however, the observations made during the season of 1873 are in the main correct, and although much remains yet to be done, future observers will find but few errors in the work already recorded.

Above Gothic Mountain, at the head of East River and on the same side of the stream, is Slate Mountain, which is so called from the fact that it is largely composed of bluish and black slates, all of which belong to the Cretaceous formations. At the base of the mountain the quartzite of No. 1 outcrops. These shales prevail toward the southwest beyond Slate River. Bellevue Mountain, opposite Slate Mountain, at the head of East River, is similar in its composition.

From East River we crossed to the head of Rock Creek, which is one of the branches of Roaring Fork, which it joins below Sopris Peak.

On Rock Creek, as I have already intimated, and as is shown in Fig. 2, Plate XVIII, the beds are again inverted on the east side. The investigation of the beds on the west side of the creek had to be left to the explorations of the next season.

The following section was made a few miles down the creek on the east side, and is in ascending order:

Section No. 27.

1. Reaching from the bed of the creek up on the hill to the point *a* in Fig. 2, Plate XVIII, we have a space filled in with limestones and black shales.

a. 2. Very hard calcareous black shales, breaking into laminæ of about $\frac{1}{4}$ of an inch, 44 feet 7 inches.

3. Argillaceous sandstone, in places very shaly, 89 feet 2 inches.
4. White limestone, breaking into laminæ of about $\frac{1}{4}$ of an inch thickness, 6 feet.
5. Black argillaceous shales, with interlaminated bands of hard sandstone, 191 feet 3 inches.
6. Space of which the upper part is probably filled with white sandstone, and the lower part with alternate sandstones and black shales, 213 feet.
7. Bluish shaly sandstone, weathering a rusty color, 8 feet.
8. Rusty-colored calcareous sandstone, 15 feet 10 inches.
9. Bluish calcareous sandstone, 4 feet.

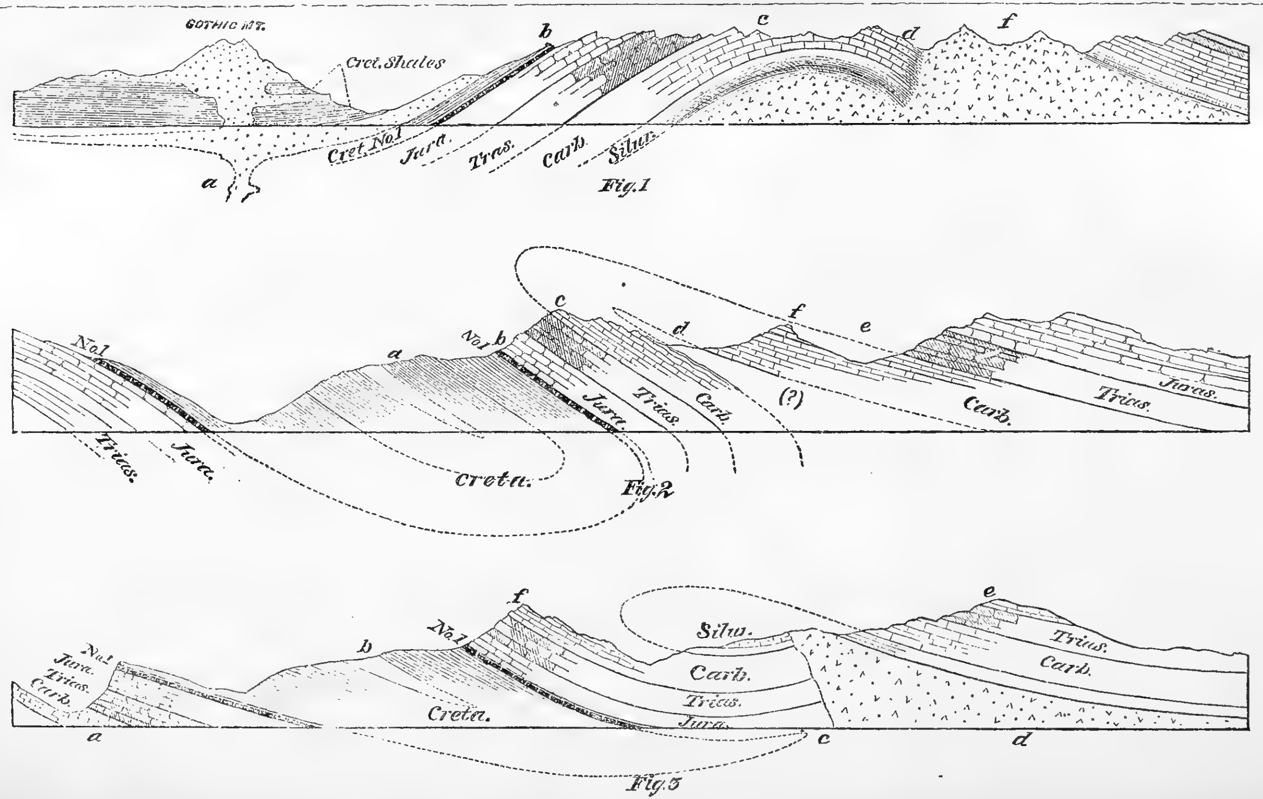
b. 10. Yellowish-white sandstone, containing impressions of leaves, 82 feet 8 inches.

11. Shaly sandstones, with included hard bands. The lower beds are rusty-colored and the upper ones greenish; 45 feet 4 inches.
12. Space, the bottom of which is probably filled with shales, gradually giving place to limestone. At the top there is an outcrop of blue limestone, having near the upper part a band of greenish shale; 90 feet 3 inches.
13. Yellowish sandstone, with bands of light blue limestone, 36 feet 3 inches.
14. Space, in which, as indicated, there are coarse red and gray laminated sandstones, 83 feet 10 inches.
15. Coarse purplish conglomeritic sandstone, 12 feet.
16. Rather fine variegated sandstone.
17. Purplish conglomerate.

c. 18. Space filled with alternations of conglomerates and fine shaly sandstones. The general color is a reddish-streaked and mottled with gray. On top there are some white beds, which, from a distance, I took to be limestones.

I was unable to determine the exact thickness of the last beds in the section. Above them, there is but little doubt that all the beds reaching through the Carboniferous to the base of the Silurian are present.

Plate 18.



Sections through Elk Mts.

The dip is north 55° east. At the point *a* in the illustration (Fig. 2, Plate XVIII) the angle of inclination is 58°, and at *b* it is 35°. Bed No. 10, in section No. 27, is the sandstone of "No. 1 Cretaceous," and in it Mr. Holmes found some fragments of leaves, none, however, very distinct, but sufficient with the lithological characters to identify the bed. The layers just above should probably be referred to the Jurassic. Fig. 2, Plate XVIII, represents a section through the Elk Mountains, near the head of Rock Creek. Section No. 27 was made from *a* to *c*. Whether the line of junction is exactly as represented at *d* in the illustration cannot be definitely determined until the line shall have been followed throughout its entire extent. The granite probably makes its appearance in places along this line. On the eastern branch of Rock Creek, (*e* in the figure,) which is in part of its course parallel to the main stream, the Carboniferous or Permo-carboniferous rocks are exposed at the bottom of the valley, and above them forming high bluff-like walls. On either side are red sandstones dipping north of east. Near its head the main branch of Rock Creek turns to the west, and at this point the dip of the rocks also changes. On the north and west side of the creek, in the space formed by this turn, is Treasury Mountain, so named from the discovery there of lodes of silver-bearing galena. At the south end of the mountain the dip of the sedimentary beds is south 5° east, and the angle of inclination is about 12°. As we follow the course of the creek the dip changes as the creek turns, and on the west side it is east of north. Treasury Mountain is composed mainly of cretaceous shales. Toward the west there are gypsiferous beds. At the point where the mines are situated, black shales containing quantities of *Inocerami* prevail. They are all very much changed, probably by the intrusion of the metaliferous lodes. The latter are described in Dr. Endlich's report.* On the east side of the creek, opposite Treasury Mountain, there seems to be either a bend or a fault in the Cretaceous beds; the shales at one place appear to dip toward the northwest. I did not have time to investigate it, but I am inclined to regard it as merely local. As we go down the creek the beds on the right side still occupy an inverted position. Just below the mouth of the eastern branch of Rock Creek, it enters a deep cañon. Here, below the cretaceous rocks, the older formations, at least as far as the Carboniferous, are exposed, as shown at *a* in Fig. 3, Plate XVIII. Following the eastern branch we cross the No. 1 Cretaceous twice. The second time the bed is inverted, as above it we find the older beds, which are beautifully shown on both sides of the deep gorge-like valley, dipping toward the northeast at an angle of from 50° to 60°. There is, therefore, probably a fold as indicated in the illustration. In the cretaceous rocks at *b* a dike outcrops. The creek, as it flows over the edges of the cretaceous rocks, does so in a series of beautiful cascades and falls. As we continue up creek the beds become more and more horizontal, until they dip slightly in the opposite direction, and we have a synclinal fold, the center of which is filled with Silurian beds, for the layers are still inverted. The ends of these beds, *c*, seem to have been broken away from those which outcrop in the cañon at *a*. We next cross a comparatively narrow belt of gran-

* Mr. R. A. Kirker, who is interested in the mines here, showed me specimens of coal found in this region. He did not disclose the locality, and I did not discover it. From his description of it, however, I judge it occurs in the Cretaceous rocks that prevail about the heads of Slate River, Washington Gulch, and East River. In appearance these specimens approach anthracite more closely than any other coal I have seen in the West; how closely, an analysis will have to prove. It has a luster like anthracite, and is very hard. I think, however, that it is only an altered Cretaceous coal. I judge it to be of excellent quality.

ite, *d*, similar to that of White Rock Mountain. Its direction as it crosses the creek is northwest and southeast. It is the south extension of an island-like area of granite like that of White Rock and Italia. Snow-Mass Mountain and Capitol Peak are two of the principal high points in this area. On the northeastern side of this belt (at *e* in the illustration) the Silurian beds are seen resting on the granite, and above are the Carboniferous and Triassic formations. Here there is a turn in the course of the creek. Above the granite belt it follows the strike of the sedimentary rocks. It is this part of its course that is parallel to the main stream, from which it is separated by two ridges, *c* and *f*, Fig. 2, Plate XVIII. The first one, *f*, is composed mainly of red sandstones and conglomerates, probably of Permo-carboniferous age, or possibly in part Triassic. Section 27 was made on the western side of the second ridge, (*c* in the illustration.) The creek rises in an amphitheater between Station E, or Maroon Mountain, and another high point of similar formation. On the eastern side of the valley is a high bluff-like wall composed of red sandstones and conglomerates, the latter prevailing toward the base of the cliff. The general dip is toward the northeast, at an angle of about 20°. There is also a slight curve on the face of the wall along the strike of the beds. As we go toward Maroon Mountain the bright red sandstones become darker. Maroon Mountain derives its name from the color of its rocks. We did not ascend it, but made a station on a high point a short distance south of it. Here the rocks are mostly sandstones and conglomerates, a thin bed of gray limestone now and then appearing toward the base of the station. The sandstones are intersected by numerous dikes, which are probably connected with the main mass of granite. This may account for the changes in color and structure that we notice in the sandstones. All the dikes are irregular. A prominent one intersects Maroon Mountain, and another the ridge that rises toward it. East of Maroon Mountain is a dike, which is probably the southern extension of the large dike seen east of Snow-Mass Mountain, and to which I shall refer again. It is only near the base of Station 76 that we find any limestone. On the summit the beds are brownish, becoming red as we go down. These beds are also, for the most part, finer grained. In some places there are circular spots resembling sections of concretions. They are generally white or light yellow, and sometimes have a black central point. Near the base of the hill are also greenish shales. The beds exposed along the creek at the bottom of the cañon are probably of Carboniferous age, while those on the summit of the ridge should perhaps be referred to the Triassic. On the southwest face of White House, or Snow-Mass Mountain, a small branch of Rock Creek rises. It soon expands into a beautiful lake, to which the name of Elk Lake has been given. A short distance below the lake, the creek falls over the edges of the stratified rocks to the level of the main creek, a vertical distance of 1,102 feet. It falls over these rocks in two falls or cascades, the white foaming belt of water contrasting with the bright-red conglomerates and sandstones. Snow Mass Peak is 13,785 feet in height, and is made up of a light-colored granite, such as we saw on White Rock and on Italia. Southwest of the peak, at the head of the creek flowing into Elk Lake, there seems to be a dike in the granite. First is a band of very fine-grained dark rock, with seams of white feldspar. It is about 100 feet in thickness, and its direction is about due northwest and southeast. Just below it is a band about 3 feet thick, of a green rock, the color of which is probably due to iron. This is probably dioritic. Next to it is about 4 feet of the same rock that we saw first. It is followed by about 50 feet of a porphyritic rock, with a green matrix containing granitic pebbles, some of which are quite large. I have already referred to the fact that Snow Mass Mountain and Capitol Peak are situated in an eruptive center that is distinct from the one in which White Rock and Italia are included. The latter is more extensive and also more irregular in shape. The amphitheater, on the eastern face of Snow Mass, contains an extensive snow-field, the largest I have ever seen on any peak in the Rocky Mountains. It is from this snow-field that the mountain was named. To the northeast of Snow Mass, on the east side of Snow Mass Creek, is a high, bluff-like wall, which must be between 1,500 and 2,000 feet high. The most remarkable feature in this wall is an immense bed of eruptive rock, probably granite. At the base of the bluff, just above the bed of the creek, are exposures of beds that from a distance I judged to be Silurian. Fragments of these beds are also seen on the opposite side of the creek resting on the granite. The dike is about 600 or 800 feet in thickness, and has just below it what I think are Carboniferous beds, although on this point I cannot be certain, as they may be Triassic. Above the dike in some places is a capping of red sandstone. This has been removed in other places by erosion. As we go southeast along the ridge the dike diminishes in thickness. The dike I referred to as extending back of Maroon Mountain is probably an extension of this one. In the latter place, however, its dimensions are much smaller. To prove that they are the same the line would have to be followed. There are a great many of these dikes in the sedimentary beds dipping away from the granite. The large one just referred to, and shown in the illustration, is very easily explained. In the upheaval of the granite the sedimentary beds were of course broken through, and wherever there was no resistance the melted material intruded itself. The planes of stratification afforded points of weak resistance, and the beds were forced apart. Subsequent erosion, effected both by water and by ice, has carried away so much material that the connection with the main mass has been cut across, and we have at present the appearance as seen in the illustration. To fully investigate and work up in detail all of these dikes would require that each one be followed throughout its whole extent. Some of them would probably be proved to be trachytic, but I am of the opinion that if they could be traced to the granite they would be seen to grade imperceptibly into it. I think the entire mass of granite in the Elk Mountain district has been in either a plastic or a melted condition, and that the granite is eruptive. It is a question whether or not it is remelted metamorphic rock. The future will have to decide this point. The elevation of the range was Post-Cretaceous. The erosion since its elevation has been enormous. The different peaks are connected by sharp, semicircular ridges, each the ruin of a huge amphitheater, in the center of which the granite appears. On some of these ridges the sedimentary beds form a capping. The occurrence of these sharp ridges, high peaks, and these huge amphitheaters, renders traveling in the heart of the Elk Mountains extremely rough. All the peaks are somewhat difficult of ascent.

Looking northeast from Snow Mass Mountain, on the ridge beyond the one in which the dike is seen, cappings of light-colored beds appear along the summit. These are probably a portion of the Cretaceous beds that slope from the Elk Mountains toward the valley of Roaring Fork. They will be referred to again in a subsequent portion of the chapter. Capitol Peak is about three miles from Snow Mass, and has an elevation of 13,816 feet. Judging from its appearance, as seen from Snow Mass, it is similar in structure. West and southwest are the inverted beds shown at *f* in Fig. 3, Plate XVIII. Northwest of the peak the relations of the beds are as shown in the section from Capitol to Sopris Peak, Fig. 1, Plate XX.

Leaving Rock Creek we proceeded down East River to Cement Creek, and then crossed to the Gunnison, which we followed to one of its sources, and then crossed to the head of Difficult Creek, one of the branches of Roaring Fork. The divide between this creek and the Gunnison where we crossed it was 11,619 feet above sea-level. The rocks here, which are all granitic and gneissic, were referred to in the preceding chapter. On one of the stations (76) near the head of the creek, I found fair specimens of rose quartz. The view from this station looking westward was extremely fine. In the foreground we had the low ridges, heavily timbered with dark-green pines, beyond and above which the mass of mountains about Castle Peak towered, their somber blackness relieved by patches of snow. To the right and nearer us the dark colors changed to a deep orange, streaked by light gray wherever there were slides of rock. Still more to the right we had the red sandstones, their bright color contrasted with the grassy slopes on the rounded hills. Beyond and reaching high above, bathed in sunlight, stood the Capitol and Snow Mass Mountains, their immense snow-fields glistening with silvery brilliancy. To the right of the Capitol is a prominent point seen from all parts of the Roaring Fork Valley. It is noticeable for a bright yellowish band which is distinctly outlined in its face, like the band on an escutcheon. It may be a dike. We did not have time to visit the peak to determine to what the appearance is due. The creek we followed to the main Roaring Fork is densely timbered, and just before reaching the main stream plunges abruptly down a steep hill about 1,000 feet in height. Here we had to work about six hours in order to get our train down. One thing particularly noticeable when we reached Roaring Fork was the change in the vegetation. On the Gunnison we had seen but little in the way of vegetation besides the sage-brush, (*Artemisia.*) On Roaring Fork, however, we found a profusion, among which we noticed the scrub-oak, (*Quercus alba,*) a willow, (*Salix,*) two species of raspberry, (*Rubus deliciosus* and *R. strigosus,*) the service-berry, (*Amelanchier canadensis,*) the common currant, (*Ribes rubrum,*) and the common wild rose, (*Rosa blanda.*) The upper part of Roaring Fork is in cañon, emerging from which the stream flows through a valley that gradually increases in width, and is filled with drift that has been carried down by the water. Above Castle Creek this drift is made up principally of granitic boulders. Castle Creek is the first large creek coming into Roaring Fork from the left side. It drains the east side of Castle Mountain, one branch also heading on the west side of the peak. All the branches have cut deeply into the red sandstones exposing the carboniferous layers below. A short distance above the mouth of Castle Creek Hunter's Creek comes in from the east. It is here that we first meet with the stratified rocks. The Silurian quartzites cross the main stream, and the line of outcrop extends up Castle Creek. On the east side the dip seems to be north 35° west, angle 25° to 30°. On the other side the beds are more highly inclined, and dip in about the same direction 50°. From this point the valley widens, and is covered with an extensive deposit of drift, a large portion of which was probably derived from the Elk Mountains. Indeed, this is shown by the great quantities of red sandstone boulders in the bed of the stream. This deposit is cut into terraces by Roaring Fork, and all the branches coming in from the southwest. The terrace on the right side of Castle Creek is 130 feet in height. On the opposite side it is about 210 feet in height. The next creek below Castle Creek, Maroon Creek, is also large, and drains the portion of the Elk Mountains east

Plate 19.

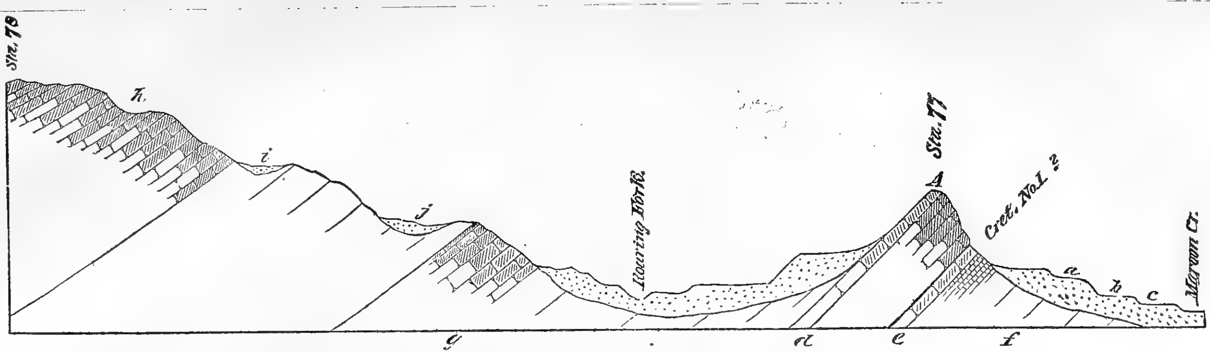


Fig. 1 Section across Roaring Fork; 2 miles

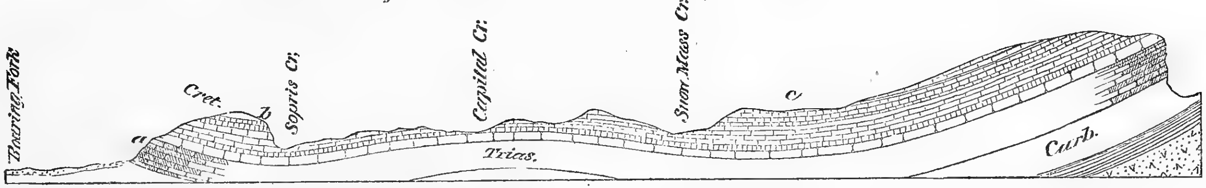


Fig. 2 Section S.W. of Roaring Fork 21 miles

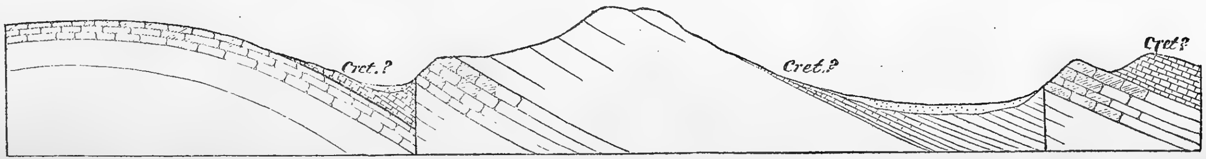


Fig. 3 Section N. from Sta. 82

of Maroon Mountain. The profile across this creek is shown in Fig. 1, Plate XIX. Here on the right side we have three steps, the first, *a*, being 15 feet; the second, *b*, 35 feet; and the third, *c*, 50 feet. The latter is about 4 feet above the level of the stream. The tops of the upper terraces seem to have a general level, and are overgrown with sage-brush. Along the streams at the bottom of the small cañons there is a growth of aspens and pines. Between the mouth of Maroon Creek and Roaring Fork there is a conical-shaped butte that rises about 350 feet above the general level. This is represented at A in Fig. 1, Plate XIX. The following section was made here from the point *d* in descending order:

Section No. 28.

d. 1. Soft fine-grained yellow sandstone. At the south end of the butte there are two small faults in this bed and in the bed next below; thickness, about 20 feet.
2. Red sandstones. The upper portion very hard, becoming softer and shaly as we go down. They become greenish also as we descend; thickness, 40 feet 2 inches.
3. Very hard greenish-gray calcareous sandstone, with calcite distributed through it; thickness, 18 inches.
4. Fine red shales, with a band of hard sandstone in the center, 1 foot.
5. Sandstone, with a band of shales 1 inch in thickness, 12 feet 6 inches.
6. Very fine deep-red shales breaking into very small pieces, and having interlaminated bands of hard sandstone each about 1 inch in thickness, 8 feet.
7. Coarse pink sandstone, shaly in places and conglomeritic at top, 15 feet.
8. Coarse pink shaly sandstone, 6 feet.
9. Coarse pink conglomeritic sandstone, like No. 7, but not quite so coarse-grained. The pebbles and matrix are both siliceous, 25 feet.
10. Irregular purplish limestone, very coarse, with shales, 8 feet.
11. Shaly sandstones, 10 feet 6 inches.
12. Coarse irregular purplish limestone, resembling a conglomerate. There is about 5 feet of this and then 1 inch of green shale, below which we have a bed of the limestone in structure like the upper part, but of brick-red color; total thickness, 8 feet.
13. Limestone conglomerate, with masses of purplish blue limestone, varying from 1 to 4 inches in diameter, 4 feet.
14. Irregular brick-red calcareous sandstone, with cross fracture. In some places there are greenish bands, 40 feet.
15. Coarse brick-red sandstone with cross fracture, 5 feet.
16. Fine-grained red sandstone, 5 feet.
17. Limestone conglomerate, like No. 13, 8 feet.
18. Irregular brick-red sandstones, 21 feet 8 inches.
19. Red sandstones, compact above, becoming irregular and mottled toward the center, and compact below again, 84 feet 10 inches.
e. 20. Compact fine-grained yellow sandstone, 77 feet 7 inches.
21. Blue limestones, with interlaminated shales. The limestone is in beds about 2 feet each in thickness, while the limestone varies from 2 to 5 feet; 155 feet.
22. Space reaching to base of hill, 155 feet.

Below these beds, on a ridge between the mouth of the creek and

Roaring Fork, other beds are exposed. Here Mr. Taggart made the following section. The beds would be represented under the drift at the point *f* in the illustration, (Fig. 1, Plate XIX.) The beds seem to be conformable, all dipping about 40° to 50° north, 45° east:

Section No. 29.

In ascending order, by Mr. Taggart:

1. Blue limestone, 20 to 30 feet.
2. Gray compact fine-grained sandstone, 10 feet.
3. Compact fine-grained blue limestone, 50 feet.
4. Fine-grained sandstone, 6 to 8 feet.
5. Space covered with *debris*, 150 feet.
6. Brown sandstone, 2 feet.
7. Brown shales, 10 feet.
8. Fine gray compact sandstones, with small quartz pebbles, 150 feet.
9. Dark shales, very much broken, 200 feet.
10. Space probably filled with shales, 200 feet.
11. Brown limestone and shales, alternating, in beds from 1 to 2 feet in thickness, and containing fossils; total thickness, 30 feet.
12. Blue limestone, with interlaminated shales, 150 feet.

This is as far as Mr. Taggart was able to carry the section. Bed No. 12 corresponds with No. 21 of section 28. When we cross to the east side of Roaring Fork, the beds on the hills are very much obscured. Enough is seen, however, to warrant the conclusion that near the base of the hills, *g*, are yellowish sandstones and shales. Above these are outcrops of red sandstones, *h*, dipping north 15° east, and inclining 50°. I am not satisfied as to the age of these beds, although I think it is probable that they are either Carboniferous or Permo-carboniferous. The beds given in Mr. Taggart's section dip conformably beneath those given in section No. 28. They are undoubtedly Cretaceous, as proved by the fossils he obtained. Bed No. 20, in section No. 28, is probably No. 1 Cretaceous. There would seem, therefore, to be an inversion of beds here, although it is difficult to imagine what should cause it. I was unable in the short time at my disposal to determine accurately the relations of these beds shown in the butte to those skirting the Elk Mountain range on the northeast. Crossing to the opposite side of the valley, the Cretaceous beds are seen dipping to the northwest. The line of outcrop follows the course of the western branch of Maroon Creek, and then turns to the northwest along the edge of the eruptive area about Snow Mass and the Capitol, and continues across toward Sopris Peak. The dip seems to change also, being at first northwest and gradually changing to the northeast. At the points *i* and *j*, in the illustration, Fig. 1, Plate XIX, we have two benches, with a gradual slope toward the northwest. They are covered in part with a growth of aspens, and strewn over the surface are numerous granite boulders of all sizes. These benches, I think, must mark the old courses of Hunter's Creek, that joins Roaring Fork above the mouth of Castle Creek coming in from the east. They curve toward the present bed of the stream. About two miles below the butte through which the section given above was made, the river cuts through the Cretaceous beds, leaving a high bluff on the west side in which the beds are inclined at an angle of 15° to 20°. Opposite these bluffs is a level valley filled with drift, which reaches to Cretaceous bluffs on the east side. The river cuts its way deeply into this drift, which is underlaid by Cretaceous rocks, as is shown by several exposures along the course of the river higher up stream on the east side, just

Plate XX.

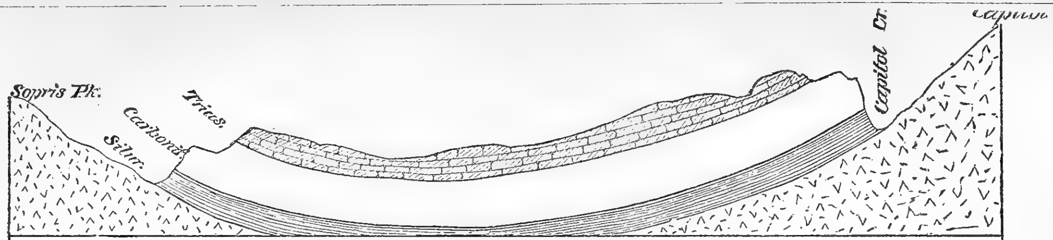


Fig. 1 Section from Sopris to Capitol 9 miles

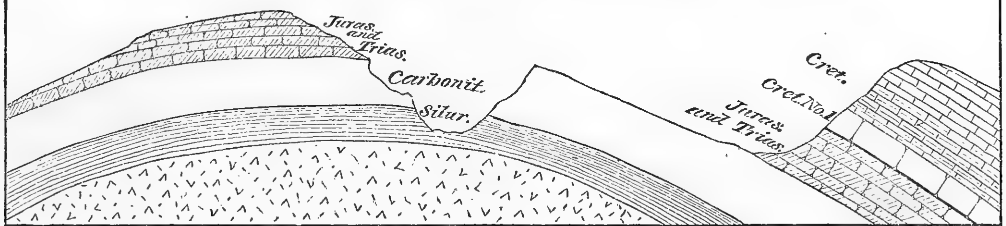


Fig. 2 7 miles

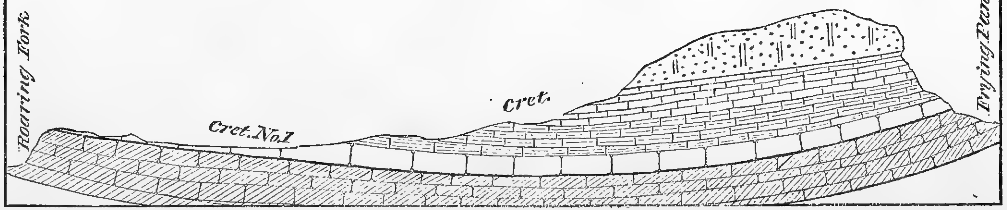


Fig. 3 12 miles

below the butte. Beyond the Cretaceous beds on the east side of the river, which are, I think, at this place right side up, there are exposures of red-beds, which I did not have time to visit. About eleven miles farther down stream, Snow Mass Creek comes into Roaring Fork from the southwest. This creek has two large branches, one of which heads near Maroon Mountain and Snow Mass Mountain, while the other, Capitol Creek, rises north of the Capitol. Opposite the mouth of the creek there is a hill capped with a volcanic rock, which is also exposed on the southwest side. It seems to be trachytic in character. A similar hill stands near the mouth of Frying-Pan Creek on the north side. South and southwest of Roaring Fork is a large area reaching from the river to the Elk Mountains, covered with Cretaceous rocks. Fig. 2, Plate XIX, represents a section across this area. At the point *a* the dip is south or a little east of south; angle of inclination about 15°. At the base of the hill *b*, on the creek coming from Sopris Peak, exposed on the left side, is a sandstone which I took to be Cretaceous No. 1, (Dakota group,) above which were limestones and shales, all dipping west of north at an angle of about 20°. There is, therefore, at this place a synclinal fold, the axis of which is northeast and southwest. At the point *c* there is a second fold parallel to the first. The Cretaceous area extends across Roaring Fork, and also westward around the end of Sopris Peak, and across Rock Creek. Opposite the mouth of Rock Creek, on the east side of Roaring Fork, there is an outcrop of red-beds below the Cretaceous. I think the section between Frying-Pan Creek and this point is as represented in Fig. 3, Plate XX. Sopris Creek, seen from a distance, has a rounded outline. It is composed of eruptive granite, and is the center of the third eruptive island in the Elk Mountains. On the southeast side we have chloritic schists, quartzites, and sandstones, all very much metamorphosed. These beds have a dip toward the Capitol. In them I found the following minerals: *Hematite, actinolite, chlorite, and talc.* The peak is 12,246 feet in height. Between the Capitol and Sopris we have a fold as represented in Fig. 1, Plate XX, the center being filled with red-beds that, I take it, belong to the Triassic. There is not only a fold in this direction, but also east and west, as shown in Fig. 2, Plate XX, which represents a section through the range at right angles to the section in Fig. —. To the westward the only rocks to be seen are Cretaceous. To the north and northwest we have the valley of Roaring Fork extending to the Grand. West of the mouth of Rock Creek there are some comparatively low hills in which there are exposures of red-beds, as seen from the summit of Sopris. Leaving Sopris Peak, we followed Frying-Pan Creek to its head. We had considerable difficulty getting up the creek, as it is in cañon the greater part of the way. The rocks exposed at the lower part are all red sandstones, dipping a few degrees east of north, inclining from 7° to 10°. About ten miles from the mouth of the creek we reached an open valley, in which we camped. Here, on the northern side of the valley, there were some very fine castellated forms in the red sandstones. These beds dip a little east of north, but as we go north the dip changes toward the south. A short distance above the camp the creek is again in cañon, and here we find the dip of the red-beds is west. This changes to southwest as we follow the outcrop. Where the beds cross the creek we have a deep narrow cañon cut through them at right angles to the strike. The dip of the beds is south 60° west, and the angle 30° to 50°. The outcrop forms a high ridge about 950 feet above the level of the valley just above. This valley is comparatively wide, and the stream flows through it in beautiful curves. On the north side we have very extensive deposits of gypsum, which, I think, occur in irregular masses. I think they are in rocks of Carboniferous age. North of Frying-Pan Creek there are broad-topped hills reaching just above timber-line, in which we have exposures of red sandstones dipping a few degrees west of north. A section made from these hills northward is shown in Fig. 3, Plate XIX. There seems to be a series of faults. The section was made from the summit of the red hills and may, perhaps, have to be modified in some of its details when the region shall have been more closely studied next season. Just above the cañon on Frying-Pan Creek there are exposures of red sandstones, on the south side of the creek, dipping nearly west at an agle of 25° to 40°. These beds are, I think, the direct prolongation of those seen on the east side of Roaring Fork near the mouth of Castle Creek. The gypsum-beds extend some distance up the creek, and in the valley there are several cold sulphur springs. The first one we met with was near the creek, and about 20 feet by 30 feet, with a deposit of sulphur at the bottom. The water is colder than the air, and tastes of the sulphur, although not disagreeably. The next spring is about three-quarters of a mile farther up the stream, and is much smaller, being only about 4 feet in diameter. The water here is also cold, and has a much stronger taste. In the hills on the north side there are outcrops of blue laminated limestone and greenish shales, mostly micaceous. These I believe to be Carboniferous. I did not have time to make a section. The north fork of Frying-Pan Creek, just before joining the main stream, cuts a cañon in a blue limestone, in which I found some corals. These limestones, I think, belong to the base of the Carboniferous. They dip a few degrees west of north, at an angle of 20°. Below this blue limestone, which is exposed on both sides of the creek, there are yellowish limestones, followed by dark limestones that are cherty and have fragments of crinoidal stems. These are succeeded by very compact light-blue limestones, below which we find pink and white quartzites, which rest immediately on the schists. On the north fork, for a short distance above the small cañon, to which I have just referred, there is an open valley. Above this valley, the stream is in a very rugged cañon in gnessic rocks, there being on the hills exposures of sedimentary rocks, dipping west of north at an angle of about 10°. Just below the cañon there is a small creek joining the North Fork on the west side. Here there have evidently once been warm springs, from the abundance of calcareous tufa seen in the course of the creek. A short distance up the creek there is a low bluff, composed almost entirely of the tufa. It is now overgrown by low bushes. The water in this creek has an alkaline taste. In the rocks that we referred to in the preceding chapter as curving around the end of the Sawatch range north of the Mountain of the Holy Cross, we doubtless have the continuation of those seen crossing Frying-Pan Creek, and which we have just described. In the valley of Frying-Pan Creek, above the North Fork, we have no sedimentary beds, except those just mentioned. The valley is filled with bowlders of a granitic porphyry, exactly like that seen in Lake Creek Cañon. At Massive Mountain, northwest of which the creek rises, we have schists. These, however, were described in the previous chapter. From the head of Frying-Pan we crossed to the Arkansas River, and visited the Holy Cross Mountain, after which we retraced our way to Colorado Springs, and thence to Denver. The facts noticed there have already been embodied in the report. We reached Denver on the 23d of October, and there disbanded, our work for the season being finished.

No. 1.—CATALOGUE OF MINERALS.

This catalogue includes only the minerals found in the South Park district. I am indebted to Mr. Peters, of Fair Play, for those marked with an asterisk. The complete catalogue will be found appended to Dr. Endlich's report.

Actinolite. (See *Amphibole.*)

Agate. (See *Quartz.*)

Alabandite*. Massive in some of the old gold-mines near Quartzville.

Amethyst. (See *Quartz.*)

Amphibole. *Actinolite* on Sopris Peak; *hornblende* on Sopris Peak; in schistose rocks near Montgomery; in trachytes of Buffalo Peak and the south end of South Park.

Anglesite. Small crystals in the lead-mines of Horseshoe Mountain.

Anhydrite.* (Crystallized.) At the salt-works in South Park.

Apatite.* (Massive.) In schists near Mount Lincoln.

Argentite.* (Amorphous and laminated.) In the Silver Star, Moose, and other mines of Mount Bross.

Arsenopyrite.* (Massive.) In Priest Mine, Mount Bross.

Azurite. Crater Mountain. In mines near Fair Play; in mines in Elk Mountain district.

Barite. In all the silver-mines about Fair Play forming the principal gangue. It is both massive and crystallized; at Homestake Mine near Tennessee Pass.

Basanite. (See *Quartz.*)

Biotite. (See *Mica.*)

Calcite. Abundant in all the limestones throughout the district; *yellow crystals* near Cheyenne Mountain; *red crystals* on Mount Bross; *rhomb spar* at Sulphur Springs in South Park; *fibrous* at the head of Trout Creek, near South Park.

Carnallite.* (*Crystallized.*) At salt-works in South Park.

Cerargyrite.* (Massive.) In small quantity in the Wade Hampton mine. The Moose and other mines in the limestones of Mount Bross carry from 5 to 20 per cent. of their contents in the shape of chloride invisible to the eye.

Cerrussite. In the mines in the Elk Mountain district near the head of Rock Creek; in the mines of Horseshoe Mountain, where it occurs abundantly; at Homestake Mine, near Tennessee Pass.

Chalcedony. (See *Quartz.*)

Chalcopyrite. In the mines of the Elk Mountain district. It is found also in all the gold and most of the silver mines near Fair Play. It is the richest matrix for gold, and often assays $150 per ton, and also $300 in silver. It is crystallized and massive, and often iridescent;* at Homestake Mine, Tennessee Pass.

Chlorite. (See *Ripidolite.*)

Chromite.* (Massive.) On Silver-Heels Mountain.

Coal. At Gehrung's Mine on Monument Creek; twelve miles east of Colerado Springs, northeast of Fair Play; in Elk Mountains, good quality.

Cuprite. In minute crystals in Sacramento Gulch and in the Sweet-Home Mine.

Dolomite. (Massive.) In limestones in cañon of Four-Mile Creek.

Epidote. Very abundant in the schists in the foot-hill range; on the summit of Mount Bross; in Lake Creek Cañon; on Massive Mountain; at the head of Rock Creek; at the Elk Mountain mines.

Feldspar. In many varieties in the schists near Montgomery.* *Labradorite* in fine crystals near Montgomery.* *Orthoclase*, flesh-red in color, from the foot-hill range. Good crystals of pale pink color in the granites of the Sawatch range. *Amozenstone*, good crystals, from Pike's Peak and Cheyenne Mountain. *Sanidine* in the trachytes of South Park and Buffalo Peaks.

Fluorite.* Massive and crystallized, pink and violet colors, from Sweet-Home mine.

Garnet. In schists, near Montgomery.

Galenite. Near Silver Heels, above Hamilton. In all the mines, in limestones and sandstones, near Mount Lincoln, Mount Bross, and Horseshoe Mountain, assaying from $3 to $200 per ton in silver, and as high as $120 in gold.* It occurs in simple and modified cubes and twins at the Homestake mine, near Tennessee Pass; in the mines of the Elk Mountain district, at the head of Empire Gulch, and Iowa Gulch.

Graphite.* In limestones on Silver Heels Mountain, containing much iron and earthy matter.

Gold. In the placer-mines of Tarryall Creek; in the placer and lead mines near Fair Play; occurring in laminæ, flat grains and shot-like, and rarely in imperfect crystals;* in plates and laminæ at the Printer Boy mine, at the head of California Gulch, near Ore City; in the placer-mines of Washington Gulch, in the Elk Mountains; in Union Park, east of the Gunnison River.

Glauconite. In the Silurian quartzites in Glen Eyrie; on Trout Creek; in Four-Mile Creek cañon, and on Eagle River.

Gypsum. *Selenite* and *satinspar*. At Pleasant Park, on Bear Creek; on Camp Creek, near Glen Eyrie; at the salt-works in South Park; at the head of Rock Creek, in the Elk Mountains. At all these localities it occurs amorphous, generally of white and pink colors. At the salt-works there is a black variety.

Halite. In the sulphur springs, South Park; in the springs and marshes at the salt-works in South Park.

Hematite. Beaver Creek, near the Colorado divide; *specular*, Philips mine;* *micaceous*, good specimens, on White Rock Mountains; on Sopris Peak; *fibrous* on Silver Heels Mountain and near Hamilton; *argillaceous* in the mines of Elk Mountain district; in many places in South Park.

Hornblende. (See *Amphibole.*)

Jamesonite, *Capillary.* At the Sweet Home mine, Mount Bross mining district.

Limonite. Earthy in Tertiary sandstones along the east range of mountains; near the coal-exposures, twelve miles east of Colorado Springs; extensive beds in South Park.*

Labradorite. (See *Feldspar.*)

Magnetite. In the granites in foot-hill range; on Tarryall and Michigan Creeks; on Silver Heels Mountains; at the head of Lake Creek; at Snow Mass Mountain.

Malachite. On Mount Guyot; at Sweet Home and Baker mines, Mount Bross mining district; in the mines of Horseshoe Mountain; in mines of Elk Mountain district.

Marcasite,* (cellular,) Philips mine, Mount Bross mining district.

Melaconite,* from the Unknown mine of Montgomery.

Melanterite, in concretions at the Sweet Home mine, Mount Bross mining district.

Mica, very abundant and of many varieties, (*biolite*, *muscovite*, and *phlogopite,*) near Mount Lincoln and Mount Bross, especially near the junction of the sandstones and schists; *biotite* in the granites of the Elk Mountains and in the rocks of the various dikes in that range; *muscovite* common in the foot-hill range, along Tarryall Creek and in the Sawatch range; *brown variety* on Buffalo Peaks; *green variety* in schists east of Italia Peak.

Molybdenite,* in thread-like veins on Silver Heels Mountain.

Muscovite. (See *Mica.*)

Obsidian, on Buffalo Peaks; chips in the Arkansas Valley and in Union Park.

Orthoclase. (See *Feldspar.*)

Phlogopite. (See *Mica.*)

Prehnite, in clusters of small crystals in trap in Mount Bross mining district.

Pseudomalachite, in gray argillaceous slates at the bend of the Little Platte River, south of Fair Play.

Pyrite, in all the gold and silver mines of Buckskin Gulch, invariably auriferous, but seldom enough to be valuable; massive in simple cubes and pyritohedrons; (perfect cubes of four to five inches are found in the Philips mine*,) on Italia Mountain in small octahedral crystals near the base of Teocalli Mountain; at White Rock Mountain; in the mines of the Elk Mountain; in a black flinty limestone on Eagle River opposite Roches Moutonnés Creek.

Pyrolusite,* massive in Buckskin Gulch and on Silver Heels Mountain.

Pyroxene, in the limestones in the Mount Bross mining district.

Quartz, in the granites of the foot-hill range, the Sawatch range, and the Elk Mountains. *Rock crystal,* in the granites and in the sandy *débris* on the Colorado divide; at Pike's Peak; in the limestones of Mount Lincoln and Mount Bross and Horseshoe Mountain; in the Cretaceous shales on East River; on Massive Mountain; in the mines of Elk Mountain district at head of Rock Creek; on Sopris Peak; Homestake mine near Tennessee Pass. *Amethystine,* on Rock Creek; *Rose,* near the head of Granite Creek; *smoky* Cairngormstone; on the Colorado divide; on Pike's Peak; near the Platte Cañon in fine large crystals; on Massive Mountain. *Milky,* on the Colorado divide in cañon of the South Platte; near Mount Howard on Granite Creek; on Massive Mountain. *Chalcedony,* in South Park east of Fair Play; near Buffalo Peaks; on Frying-Pan Creek; in the small park at the head of Trout Creek near the salt-works southwest of South Park. *Agate,* in South Park on Frying-Pan Creek; in the Arkansas Valley in the park at the head of Trout Creek; on the butte east of the salt-works. *Basanite,* on the butte east of the salt-works in South Park. *Silicified wood,* at petrified stumps near Florissant.

Rhodochrosite,* (crystallized,) in the gangue of the Diadem mine, Buckskin Gulch.

Ripidolite, on Sopris Peak, near Red Rock Pass, at the head of Lake Creek.

Rutile,* in veins of quartz traversing the limestone in Ute Pass.

Sanidine. (See *Feldspar.*)

Satin spar. (See *Gypsum.*)

Selenite. (See *Gypsum.*)

Siderite,* (crystallized,) at the Sweet Home mine and many places in South Park.

Silicified wood. (See *Quartz.*)

Silver, (native,) in nuggets, wire, and thin scales in the mines around Fair Play; in Washington Gulch, in the Elk Mountains; in the mines at the head of Rock Creek in the Elk Mountains; at the Home stake mine, near Tennessee Pass.

Sphalerite,* in large quantities in the Mosquito gold mines; also in some of the silver mines, carrying from $10 to $150 per ton in silver: (some specimens contain cadmium: it is mostly massive and highly ferruginous;) at the Homestake mine, near Tennessee Pass.

Stephanite,* (crystallized and massive,) in the Moose and other mines in the Mount Bross mining district.

Sulphur, in the springs in South Park, and also on Frying-Pan Creek.

Talc, on Sopris Peak.

Tennantite,* (crystallized,) in Buckskin mining district.

Tetrahedritre,* in complicated crystals and massive. It is the principal silver ore of the Buckskin mines, and assays from $50 to $300 per ton.

Tourmaline, on Italia Peak; no fine doubly terminated crystals in the schists near Montgomery.

Tufa, (calcareous,) on Roaring Fork; on the North Fork of Frying-Pan Creek.

Vesuvianite, in fine crystals on Italia Peak.

Wollastonite,* in veins traversing the lower limestones in the Mount Bross mining district.

Zinkenite,* in minute crystals in the Sweet Home mine.

No. 2.—CATALOGUE OF ROCKS.

Catalogue of rocks collected by A. C. Peale and W. R. Taggart.

No.	Name.	Locality.
1	Yellow sandstone, (Cretaceous ?)	South side of South Platte River below the cañon.
2	White sandstone, (Cretaceous ?)	Do.
3	Purplish sandstone, (Cretaceous ?)	Do.
4	Arenaceous limestone, (Jurassic ?)	Do.
5	Brick-red limestone, (Jurassic ?)	Do.
6	Gray limestone, fossiliferous, (Cretaceous No. 3)	Willow Creek.
7, 8	Red feldspathic granite	Cañon at head of Bear Creek.
9	Red sandstone, (Triassic ?)	Pleasant Park, on Bear Creek.
10	Gneiss	Hills west of Pleasant Park.
11	Gypsum	Pleasant Park.
12	Pink calcareous sandstone shale, (Jurassic)	Do.
13	Pink mottled limestone, (Jurassic)	Do.
14	Gray sandstone, (Tertiary)	Mesa east side of Plum Creek.
15	Pink trachyte	Summit of mesa east side of Plum Creek.
16	Gray trachyte	Do.
17, 18	Ferrugineous sandstone	Monument Park.
19, 20	Gypsiferous sandstone, (Jurassic)	Near the Garden of the Gods.
21	Gypsum, (Jurassic ?)	Do.
22	Pink limestone	Do.
23, 24	Dark-green sandstone, (Potsdam ?)	Glen Eyrie.
25	Red sandstone, (Potsdam ?)	Do.
26	Pinkish-gray limestone, (Silurian ?)	Do.
27	Granite	Summit of Pike's Peak.
28	Gneiss	Upper Cañon of South Platte River.
29	Granite	Do.
30	Trachyte	Beaver Creek Valley.
31–33	Argillaceous shale, (Tertiary)	Beaver Creek Valley, near Florissant.
34	Coarse sandstone, (Tertiary)	Do.
35	Conglomeritic sandstone, (Tertiary)	Petrified Stumps, near Florissant.
36	Shaly sandstone	Do.
37	Brown sandstone, (Silurian ?)	East side of Trout Creek, below Bergen Park.
38	Green sandstone, (Silurian ?)	Do.
39	Yellow sandstone, (Silurian ?)	Do.
40	Red limestone, (Silurian ?)	Do.
41	Red limestone, green spotted, (Silurian ?)	Do.
42	Mottled conglomeritic limestone, (Silurian ?)	West side of Trout Creek, below Bergen Park.
43	Red limestone, (Silurian ?)	Do.
44	Pink shaly limestone, (Silurian ?)	Do.

Catalogue of rocks collected, &c.—Continued.

No.	Name.	Locality.
45	Red sandstone, (Silurian ?)	West side of Trout Creek, below Bergen Park.
46	Pink limestone, (Silurian ?)	Do.
47	Yellow limestone, (Carboniferous ?)	Do.
48	White arenaceous limestone, (Carboniferous ?)	Do.
49	Pink quartzite	One mile east of Trout Creek.
50	Yellow quartzitic sandstone	Do.
51	Brown quartzitic sandstone	Do.
52, 53	Red sandstone	Do.
54, 55	White quartzite, (Cretaceous No. 1)	Sulphur Springs, South Park.
56	Gneiss	East side of Tarryall Creek.
57, 58	Granite (?)	North of Hamilton.
59–63	......do	Mount Guyot.
64	Metamorphosed slate	East of Mount Guyot.
65	Quartzite	Do.
66	Gneiss, (Micaceous)	Do.
67, 68	Trachyte (?)	Silver Heels Mountain.
69	Gray sandstone	Do.
70	Green slate	Do.
71	Quartzitic sandstone	Do.
72, 73	Trachyte (?)	Do.
74	Coarse micaceous sandstone	Do.
75	Blue limestone	Do.
76	Sandstone	Do.
77	Red calcareous sandstone shale	Do.
78	Quartzitic sandstone	Do.
79	White quartzite, (Silurian)	South side of Four-Mile Creek.
80	Purple sandstone, (Silurian)	Do.
81	Green clay shale	Do.
82	Blue-gray limestone	Do.
83	Trachyte (?)	Three miles above Hamilton.
84	White micaceous sandstone	East of Fair Play.
85	Blue limestone	Do.
86	Micaceous sandstone shale	Do.
87	White sandstone, (Cretaceous)	Do.
88, 89	Andesite (?)	Do.
90	Rhyolite (?)	Mount Lincoln.
91	Dark quartzite	Do.
92	Micaceous sandstone	Do.
93	Shaly sandstone	Do.
94–97	Quartzite	Do.
98	Limestone	Do.
99	Trachyte (?)	Ridge northeast of Mount Lincoln.
100	Conglomerate	Do.
101	Limestone	Do.
102	Quartzite	South Platte River, below Hoosier Pass.
103	Limestone	Do.
104	Black argillaceous shale, (Cretaceous)	East of Fair Play.
105	Red and white shaly sandstone	Do.
106	Blue limestone	Do.
107	Mottled sandstone	Do.
108	Coarse red sandstone	Do.
109	White micaceous sandstone	North of Fair Play.
110	White quartzite	Mosquito Gulch.
111	......do	Buckskin Gulch.
112	Trachyte (?)	Do.
113	......do	Iowa Gulch.
114	......do	South side of Four-Mile Creek.
115	Magnesian limestone	Do.
116, 117	Sandstone	Do.
118–121	Rhyolite (?)	Do.
122	Sandstone	Do.
123–125	Sandstone shale	Do.
126	Sandstone	Do.
127, 128	Micaceous sandstone shale	Do.
129	Trachyte (?)	Head of Iowa Gulch.
130, 131	......do	Stray Horse Gulch.
132	......do	Near Fair Play.
133	Quartzite, (Potsdam)	Horseshoe Mountain.
134	Trachyte	South side of Four-Mile Creek.
135	Gneiss	Horseshoe Mountain.
136	Granite	Do.
137	Quartzite, (Potsdam)	Do.
138	Gneiss	Weston's Pass.
139	Trachyte (?)	Buffalo Peaks.
140	......do	Do.
141	......do	Do.
142	......do	Do.
143	......do	Do.
144	Pitchstone	Do.
145	Trachyte	Do.
146	Granite	Mount Harvard.
147	......do	East of La Plata Mountain.

Catalogue of rocks collected, &c.—Continued

No.	Name.	Locality.
148	Quartz	East of La Plata Mountain.
149	Quartzite	Do.
150	Rhyolite	Do.
151–153	Trachyte	Near Grizzly Peak.
154, 155	Obsidian rock	Do.
156	Trachyte breccia	Do.
157	Rhyolite (?)	Do.
158	......do	Do.
159	......do	Do.
160	Trachyte	Cañon of Lake Creek.
161–163	Quartz	Red Rock Pass.
164, 165	Trachyte	Do.
166, 167	Gneiss	Do.
168–170	Trachyte	Do.
171–173	Granite	Do.
174	Chlorite-schist	Do.
175	Micaceous gneiss	Ridge South of Red Rock Pass.
176, 177	Trachyte	Do.
178	Mottled quartzite	Head of Spirifer Creek.
179, 180	Porphyritic trachyte	Eastern Branch of Taylor's River.
181–183	Rhyolite (?)	Do.
184	......do	Do.
185–188	Granite	Italia Mountain.
189–191	......do	Ridge east of Italia Mountain.
192, 193	Gray calcareous sandstone	Ridge south of Italia Mountain.
194	Red sandstone	Do.
195	Micaceous-sandstone shale	Do.
196	Greenish sandstone	Do.
197–200	Trachyte (?)	Dike on Cascade Creek.
201	Brownish-red sandstone	Cascade Creek.
202	Red conglomeritic sandstone	Do.
203	Maroon-colored sandstone	Teocalli Mountain.
204	Light-purple sandstone	Do.
205	Coarse gray sandstone	Do.
206	Coarse greenish sandstone	Do.
207	Brown sandstone	Do.
208	Granite (?)	Do.
209	Red calcareous sandstone	East side of East River.
210	Pink-calcareous sandstone	Do.
211	White sandstone, (Cretaceous)	Do.
212, 213	White limestone, (Cretaceous)	Do.
214–216	Granite	Snow-Mass Mountain.
217–219	......do	Do.
220	......do	Do.
221	Brown calcareous sandstone	Maroon Mountain.
222	Coarse gray sandstone	Do.
223, 224	Red sandstone	Do.
225	Laminated limestone	Do.
226	Trachyte (?)	Do.
227	Calcareous conglomerate	Do.
228	Metamorphosed argillaceous slate	Near head of Rock Creek.
229	Green metamorphosed sandstone	Castle Peak.
230	Conglomerate sandstone	Do.
231	Trachyte (?)	Do.
232	Conglomeritic sandstone	Do.
233, 234	Purplish trachyte	East River, below Cement Creek.
235	Light-gray compact limestone	Station 72.
236	Glauconitic limestone	Do.
237	Black limestone	Do.
238	Calcareous conglomerate	Do.
239	Cherty limestone	Station 73.
240	Purplish-gray limestone	Do.
241	White sandstone	Do.
242	Red shaly limestone	Ridge northeast of Station 72.
244	Limestone	Station 73.
245	White sandstone	Do.
246	Mica-schist	Do.
247	Red granite	Do.
248	Gray trachyte	Below Station 73, on East River.
250	Light-gray gneiss	Union Park, on Gunnison River.
251, 252	Rose quartz	Station 76, near head of Roaring Fork.
253	Gneiss	Station 76.
254	Granite porphyry	Head of Roaring Fork.
255	Gray calcareous sandstone	Roaring Fork, near Castle Creek.
256	Coarse red sandstone	Station 78.
257, 258	Chloritic schist	Sopris Peak.
259	Granite	Do.
260	Coarse red sandstone	Frying-Pan Creek.
261	Micaceous sandstone	Do.
262	Fine red sandstone	Do.
263	Compact red sandstone	Station 82.
264, 265	White gypsum	Frying-Pan Creek.

Catalogue of rocks collected, &c.—Continued.

No.	Name.	Locality.
266–268	Blue gypsiferous limestone	Frying-pan Creek.
269–271	Gray gypsiferous limestone	Do.
272	Gray limestone	Do.
273–275	Calcareous tufa	North Fork of Frying-Pan Creek.
276	Brown micaceous sandstone, (Permian)	Eagle River, opposite Roches Moutonnés Creek.
277–279	Green conglomeritic sandstone	Do.
280	Brown shaly sandstone	Do.
281, 282	Limestone	Do.
283	Pink conglomeritic sandstone	Do.
284, 285	Coarse green sandstone	Do.
286	Green sandstone conglomerate	Do.
287	Dark-gray micaceous sandstone	Do.
288	Coarse gray sandstone, (Carboniferous)	Do.
289	Coarse white sandstone	Do.
290	Pink conglomeritic sandstone	Do.
291	Fine red sandstone, (Carboniferous)	Do.
292	Trachyte (?)	Do.
293	Black flinty limestone, (Silurian)	Do.
294	Quartzitic conglomerate	Do.
295	Coarse red sandstone	Do.
296	Greenish-gray sandstone	Do.
297	White quartzite	Do.
298–301	Gneiss	Mouth of cañon of Eagle River.
302	Trachyte (?)	East side of Eagle River.
303	Trachyte	Forks of Trout Creek.
304	Greenish sandstone	Small park at head of Trout Creek.
305	Gray sandstone	Do.
306	Blue argillaceous slate	Do.
307	Light-red sandstone	Do.
308	Black slate	Do.
309	Trachyte	Butte east of salt-works, South Park.
310	Impure gypsum	Butte north of salt-works, South Park.
311–313	Gray limestone	Do.
314	Sandstone shale	Do.
315, 316	Black gypsum	Do.
317	Granite	Butte east of salt-works, South Park.
318, 319	Trachyte	Do.
320, 321	Limestone	Edge of salt marsh, east of salt-works, South Park.
322	Trachyte	Butte at bend of Little Platte River.
323–325	Sandstone	East of butte at bend of Little Platte River.
326–329	......do	Station 92, South Park.
330, 331	Basalt	South end of South Park.
332	Gray sandstone	North of salt-works.
333	Brown sandstone	Do.
334	Pink sandstone	Do.
335	Gray sandstone	Do.
336	Black limestone	Little Platte River, South Park.
337	Gray shaly sandstone	Do.
338	White sandstone	Do.
339	Coarse red sandstone	Do.
340	Fine red sandstone	Do.
341	Coarse white sandstone	Do.
342	Gray sandstone	Do.
343	Brown sandstone	Do.
344, 345	Trachyte	South Park, northeast of Fair Play.
346	Gray sandstone	Do.
347	Trachyte	Do.
348	Sandstone shale	Do.
349	Gray sandstone	Do.
350	Trachyte	Do.

REPORT

OF

F. M. ENDLICH, S. N. D.

WASHINGTON, D. C., *June* 1, 1874.

SIR: I have the honor herewith to submit my report for 1873. As directed, the mines of Gilpin, Clear Creek, and Boulder Counties were first visited by me, with the view to study their geological and mineralogical relations, as well those referring to the ore-veins as a whole as those they bear to the surrounding rocks. In almost every instance where time and the condition of the mine permitted it, a personal examination of the conditions under ground was made, and the report confines itself chiefly to those lodes and mines that have been thus visited. On July 3, I took the field as the geologist of the San Luis division, returning from it to Denver on October 5. Nearly 7,600 square miles were surveyed topographically and geologically during that time, and the results of the examinations relating to the geognostic and geological features of the country are laid before you in the subjoined report. It is evident that on a survey of this kind, where a large area must be traversed in a comparatively short time, geological research cannot be carried on in as much detail as might appear desirable to the investigator. By working in perfect unison, however, with the topographer, the geologist will be able to form a correct idea of the horizontal and vertical distribution of formations in a very short time.

Four chapters and an appendix comprise the annexed report. The first chapter treats of the mining-regions; and I beg leave to submit it merely as a preliminary report, in the hope that at some future day I may be enabled to make more thorough and extensive examinations. The three following chapters are devoted to the geology and geognosy of the district assigned to the San Luis division. In the appendix, "Mineralogical notes" and a "Catalogue of the minerals of Colorado" are contained.

At this place, I wish to express my sincere thanks to Mr. A. D. Wilson and Mr. G. B. Chittenden, the topographers of the party, for their hearty good-will and co-operation during the field-season, and to the latter for the kindness with which he supplied me during the winter with the illustrations necessary for the report.

To Prof. F. L. Schirmer, of Denver, and Mr. A. von Schultz, Mr. J. Alden Smith, and Mr. Smart, of Central, Col., I am greatly indebted for courtesies shown me.

Hoping that the report may meet your requirements, I have the honor to remain, your obedient servant,

FREDERIC M. ENDLICH.

Dr. F. V. HAYDEN,
Geologist-in-Charge,
United States Geological and Geographical
Survey of the Territories.

CHAPTER I.

PRELIMINARY REPORT UPON THE MINING-DISTRICTS OF COLORADO.

According to instructions received, I visited the mining regions of Gilpin County, Colorado, about the middle of May, 1873, and subsequently those of Clear Creek and Boulder Counties. The object in view was a thorough recognition and definition of the geological and mineralogical relations shown by the lodes of these localities to each other as well as to the surrounding rock. Owing to the early season, a number of mines that afterward were worked, were not then in operation; and as a personal visit to all, or even only the greater portion of the mines, was entirely out of the question, such were selected for examination as were acknowledged to be the most important ones of the district, besides those possessing any particular interest from a geological or mineralogical point of view, the acquaintance with which seemed necessary for a successful completion of the work undertaken. It is mainly of the mines visited personally that I shall speak in the subjoined pages.

The lack of statistics, which may be considered very essential in a mining-report, is to be accounted for by the fact that this report pretends only to examine the geological and mineralogical relations of the ore-bearing veins of those districts. As a large percentage of the mining population follow this occupation upon claims in their own possession, for the purpose of making a livelihood, the facilities for obtaining statistics are by no means satisfactory, and it would require more time than I could spend to compile thorough statements of production, returns, &c. A carefully-compiled statement of the work done at the Monte Cristo mine has been very kindly allowed me for publication by Mr. Mills, of Central. From it can be seen an account of the actual cost of working a mine on a small scale, and calculations for more extensive operations may be made accordingly.

Neither historical notes nor descriptions of machinery employed have been given in the report, as both have been treated of in Mr. Hague's excellent report upon the mining regions of that section. Merely the geognostic, geological, and mineralogical features of the localities under consideration, and their mutual relations, are dwelt upon. It is hoped that by presenting this character of the mining regions, which has not been sufficiently done before, more light may be thrown upon their merits or demerits as such, and more definite knowledge gained regarding their constitution.

In order to facilitate the ready comprehension of terms used almost exclusively by miners, and in order to give a more definite idea of the questions involved in the subjoined report, a short introduction is given, treating briefly on the subject of ore-deposits.

The substances mostly occurring in deposits that are sought after by man are gold, silver, platinum, copper, lead, tin, zinc, iron, coal, salt, bitumen, petroleum, and others, existing partly in their native state, partly in combination with other substances. Two great divisions are distinguished, and imbedded deposits—superstratoid deposits; the former being partially or entirely surrounded by a valueless material, the "country;" the latter deposited upon the surface, and containing its valuable minerals partly as float, partly as a superficial deposit. Im-

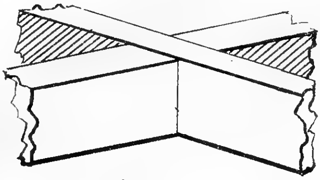


Fig. 1.

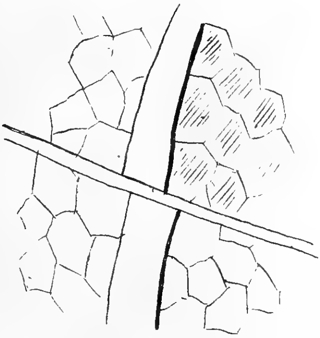


Fig. 2.

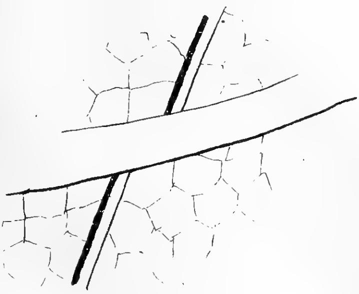


Fig. 3.

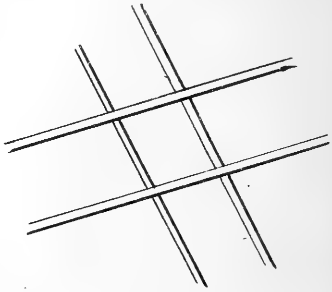


Fig. 4.

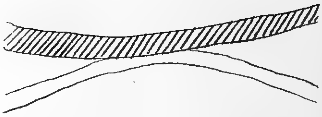


Fig. 5.

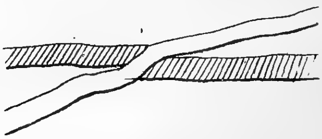


Fig. 6.

bedded deposits are more frequently met with, and it is of them the report on Colorado mines will treat almost exclusively.

An ore-vein is a tabuloid body of mineral matter, aggregated so as to be entirely distinct from the surrounding rock—from the "country"—in its lithological and chemical character as well as in its physical structure. It is necessary that a fissure—or filled—a vein should be bordered on either side, the sides being called "walls." As the greater number of veins show an incline to one side or the other, it has become customary to term the wall upon which it rests the "foot-wall;" the one resting upon it, the "hang-ing-wall." Frequently these walls are of a different lithological and geological character, as at the Winnebago mine, where the foot-wall is gneiss; the hanging-wall granite. In that case the vein is termed a "contact-vein."

The line indicated by an outcropping vein, if cut off horizontally, is called the "course," or "strike," of a vein; variation from the horizontal is the "dip;" the thickness is measured from wall to wall.

In distinction between a vein and a stratum, the former must be regarded as representing the filling material of a fissure in the adjoining rocks, whereas the latter—a coal-bed, for instance—is merely one of a succession of strata. From the nature of its occurrence, it becomes evident that the contents of fissures must be younger than the surrounding "country;" whereas, in the case of a stratum, it must be said that it is younger than the underlying but older than the superincumbent strata, provided the beds have not been overturned. An exception to this rule takes place when an ore-deposit is formed by pseudomorphic action.

Massive deposits may be regarded as local widening of veins, but more correctly as segregations.

Impregnations sometimes form deposits of large bodies of ore, as, for instance, the tin-mines of Saxony and Bohemia, but rarely produce a sufficient amount of metal to prove valuable.

Superstratoid deposits owe their origin mainly to mechanical action, but in part to chemical. To the former class belong deposits of gold, silver, platinum, tin, &c.; to the latter, bog-iron ore, bog-manganese, &c.

Veins are subject to frequent and often serious disturbances, mostly demonstrated by having caused or causing dislocations, in which case they are of mechanical nature, while other disturbances occur, attributed to chemical action. Dislocations often cause intersections of two veins, (Pl. A, Fig. 1,) of which the disturbed one is the older; the younger, disturbing, keeping its course. The disturbing vein can either be larger (Pl. A, Fig. 3) or smaller (Pl. A, Fig. 2) than the other one. An occurrence that can very readily be mistaken for crossing is termed "dragging," (Pl. A, Fig. 5;) and it is important in some cases to determine whether an actual crossing takes place, or merely a drag is found. Two veins may approach each other at a small angle, touch, and remain in contact for some distance, and then each one turn off again to its own side; or they may cross and drag on either or both sides of the crossed vein, (Pl. A, Fig. 6.) If the one vein is rich and the other one poor—at the same time, however, of equal thickness and similar mineralogical character—it becomes necessary to determine this point. It may also occur that several veins cross several others, (Pl. A, Fig. 4,) in which case, however, all the above-stated conditions remain unchanged.

Veins frequently ramify, sometimes the several parts returning to the main vein again, sometimes pinching out entirely. The included portions of "country" are termed "horses," (Pl. B, Fig. 1.) Usually the termination of veins is effected in three ways: by ramification, (Pl. B, Fig. 2,) where it splits up into a number of smaller veins that gradually thin out and disappear, (Pl. B, Fig. 3;) by pinching out of the main vein, (Pl. B, Fig. 4;) and by being cut off, (Pl. B, Fig. 5,) which can occur as the result of considerable disturbance, whereby an entirely different kind of rock can cut off and obliterate the vein. Cuts-off occurring without the intervention of any new rock belong to the series of common dislocations, and in that case the continuation can mostly be found again. This latter takes place very frequently in coal-mines, (Pl. B, Fig. 6,) where the beds have originally had an approximately horizontal position, out of which they are thrown by any disturbance caused either by vertical or lateral pressure. In ore-veins, this kind of dislocation is not so often met with.

Sliding of veins is not infrequently found, as, for instance, in the Gregory extension, where the one wall has changed its position parallel to the medial plane of the vein-body. If any irregularities have occurred in the vein, a slide of this kind will tend to increase them, and the vein will consist of a series of accumulations of mineral and gangue matter along its former strike and dip.

FORMATION OF VEINS AND LODES.

The formation and contemporaneous or subsequent filling of fissures has given rise to a great deal of speculation. Although it may be supposed that an irregular contraction of the earth's crust would produce at points fissures similar to those observed, their form, in detail, and the character of their arrangement with reference to each other, would probably not be the same as is really found in nature. An explanation of the origin of fissures based upon the recognition of volcanic or plutonic activity seems most satisfactory, and will apply in the by far greater number of cases. Earthquakes of the present day, due to volcanic activity, form fissures and series of fissures analogous and even similar to those that are now filled with ores. Without penetrating the earth's crust to any considerable percentage of its thickness, a vein will still be practically inexhaustible in depth until machinery may be so perfected as to overcome the increasing temperature as the descent is made. With the help of the annexed cut, the formation of fissures by plutonic activity will become apparent. If a considerable thickness—a mile or more—is allowed for the crystalline rocks *a*, any disturbance on the part of *b* would have a tendency to crack the strata or the masses of *a*, thus giving rise to the formation of fissures; and if *b* becomes eruptive, contact-veins would be formed between the two formations. The expression of this phenomenon, however, will, as a rule, be local. Circumstances can occur under which it may cover a very large area, but the existence of fissures within a small compass has been observed far more frequently.

Another kind of fissures is found that owe their existence to disturbances as well, but disturbances having a different effect. If any stratified or stratoid rock is disturbed in such a manner as to separate the strata from each other at one or more points, while they remain in connection at others, fissures are formed between these strata, and their strike and dip will be conformable to those of the strata.

After the fissures have been formed, they will be filled. It is a well-known fact that any excavation in the ground or in rock, such as a cellar, tunnel, shaft, &c., serves to collect and partially retain the waters percolating through the surrounding medium. This is infiltration. Taking the term infiltration in its widest sense, it may be accepted as an explanation for the filling of fissures. It remains to be decided, how-

PLATE. B.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

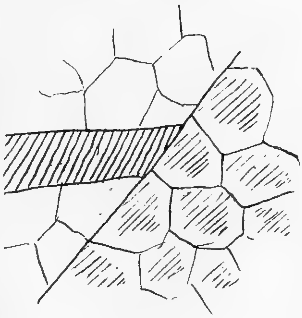


Fig. 6.

Fig. 1.

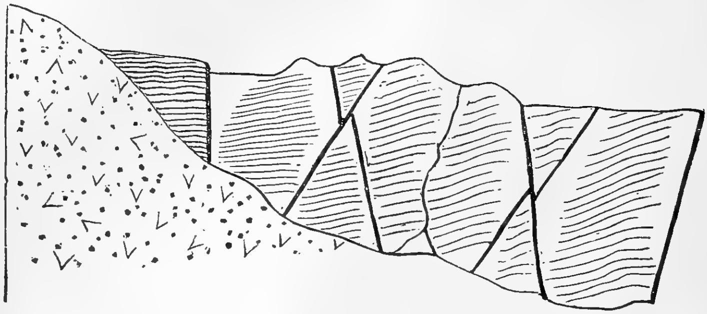
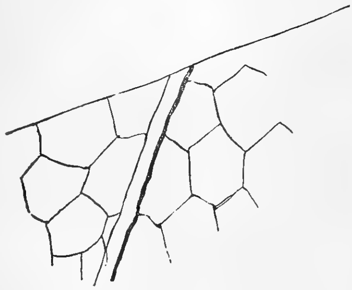
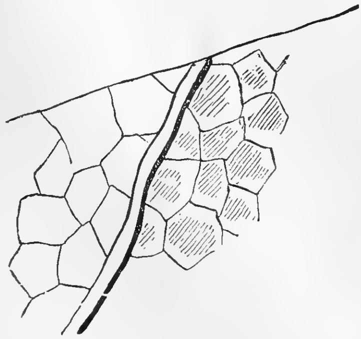


Fig. 3.



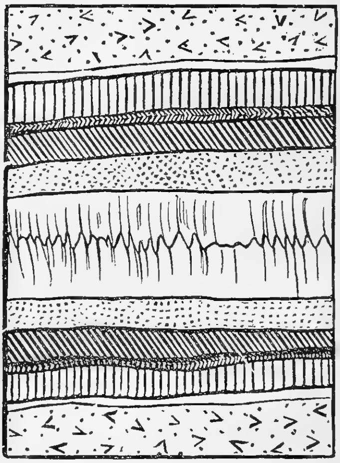
Vein.

Fig. 4.



Contact vein.

Fig. 2.



Combed structure.

ever, what kind of infiltration is usually employed in filling these fissures. Numerous hypotheses have been offered in explanation, favoring infiltration from above, below, from the side, &c.; but the reliable data obtained are too few as yet to admit of any well-grounded view. One fact has been elicited, however, the cause of which is obvious, and may eventually lead in the right direction towards solving the problem. In a large number of instances it has been noticed that the filled fissure, the lode, showed a symmetrical arrangement of its component minerals, so that by dividing it into two halves, parallel to the walls, these halves would each contain the same minerals in the same consecutive order. This structure has been termed "combed," and leaves no doubt that the same minerals, at their corresponding positions, were deposited contemporaneously, and that the filling must have progressed from the walls inward, *i. e.*, to the center of the fissure. The why and wherefore cannot yet be answered satisfactorily.

Attempts have been made to explain the filling of fissures by the action of electric currents; but it seems more probable that those currents, which really do exist in lodes, are not the cause, but the result of their formation.

SEARCH FOR LODES.

In searching for lodes, it is undoubtedly best to simply follow the teaching of sound judgment, combined with empirical and other knowledge.

Should the gangue-rock be harder than the surrounding "country," offer more resistance to atmospheric influences, the aspect of a hill or ridge will often reveal the desired point at a glance. Apart from this very convenient method of prospecting, inquiry should always be made whether at any time mining operations had been carried on in the district being prospected; if so, the strike of the lodes then discovered—if ascertainable—will always afford a valuable hint to the prospecter. If it is an entirely new country to mining-industry, the experience gained upon former occasions must be applied to decide whether it may look "promising" or not. Valuable and time-saving is the custom of examining the sand of rivers and creeks, because any mineral found in this sand must necessarily occur exposed at some point above the one where it was first observed. Not having obtained any satisfactory results from this process, an examination of the rocks in position, as far as they are exposed, can be undertaken. The color of the soil must be observed, if possible, as sulphurets and iron ores mostly produce a red; copper compounds, a greenish color. Vegetation is an important indicator for the prospecter. If it is particularly luxuriant along certain limited areas, or the reverse, it may lead to valuable discoveries. In prospecting for salt and similar compounds, the character of the vegetation is of the greatest aid.

After having found any mineral that may have the appearance of an ore, it becomes necessary to recognize its nature, and, if it is decomposed, the nature of that from which it resulted. An old plan in prospecting a country where veins are supposed to exist is to start from any point where a piece of ore has been found in two directions at right angles with each other, whereby every lode within the one-half of the circle will be crossed. In a country where mining has been, or is still, carried on, it will be of use to make the examination while traveling at a right angle to the usual strike of the lodes.

When the presence of the lode has been established, it must be followed up, and here frequently the skill of the prospecter is subjected to severe tests. If the gangue-rock is sufficiently hard to preserve its outcrop, or if the ores stain the soil, it becomes a comparatively easy task; but when all traces of this kind are obliterated, he must resort to uncovering the lode, unless, again by means of the appearance of the vegetation, he can follow it up. It has been mentioned above that excavations, &c., serve to collect the percolating waters; and although the fissure may be filled, it will, as a rule, retain this quality to some extent, so that, in a dry country, trees growing immediately upon the lode will frequently show a more luxurious development than their neighbors.

For nearly horizontal veins and beds, boring is of importance, but sometimes impracticable.

Prospecting in our western countries is combined with so many hardships and dangers that great credit is due to those men who spend years of their lives in seeking for and developing the mineral wealth of their adopted home.

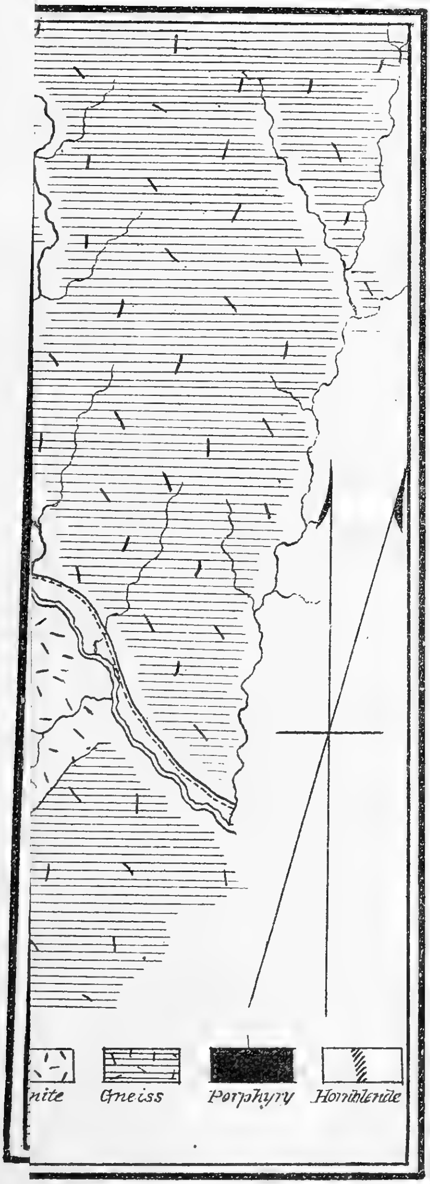
PART I.

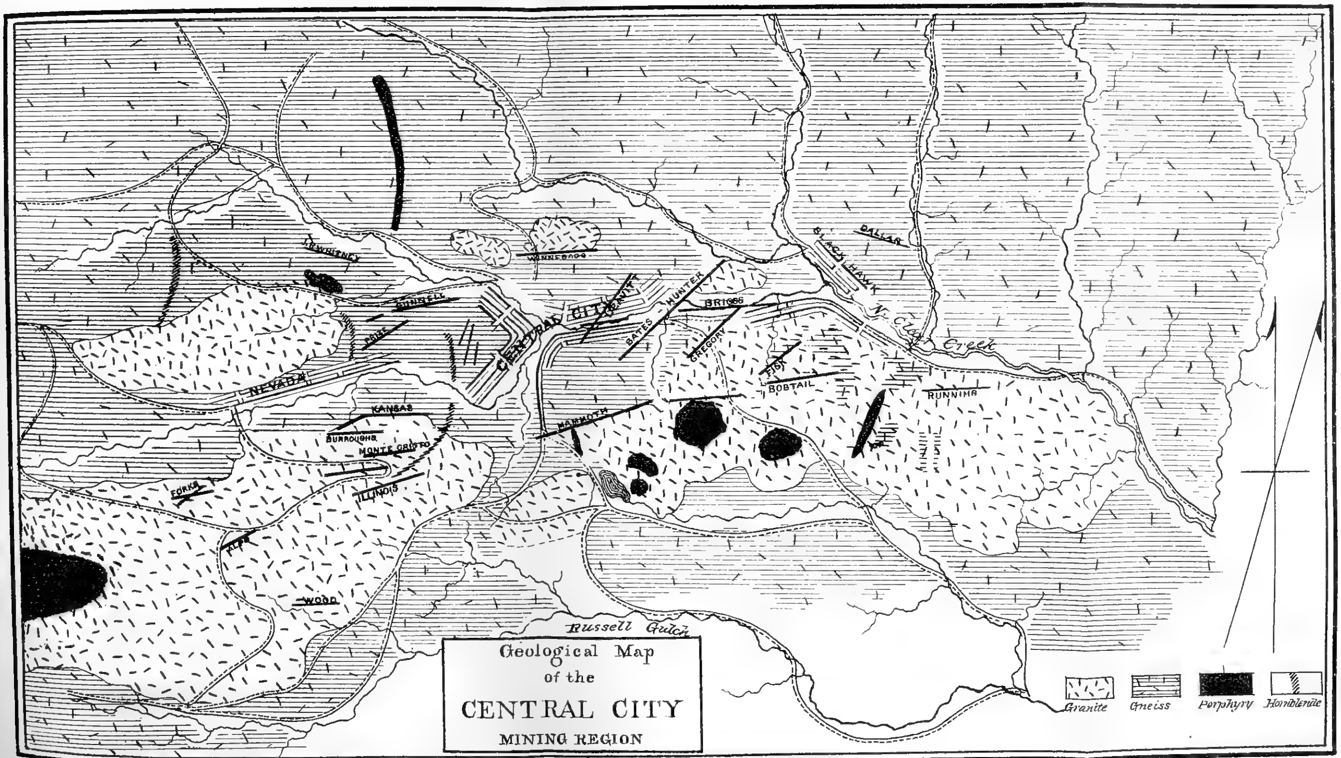
In Gilpin County, the mining locality is found within a radius of about three to four miles, starting from Central City, and is distinctly limitable at a glance by the perfect bareness of those hills in which the precious metals are contained. Approaching Central from the east, through Clear Creek Cañon, a number of rounded hills are seen to the left—higher ones to the right. Not a particle of timber remains on those that have been prospected over; no low vegetation has had time to develop. Black Hawk, at an elevation of 7,543 feet, Mountain and Central, of 8,300 feet, are seemingly one continuous town, although provided with three city governments, located in Eureka Gulch, with mines on every side, even in the very centers of the towns. Westward of Central, several hills are located, also containing a number of lodes, some of which are being worked. On all sides, this comparatively small mining district is surrounded by higher mountains, densely wooded, in which every now and then an isolated lode is found. The geognostic features in the immediate neighborhood of the mines are somewhat difficult to determine with accuracy, owing to the great displacement of rocks that has been occasioned by the search for lodes. Throughout the vicinity of this mining locality, the main rock is a gneissic one, showing numerous changes and varieties, of which Mr. Marvine speaks more fully in his report upon the geology of that section. In the immediate vicinity of the mines, however, the rock is granitic, sometimes changing into that variety which has been termed aplyte, composed only of orthoclase and quartz. Mostly, it is coarse-grained, inclined to separate in stratoid portions, and yields readily to the decomposing action of atmospheric influences.

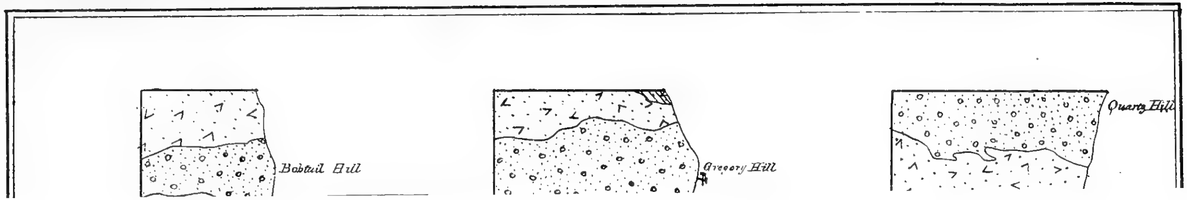
The accompanying geological map* (Plate I) will explain the distribution of the granite. Beginning at the summit of Quartz Hill, it extends eastward, keeping a little to the north, with the connection broken only at one point, until Running Hill is reached. Composing the main or entire portion of the small intervening hills, its limit southward is defined by their own, on the north mainly by the gulch. This granitic area is superficially entirely isolated from any other, having a main longitudinal direction of almost due east and west, a little north of west. On Procer Hill, granite is again found, having the same strike,

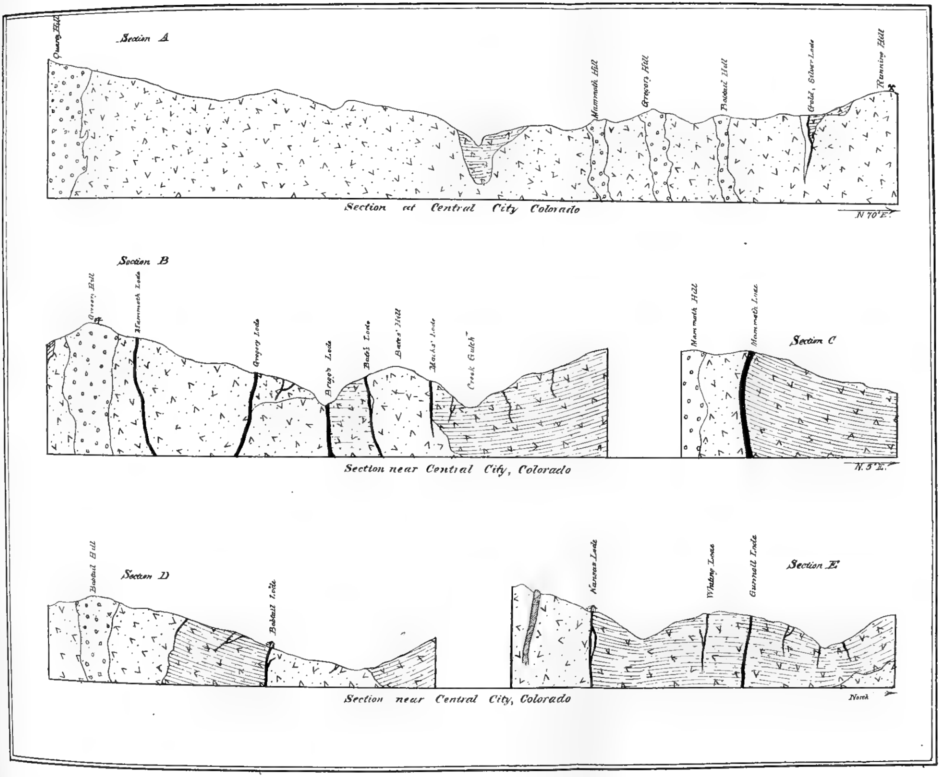
*The drainage has been taken from the map published in Mr. Hague's mining report, and also the roads, besides some of the lodes, the location of which corresponded with mine.

PLATE. I.




Geological Map
of the
CENTRAL CITY
MINING REGION
Granite
Gneiss
Porphyry
Hornblende
Russell Gulch
N. Clear Creek
CENTRAL CITY
BLACK HAWK
DALLAS
WINNEBAGO
GUNNELL
HUNTER
BATES
BRIGGS
GREGORY
BOBTAIL
RUNNING
MAMMOTH
NEVADA
KANSAS
BURROUGHS
MONTE CRISTO
ILLINOIS
FORKS
WOOD


Bobtail Hill
Gregory Hill
Quartz Hill


Section A
Quartz Hill
Mammoth Hill
Gregory Hill
Bobtail Hill
Gold, Silver Lode
Running Hill
Section at Central City Colorado
N 70° E.
Section B
Gregory Hill
Mammoth Lode
Gregory Lode
Briggs Lode
Bate's Lode
Bates' Hill
Mack's Lode
Creek Gulch
Mammoth Hill
Mammoth Lode
Section C
Section near Central City, Colorado
N. 5° E.
Bobtail Hill
Section D
Bobtail Lode
Kansas Lode
Whiting Lode
Gunnell Lode
Section E
Section near Central City, Colorado
North

pointing toward some small outcrops of it on Casto and Bates Hills. North of the Winnebago mine, it crops out; also west of it, and east of the Bates lode. How far it extends westward from the summit of Quartz Hill, I am unable to say; probably not far, however. This is the extent of the granite, and it will be found that within its limits, or in portions immediately contiguous, the greater number of the lodes are located. Porphyry crowns the top of Quartz Hill, Mammoth, Gregory, and Bobtail Hills, occurring besides in a dike on the western slope of Running Hill, on Procer, and in a large dike north of Procer. Drawing a line from the summit of Quartz Hill to that of Bobtail, it will be found to run parallel with the main strike of the lodes, parallel with the longitudinal axis of the granite—in other words, the porphyritic outflow has a strike parallel to that of the granite, and both are parallel to that of the lodes.

Hornblende-rock occurs in dikes having an approximate strike of north to south, composed of oligoclase and hornblende, associated with epidote and garnet. Several, from three to twenty feet in thickness, cross Gunnell Hill, one extending across to Kansas Hill, and one crossing Procer. Lithologically, the rock forming these dikes is diorite, although it undergoes a series of modifications.

On Plate II, a number of sections are given that will explain the relative position of the three formations occurring. Section A runs from Quartz Hill to Running Hill, almost east 20° north. Chimneys of porphyry break through the granite at four points along that section, always forming the summits of small hills. Probably, without any deep-reaching separation, the granite continues in narrow line for more than three miles. Small patches of gneiss are found every now and then, but are merely superficial. As this section runs parallel to the strike of the lodes, none are cut by it, with the exception of a small one on Running Hill, that occurs out of course contact between porphyry and the granite. Section B runs almost north 5° east from Gregory Hill to Bates Hill, cutting the Mammoth, Gregory, Briggs, Bates, and Mack. Mammoth, and probably Gregory, as soon as it goes deeper, run in granite only, while the remaining three are contact between gneiss and granite. Section C shows the Mammoth on Mammoth Hill, where it has become contact, while it is not farther east. Section D has a course from south to north, running through Bobtail Hill, cutting the lode. Porphyry, surrounded by granite, forms the top of the hill, while a portion of gneiss comes in toward the north, and between this and the following granite the Bobtail is contact. Section E runs from south to north, starting from the eastern slope of Quartz Hill and continuing over across Gunnell, cutting in its course the Kansas, Whiting, and Gunnell. The Kansas is contact between granite and gneiss, while the rest run entirely in gneiss.

On Procer Hill, the granite is of a light yellow to white color, coarse-grained, with yellowish orthoclase, white quartz, and black mica, and this character may be taken as a type. Throughout the district the granite contains small crystals of magnetite, the largest of which are found on Gunnell Hill, almost an inch in diameter. On this hill the granite assumes a more gneissic structure, which it shows at no other point to that extent. On Quartz Hill, and from there eastward to Running, its character remains almost the same as well in mineral constituents as in structure. Sometimes the line between it and the gneiss is distinctly marked along the sides of gulches—particularly so on Kansas Hill—but oftener it is obliterated. Slight variations of composition are shown by the porphyry, which must be classed among the quartzose.

The well-known crystals of orthoclase, both simple and Carlsbad twins, from Gregory Hill are contained in the porphyry that forms its summit. On Bobtail Hill it has a greenish to maroon color, containing smaller crystals of orthoclase and numerous small crystals of pyrite. At the dike, on Running, it is more compact, of a brown color, containing, in the microcrystalline paste, very small particles of hornblende. Different from these is that on Procer, very compact, with a large percentage of quartz; it has a light-yellow to flesh-colored tint.

The gneiss of the entire region is of one type, although numerous varieties occur. Mostly it is finely laminated, of a bluish color when fresh, brown when decomposed. Black mica accumulates at some points, changing its character into that of a mica-schist. Neither in any of the gneiss or the granite is magnetite wanting. With reference to the relation of lodes to these formations, it may be said that they are extremely simple, being contained either in the gneiss or the granite, if not forming contact-veins between these two, and again found between granite and porphyry. Quite a number of them are contact-veins—sometimes only for a portion of their entire length, as, for instance, the Bates. Rarely can the fact of their being contact-veins be determined on the surface, only a few cases having been observed in which it could be done; but, by carefully observing the walls of a lode, the respective formations to which either one belongs could mostly be ascertained. Upon the strike or dip of the lodes, these various circumstances seem to have had little or no effect; neither have they, within certain limits, changed the character of the ore. Although it might seem possible or even probable, the porphyritic eruptions have produced no noticeable change in the lodes of their vicinity, unless it might be regarded as an effect of this kind that those lodes found in immediate proximity to the porphyries generally yield lower returns in bullion than others farther off.

Two main systems of lodes are found here, those belonging to the one striking almost due east and west, the others about northeast to southwest. Of the two, the former are the most numerous; to the latter belong the Fisk, Gregory, Bates, Leavitt, Prize, and a few small lodes. No distinctions from a mineralogical point of view can be made, neither is there any constancy noticeable in the mode of occurrence of these veins. Contrary to my expectations, the mineralogical character of the ores was found to be a very uniform one, showing little variation in the number and species of minerals composing them. But one interesting fact was observed, that in the more or less central portions of that mining district the lodes showed but very little blende and galenite—mostly pyrite and chalcopyrite. If an elliptic line is drawn, inclosing just within it all the principal mines of this section, it will be found that the J. P. Whitney, the Forks, Running, and Dallas are nearest or on that elliptic line, and these lodes are all worked for lead and silver, containing galena and blende as their principal ores. A limited number of workable gold-mines are situated outside of this circle yet, but those upon which the mining enterprise is chiefly based are within.

Disturbances—dislocations—are very rarely found in the lodes of this region; scarcely even any material deviations from the dip.* Only a few of the lodes slope over 10°; as a rule they are very nearly or quite vertical. Ramifications occur quite frequently, more so toward the west end of the lode than at the east—a feature which was observed in a con-

*A deflection from the usual course takes place on the eastern slope of Gunnell Hill, where a dike of garnet and epidote rock crosses it, in consequence of which three or four small veins near it were formed that have a course about north 10° east.

siderable number of mines. As an average width for the lode between walls, about 4 to 6 feet might be given, although some of them widen out to nearly 30 feet.

Taking all these observations and facts into account, we may be able to arrive at some conclusions regarding the formation of these lodes. Von Cotta says,* "It is still most probable, as von Beust in his criticism of Werner's theory has clearly shown, that the majority of lode-fissures have been torn asunder by concussions caused by volcanic or plutonic activity, or, in other words, by volcanic or plutonic earthquakes." In applying this sentence to the case now under consideration, it becomes necessary to inquire into the geological nature of the formations involved. The crystalline gneiss is probably the oldest rock in that section of Colorado, while the granite and porphyry are younger. A simple metamorphosis, a remelting of some one or the other portion of this gneiss at a comparatively shallow depth, would undoubtedly produce the effect of a "plutonic earthquake," whereby not only the fissures could have been formed, but the granite have become eruptive. Subsequent disturbances from the same direction may have produced the parallel fissures in the granite, while the eruption of the porphyry seems to have been accompanied by very slight or no such demonstrations. Besides the great uniformity among the lodes *per se*, the similarity shown in the character of the ores within certain limits of locality speaks for a common origin of almost all the vein-matter and ore contained within those certain limits. Although the lodes on the outer edge of the district vary in the character of their ores from the others, this may still not justify assigning to them an age very widely separated either before or after from the latter.

As ore, mainly pyrite, chalcopyrite, galenite, and sphalerite are found in this district, and in a few isolated points argentite. Experience has shown that the chalcopyrite and the finely-disseminated pyrite yield the best production of gold, while galenite and sphalerite contain silver; the massive pyrite, however, only small quantities of gold. Frequently bands and veins of this pyrite occur more than a foot in thickness, but, as a rule, from two to six inches.

Toward the surface, the ores decompose through the action of atmospheric influences partly, partly through chemical agents. The result of this decomposition is usually termed "surface-ore," and contains, in contradistinction to the ores of lower depths, its gold as free gold. Pyrite loses its sulphur, as also does the chalcopyrite, and more slowly sphalerite and galenite, and either oxides, carbonates, or sulphates are formed. From the fact that so little native gold is observed, even with diligent search in the deeper portions of lodes that on the surface show or showed it in considerable quantities, it might seem possible that the gold was contained in the original ore as a compound, and became free through the action of decomposing agencies. Thus far, no experiments that may have been made afford any proof that such a compound of gold should exist, although circumstantial evidence points very strongly in that direction. It is a question that would require for its answer, by means of chemical investigation, the most subtile manipulation, unwearying attention, and a large, judiciously selected material.

In speaking of the various lodes and mines in the following pages, only those shall be spoken of at any length with which I have become personally acquainted by one or more visits. No further attention was paid to the names of individuals or companies owning the mines, as they

* Ore Deposits, translated by F. Prime, jr., 1870, p. 65.

may change hands, while they will not often change their names. Mining enterprise in the region of Central City is comparatively old, and the more celebrated lodes and mines are well known. Beginning with the main veins of the system, striking about northeast to southwest, the central portion of the rest, and afterward the outside ones will be treated of.

The Fisk lode, located on the northern slope of Bobtail Hill, was not being worked at any point during my stay, so that no reliable data could be obtained. It has a strike of east 37° north, with an almost vertical dip. Approximately parallel to it, a short distance west, run the Milwaukee and Devil's Grip, two small veins.

The Gregory lode was not worked at the time. Situated on the northern slope of Gregory Hill, with a strike of east 45° north, it is the first one that was discovered in this region. It strikes the Briggs lode down in the gulch, and has been found at a depth of 250 feet, where it is known as the Gregory extension, and worked. At that point it is a contact-vein, having the east hanging wall of gneiss; the western, granite. By virtue of a dip of 30° to the east, it diverges from the Briggs, which it strikes. It is here that the case of a slide to the eastward occurred, alluded to above, by which the vein appears of varied thickness. Some disturbance has taken place here, probably occasioned by slides of the ore-wall, whereby fragments of the granite and gneiss both have been thrown into the gangue-material, and are now cemented together by white quartz. The ore-bearing vein is somewhat irregular at the point where it was exposed—ramifying, connecting again, sending off a number of spurs and shoots, and keeping a wavy course. Of the walls, the hanging wall was well defined; the foot wall more broken, with gneissic fragments resting upon it.

The Bates-Hunter lode begins on the northern slope of Mammoth Hill, runs through Mountain City, and is finished on Bates Hill; strike east 43° north; dip almost vertical. Neither of the two mines on that lode were in operation during May, although I am informed that the Bates took up work again. The Bates is partly a contact-vein.

Leavitt lode is located a short distance west of the Bates-Hunter, having a strike of about east 40° north, and is the last large vein of that northeast series. This vein is one of the best developed in the district, and yields an abundant supply of ore. Very little variation from the vertical is shown in the dip, and also the course of the vein is quite regular. Well-defined walls border the vein on either side, consisting of granite on the north wall, gneiss on the south, to a depth of 150 feet, where gneiss comes in on both walls. The distance between walls at a depth of 250 feet is between 4 and 5 feet, varying but little from the surface down, but seeming to increase, however, with depth.

Pyrite and chalcopyrite compose the main portion of the ore, a vein of the former two feet thick being found at one place, while the latter is distributed throughout the gangue-rock in small particles and masses; at times intimately associated with the pyrite, again occurring free from any admixture of it. Galenite and sphalerite occur very sparingly, and may not be regarded as ore. The gangue-rock is composed of quartzitic and feldspathic particles, more or less compactly agglomerated or cemented. Sometimes large pieces of quartz will occur, thereby rendering penetration difficult for the drillers. Although the arrangement of minerals between walls shows some regularity, there is no symmetry about it. (Plate IV.) In this mine the following minerals were found: pyrite, occuring massive and in small pentagonal dodecahedral crystals; chalcopyrite, massive; sphalerite, in narrow seams, running through the quartz; galenite, in little cubical crystals, contained in the gangue-rock as a matrix; quartz, as vein-matter and in small crystals; orthoclase-feldspar, partly decomposed, forming caolinite, found in the gangue, and delicate flakes of a white talc also contained in the gangue.

It is stated that during the month of May, 1873, 745 cords of ore were hoisted from this mine at 8 ounces per cord. A cord is between 7 and 8 tons.

With the Bobtail lode we commence the second series of veins, striking approximately east and west. This lode is located on the northern slope of Bobtail Hill, which was named after it, and has a course of east 8° north. A number of claims have been taken up on the same lode, so that it is necessary to mention that the mine on this lode that will be treated of in the following pages is that owned by the Bobtail Gold-Mining Company. At the western end of Black Hawk, a tunnel has been driven into Bobtail Hill in a southerly direction, intending to strike the vein, which was accomplished after driving something over 1,200 feet. At the point of intersection, the shaft had reached a depth of 480 feet, and was then sunk farther. The vein runs between granite on the south side and gneiss on the north, and is, therefore, a contact-vein. Possibly the gneiss on the northern side may not extend down to any very great depth, because its outcrop is isolated, in which case granite would supply its place. A dip of 15° to 20° to the south was observed at the lowest level, while higher up it seemed to become almost vertical. The distance between walls may be given from 1 foot, where the vein sends out shoots or ramifies, to 5 feet. Very clean and well-defined walls are found separated from immediate contact by the characteristic narrow clay selvage. To the west, the vein continues beyond the shaft of this mine in a regular course, while it splits toward the east. Whether this split, that had reached a width of about 18 feet in one of the levels during my visit, will continue, or whether merely a "horse" comes in, could not then be determined, but the latter seemed more probable. With the exception of this case, great regularity in every feature characterizes the Bobtail vein. Small spurs, from the thickness of a sheet of paper to several inches, separate from the main vein and enter either wall.

The ore is, as in the preceding instance, pyrite and chalcopyrite, massive quantities of the former having been found up to 9 inches in thickness; of the latter, of several inches. A partly symmetrical arrangement can be noticed by observing the diagram taken at a depth of 520 feet across the vein. (Plate III.) Pyrite occurs on either side of the vein, next to the wall, separated from it by a narrow selvage, then scattering quantities of chalcopyrite and isolated threads of sphalerite and galenite are found, until the middle again is formed by a thicker band of pyrite.

Of minerals, the following were found: Pyrite and chalcopyrite, massive, and the former in crystals—rarely, however, in cubes; sphalerites, in crystalline threads; galenite, dispersed either in threads or small crystals; mispickel, massive, with pyrite, or in small crystals on quartz; gold, showing crystallized faces, on quartz; composing the gangue-rock, gray and white quartz, a pink, yellow, and white orthoclase, partially decomposed: flakes of talc and clay in the selvage.

As the Bobtail mine is one of the deepest in the central mining-region, a trouble that is not yet experienced to any extent in mines of less depth occurs here. It is the accumulation of water, which has been very efficiently overcome by means of a pump supplied with a movable suction-hose, which has been placed in the second lowest level.

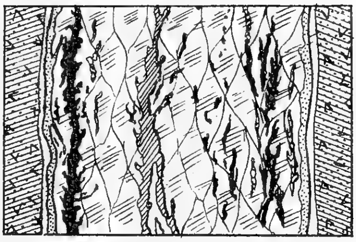
Mining is carried on pretty much upon the same plan of working throughout this section; therefore mention will be made of it only in concluding the first part of this chapter.

The Briggs lode is situated between Gregory and Bates Hills, in the gulch parallel to which it strikes, having a course of about east 3° north. It is a contact-vein, having the granite of Gregory Hill as a south wall, the gneiss of Bates for a north wall. Between walls the distance is about 4 feet at the surface, gradually increasing with depth, so that at 545 feet it is 11 feet wide, while a little higher up it bulges out to 27 feet. This considerable lateral extension, however, is owing to a number of gneissic "horses" that occurred there, causing a splitting and widening of the vein. Although not disturbed to any extent, the walls appear rough at some places, which is due to the fact that at some points there seem to have been dislocations at one time, whereby portions of the wall were broken, and cemented again by quartz. As a rule, it may be said that the south wall is smooth and of a good character. Dislocations of the vein are very rare, scarcely even variations in the almost vertical dip being noticeable.

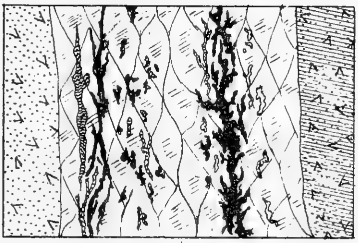
Pyrite and chalcopyrite, as usual, form the bulk of the ore, with sphalerite and galenite as accessories. At the depth of 545 feet, a vein of massive pyrite 4 feet in thickness was found. Quartz and feldspathic minerals, together with fragments of granite and gneiss, form the gangue-rock. Minerals found are: Pyrite and chalcopyrite, the former also incrystals; galenite, sphalerite, gold, dolomite, quartz-crystals in small cavities; quartz, feldspar, and mica in the gangue. The owners of this mine are the Messrs. Briggs, one of whom, Mr. G. Briggs, kindly furnished me with some data regarding wages and contracts that will be found at the end of part 1.

The Mammoth lode, beginning on Gregory Hill and running across westward on Mammoth Hill, has a strike of about east 10° north, showing a curve toward the north. A connection between the Bobtail, Mammoth, and Illinois has been supposed to exist, and may exist, but not sufficient proof has yet been produced to substantiate the supposition. The very similar character of the ore and the percentage of gold decreasing westward might speak for such a connection. On Gregory Hill this vein runs in granite, coming up very near to the porphyry; while on Mammoth Hill it becomes a contact-vein between granite on the south and gneiss on the north wall. Along its entire course, the width of this vein between walls is considerable—between 20 to 30 feet—containing large quantities of pyrite, with some chalcopyrite, too poor in gold, however, to pay working at present. Its dip is almost vertical, and the walls seem to be clean and well defined.

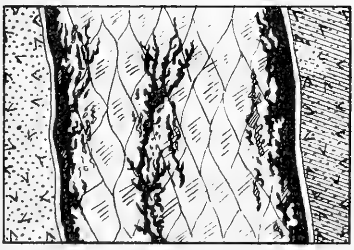
The Winnebago lode, opposite the Mammoth, on the north side of the gulch, located on Casto Hill, has a strike of about east 4° north. Gneiss on the south side forms the hanging-wall, while granite borders the vein to the north. Clean walls, at some places almost of a polished appearance, characterize this contact-vein: dip to the south of about 8°—12°, varying at different depths, strongest at the top. A shaft has been sunk down on the vein, first inclined, then vertical, following it in its course, and the depth reached is 350 feet. Between walls the lode is from 3½ to 5 feet thick. Near the western end of the Winnebago claim the vein seems to split; but as it does not split into two equal halves, and the continuation of the vein can be traced westward on the surface, there is reason to believe that this lode connects with Casto, which is a little farther west, running through granite and gneiss, partially being contact between the two.



Coleman Gummell 130 ft.

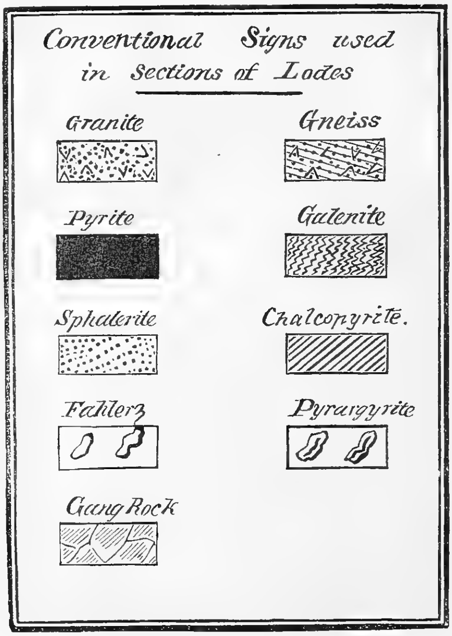


Winnebago 130 ft.



Bobtail 560 ft.

Fig. 5.


Conventional Signs used
in Sections of Lodes
Granite
Gneiss
Pyrite
Galenite
Sphalerite
Chalcopyrite.
Fahlerz
Pyrargyrite
Gang Rock

Following the example of the main lodes of this region, the chief ore is pyrite and chalcopyrite, as seen in Plate III, but galenite and sphalerite begin to make their appearance in more connected quantities. Quartz and feldspar compose the gangue-rock. Wherever granite forms the one wall of a lode, the feldspathic compounds appear in greater quantities in the gangue than in other formations, or even in such where the granite is hard and fine-grained. In that case the gangue is mostly quartz alone, or the ore-veins are found to traverse the granite itself, without any younger formation of gangue-rock appearing.

Of minerals, only the four mentioned above are found, besides native gold. Pyrite occurs here in cubical crystals as well as in dodecahedral.

The Gunnell lode is situated on Gunnell Hill to the west of Central, and has a strike of about east 8° north. It has been one of the most productive veins of that region, and is supplied with a number of shafts, the levels driven in the different claims mostly connecting underground. Of those claims located on this lode, the following were visited: Gunnell, Pippin, Coleman, and Peers. The latter had not reached a depth of more than 120 feet at that time, and nothing but surface-ore was obtained, while the shafts on other claims had been sunk much deeper. The peers varied from 4 to 5 feet between walls, with a body of ore 6 inches to 2 feet thick, mostly decomposed pyrite.

On the Pippin claim, the shaft has reached a depth of about 415 feet, and a number of levels have been worked out on either side. Along its entire length, the Gunnell runs in gneiss, modified somewhat in texture and structure, so as to be termed a granitic gneiss. It has clean, well-defined walls, with a slight dip to the south, varying in different parts of the mines. A number of small veins, from mere seams up to more than half a foot, run into the main vein, in two instances traversing it, but apparently extending only a short distance on either side.

Scarcely any difference can be observed in the character of the ore from that of other mines previously described, except the presence of greater quantities of chalcopyrite. Pyrite has a tendency to accumulate in long sheets in several horizons throughout the vein of the Pippin claim, which measures, on an average, 4 feet in thickness. As usual, the gangue is composed of quartz, having, however, far less feldspar than in those veins that are in contact with granite.

Of minerals, the following were found in this mine: Pyrite, chiefly massive, otherwise in cubical crystals, in distinction to the more centrally located mines, where they are dodecahedral; chalcopyrite, sphalerite, galenite, melaconite, (as a result of the decomposition of chalcopyrite,) quartz-crystals, and native gold. In the gangue, quartz, feldspar, and some talc were contained.

A shaft of about 250 feet in depth has been sunk on the Coleman claim, to which almost all the characteristics given for the Pippin will apply. Between walls, the vein is a little thicker here than in the Pippin, averaging from 5 to 6 feet. At a depth of 240 feet, a cross-section of the vein was taken, which can give an idea of the distribution of the ore, (Plate III.) On either side, nearest to the wall, is a very considerable segregation of pyrite, intimately associated with chalcopyrite, and interspersed with grains and threads, even small massive quantities of sphalerite and galenite. Next to that, toward the center, quartz sets in—a light-gray to white quartz—containing, disseminated all through it, numerous small particles, mainly of pyrite, but also of the other minerals occurring. In this mine there is but very little dip noticeable in the vein, which is bordered by clean walls. Its minerals are identical with those of the Pippin. In all its parts, the Gunnell shows a very great uniformity, which can be very well noticed, as it is conveniently opened to some depth at a number of points.

The Grand Army mine, located west of Gunnell, with a strike of about east 22° north, may be only a spur or portion of the deflected Gunnell lode, although the connection has not been traced thus far.

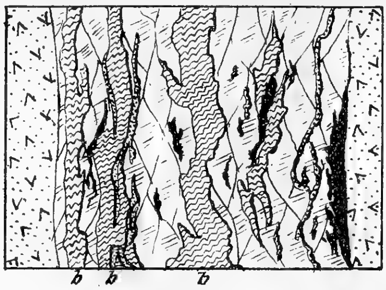
The Prize lode, located to the southwest of Gunnell, at one time enjoyed a considerable reputation, but was not working, however, while I was there. Its strike is somewhat out of course, being east 32° north.

Crossing Nevada Gulch, and traveling over southward, we reach another locality that abounds in lodes, some of which are quite large, and have proved remunerative, while others have been—perhaps temporarily—abandoned. This locality is Quartz Hill, so named from the numerous little quartz crystals that have been and are still found there in the decomposed granite. A long, narrow hill, it stretches along, sloping off gently from west to east, more steeply on its two sides. Where the steepest ascent from the north has been completed, where the gneiss stops and granite sets in, there we find the first vein—the Kansas lode. As most others, this lode is divided into a number of claims, owned by various individuals and corporations. It is mainly of the claim worked by the Kansas Mining Company that I shall speak. Taking the entire Kansas lode, its course is about east 3° north, until it deflects about 8° southward, near the Waterman shaft.

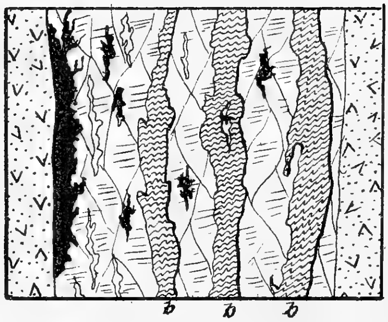
Along its entire course it is a contact-vein, between gneiss on the north and granite on the south side, keeping a tolerably even thickness of the vein, but varying in the angle of the southerly dip from 10° to 30°. The thickness of the vein is between 3 and 4 feet, with a good body of ore, which receives and sends out quite a number of shoots from and into either wall, while some cross the main vein; and in this case the intersections prove, as a rule, to be richer than the other portions. Converging in one direction are the Camp Grave, (which joins the Kansas as Waterman shaft,) the Kansas, and the Burroughs, but whether they actually do come together and form one strong vein—what miners would term a "mother-lode"—seems doubtful. Near the eastern end of the Kansas, Tascher's claim is located, with a shaft of 90 feet in depth, just about having gone through the surface-ore and reached the undecomposed material. The vein is 4 feet to 5 feet wide here, with a southward dip of about 12°, still continuing on eastward. West of Kansas claim is the Waterman shaft, which dips at about 20° to the south, retaining its character as a contact-vein.

Minerals found in the Kansas are identical with those from the lodes previously spoken of, the only difference being that the cubical form is almost exclusively the only one for pyrite. Sphalerite begins to grow a little more abundant than it was in the central portion of the mining-region. The ore of this lode is said to yield good pay, containing an appreciable quantity of gold.

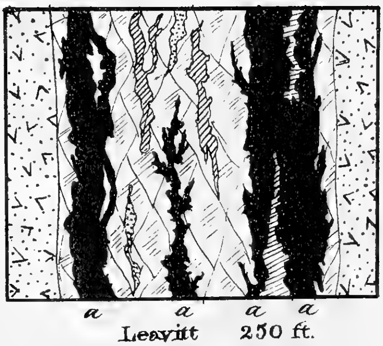
South of the Kansas, running almost parallel with it, is the Monte Cristo Lode, having its course entirely in gneissic granite, striking east 7° north, with the dip almost vertical. A number of small veins, of inferior thickness, come in to the main one from the southeast. About 90 feet west of the shaft, the vein splits into two of somewhat unequal size, which seem to remain separated, the gap between them widening with increasing depth. Two hundred and ten feet the shaft has been sunk, and at that depth the vein is found to concentrate its ore, which is more loosely distributed through it higher up into a body of pyrite and chalcopyrite 9 to 10 inches thick. The ordinary width between walls



J. P. Whitney 40 ft.



Running 100 ft.



Leavitt 250 ft.

is 3½ to 4 feet. The minerals of this mine do not vary from those of the others, either in relative quantity or mode of occurrence.

South of the Monte Cristo are the Gardner and Illinois, of a little more northerly strike, neither of which was worked during my stay. The distribution of the precious metals seems to vary constantly, and thus far science has not been able to produce a guide whereby mistakes can be avoided in the appreciation of the relative or absolute value of ore from lodes contiguous to those yielding good profits. In no branch, perhaps, is a want of this kind so keenly felt as in mining, where experience must always be bought at a high price. Upon a large number of lodes in the district at present under consideration, large sums of money have been expended, but the owners or workers were obliged to abandon them—temporarily, it may be hoped—for some pursuit more remunerative. The Alps lode, to the southwest of the Illinois, is reported as having been doing very well some years since.

Besides the mines that have been enumerated here, quite a number of small ones are in operation, only presenting features that would essentially repeat those given above, or possessing no further interest. On the other hand, a considerable percentage of the more important mines were closed during the short time of my stay, partly on account of the inability of owners to resume work, partly on account of the spring-waters filling the levels and shafts, so that the facts given of the gold-mines of this section, taken as a whole, must necessarily be incomplete.

There yet remain to be treated of, five lodes belonging to this region, located on the outer edge of what might be termed the lode-circle.

The Forks lode, situated on Quartz Hill, in the immediate neighborhood of the California, Mercer, and Flack, has a strike of east 10° north. Gneissic granite composes the walls on either side, which are smooth and well defined, the hanging one dipping about 25° to the south. At present the working-shaft is 250 feet distant from the discovery-shaft, located on the line of intersection of the Helos with the Forks, on which it remains down through its entire depth of 517 feet. Keeping on regularly in its course, the Forks shows very little deviation either in direction or in thickness of vein between walls; the thickness is about 5 feet.

Both the Forks and Helos are galena veins, and have as such afforded already a large quantity of that mineral, but the main reliance for remuneration is upon the silver contained therein. To some extent only has the Helos been worked, as the Forks showed a larger body of ore.

Of minerals, mainly galenite and sphalerite are found, mixed with small amounts of pyrite on chalcopyrite. Galenite occurs, from the very fine-grained feathery variety to the coarse-grained breaking in cubical fragments. Argentite is contained between the single crystals of the latter. Of a similar character is the J. P. Whitney, although scarcely developed sufficiently to admit of any opinion. This also is a galena-vein, showing at a depth of 50 feet a body of galena 12 inches in thickness, with other portions of the same mineral at either side of the walls. (Plate IV.) Pyrite and chalcopyrite occur as ores, and yield a small amount of gold; but silver is the main object for mining here; strike is east 12° south. Besides galenite, sphalerite, pyrite, and chalcopyrite, we find small quantities of argentite and cerussite.

The Dallas lode is located on the eastern slope of the hill immediately north of Black Hawk. It has been worked quite extensively, and the vein can be traced along for nearly 1,000 feet. Contrary to the usual course, it strikes a little south of east; the exact number of degrees could not be determined by the compass on account of strong local attraction.

A southeasterly dip of about 15° to 20° is noticeable. The thickness of the vein between walls varies from 6 to 10 feet along its line of exposure as well as going down deeper. Galena, mostly of the fine-grained variety, forms a large body of ore in the vein, associated with sphalerite and some pyrite, while the gangue-rock is made up of quartz, with a small amount of calcite. At this point, the sulphuret of cadmium, greenockite, was found in a specimen of sphalerite, which had been thrown out on the dump several years since. In no other mine or other dump was this mineral found, although search was made for it. Besides the minerals mentioned above as occurring, there is chalcopyrite and cerussite.

The Running lode is the last one of these galena lodes, and is situated on Running Hill, southwest of Black Hawk. Its course is almost due east to west, with a vertical dip. For 700 feet the vein has been traced and partially worked, reaching a depth of about 100 feet. Single streams of galenite are distributed throughout the vein, (Plate IV,) running parallel to its walls, but toward the west they seem to consolidate into one mass, forming a galena-vein 14 to 15 inches in thickness. Sphalerite occurs quite abundantly; less so pyrite and chalcopyrite, which are both found in thin seams, or dispersed throughout the gangue-rock. This latter is composed mainly of quartz, with some feldspar and magnesite.

These four lodes are perfectly isolated in their character as well as in their position from all the others, and, although they show but little deviation from the ordinary strike and dip of the others, their occurrence seems out of the regular order of things. In explanation, if one were desired, the view might be offered that, provided heat was ever one of the agents in forming those lodes, those metals requiring a lesser temperature for volatilization are now found to be removed farthest from the center of the vein-system.

Another lode that has become famous for its production in quantity of a mineral thus far regarded as a rare species is the Wood lode, situated to the north of the creek in Leavenworth Gulch, also outside of the regular vein-circle. With both walls of granite, it strikes about east 3° north. When I visited it, the shaft was full of water, and it was impossible to get access. Besides producing the unparalleled yield of pitchblende, it is said to pay well in gold; but as I have no reliable data with reference to the mine at all beyond the fact that it contained and probably still contains pitchblende, it may be justifiable to stop here.

It remains to be said, with reference to the minerals found in and belonging to the various lodes, that, almost without exception, products of decomposition may be collected on the dumps; for instance, pseudomorphs of limonite after pyrite, sulphates of iron, copper, and zinc, and others. A portion of the soluble sulphates is carried off by the waters washing down the hills, and transferred thereby into Clear Creek, which carries them in solution for a long time, and evidently does not deposit them until it reaches the plains. I have observed that if some of the deposit of Clear Creek was taken at Fisher's ranch, which is only five miles from Denver, and rubbed on a bright iron or steel knife-blade, after having been slightly moistened, metallic copper would at once be deposited on the blade, owing to the sulphate of copper, which had been carried down for about forty miles and deposited at that point.

After having examined the greater portion of the main lodes of this district with a view to determining their correlation as well as their persistency, the deduction seems justifiable, based upon the observed features of numerous veins, that practically their depth is inexhaustible; that they are what is popularly termed true fissure-veins, although their yield of the precious metals may fluctuate. All observations of strikes, &c., have been given in the true, not magnetic, meridian, allowing 15° deviation for the reduction. Local attraction is very strong at times, and the best way of getting the true course was to locate the lodes on a map prepared for field-use.

When first that mining-region became known, a great deal of gold was obtained from the gulches, where it had accumulated for ages; but, although gulch-mining is still carried on to a small extent, practically that source for obtaining the precious metal has ceased. It follows necessarily that, with the decrease of the production of gulch-gold, the mining industry will rise, provided the veins are sufficiently rich to be remunerative. That this is the case is demonstrated by the fact that quite a number of mines have been in operation now for several consecutive years. Were it not that reported discoveries of new mining-districts, more prolific than those occupied at the time, attracted labor and capital, the development of these older regions would have progressed much more rapidly. Nevertheless, it seems highly probable to me that when labor will be cheaper, and competition reduces the smelting-processes to their most economical form, the mines of a district like the one under consideration will rank by far higher than at present.

Although not strictly within the limits that have been assigned to these examinations, I wish to say a few words about the treatment of the ores. Formerly, when a large proportion of ores could be classed as surface-ores, the process of amalgamation returned very favorable results; but experience has shown that either the ore from lower depths is not so rich as that found nearer the surface, or there is a defect in the process. It must be admitted that, as a rule, the lower ores will not be quite so rich as those from the surface, because the particles of gold that have weathered out may accumulate on the surface to some extent and produce a higher average percentage of the metal. On the other hand, the recognition and appreciation of this fact turns upon the question, Is gold contained in the ore as a compound? An answer to this would answer the other question. Significant remains the fact that, while a number of mills and other amalgamation establishments have failed and have been abandoned, the few smelting-works that have been constructed upon and regulated by a reasonable basis, not attempting to introduce processes that looked very well when regarded in the light of a reminiscence of alchemistical experiments, have thus far been successful in their treatment of ores.

Through the kindness of Mr. Hill, of Black Hawk, I have been supplied with a schedule of the prices he pays for ores delivered at his smelting-works: Ores containing, per ton, $50, charges for smelting $35, pays $15; ores containing, per ton, $100, charges for smelting $40, pays $60; ores containing, per ton, $150, charges for smelting $45, pays $105; ores containing, per ton, $200, charges for smelting $50, pays $150; and, in addition to this, $1.50 for every per cent. of copper in 2,000 pounds. All the prices of this schedule are in currency.

Since returning from the field, I have been informed that Mr. Hill has erected quite extensive refining-works, and instead of sending his matter to Swansea, England, as heretofore, it is refined there, and, according to statements received, with very satisfactory results.

Lately some concentration-works have been put up in Colorado, partly not quite completed, partly still in their infancy, so that but little can be said about them. It is evident that if all the finely-disseminated metalliferous minerals could be collected at a moderate expense, and their valuable constituents extracted, a considerable saving would be effected in the expenses of mining. To this end it becomes necessary to concentrate the ores, to separate, by such means as may be found most effective and cheapest, the dead rock from the valuable minerals that are contained in it. Although but small beginnings have been made in that direction, it is to be hoped that they will succeed, and raise the productions of the mines by the more economical treatment of ores. In Europe, concentration of ores has become a matter of vital importance, and in our western country it would greatly assist mining enterprise, although it is not yet so imperatively demanded.

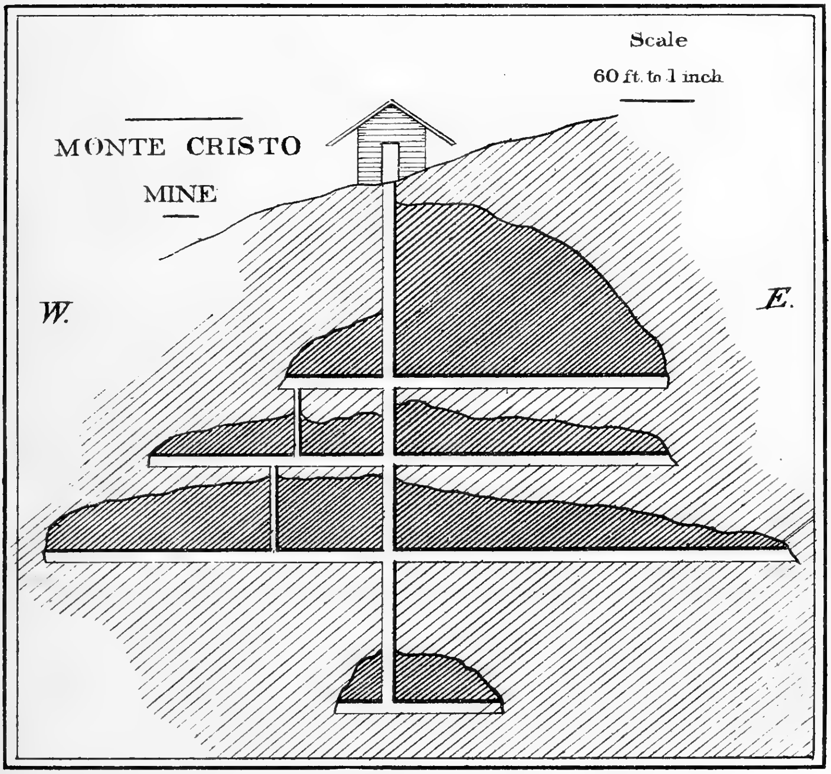
Mining is carried on economically, as a rule, in this as well as in the other districts of Colorado. Ordinarily a shaft is sunk down on the vein, which is a matter of little difficulty remembering the surprising regularity of the dips. From this shaft, which usually follows the dip, levels are struck off into either side of the vein, sometimes certain distances apart, sometimes at random, or according to the prospects of finding a large body of ore. These levels are driven either to the limits of the claim or their termination is induced by a deterioration of the ore, or an irregularity of the vein that may be destructive to the ore-body. By means of overhand and underhand stoping, the ore is taken out, and conveyed either on a tramway or by hand to the shaft, and thence hoisted up by steam-power, horse-power, or by a hand-windlass. Should the mine be more extensive, other shafts are sunk, as necessity may require it; vertical connections between the different levels are made, partly to facilitate the extraction of ore, partly to regulate the supply of fresh air; and apparatus for controlling the collecting waters are constructed. Mr. Hague, in his report on the mining industry of Colorado, has dwelt considerably upon these points, and to his book I would refer any one seeking information with regard thereto.

In illustration of the above remarks, a diagram representing the work done in the Monte Cristo mine is given on Plate V. The dark shades indicate how much of the ore has been taken out.

A continuation of this process of extracting the ore throughout the entire vein from the surface downward seems to have one disadvantage, however. I am fully aware that a method of this kind is demanded by the very simple fact that the men owning and working the greater portion of the mines are not men of capital, and it is necessary that they should derive from their mines as much remuneration as possible at the smallest expense. Therefore, they rob the vein of all its contents so far as of any use to them directly from the surface downward, frequently along the entire extent of their claim, leaving a long, narrow aperture in the hill, on which they may be working, of sometimes 100 feet in depth. It is evident that in course of time progressing decomposition of the rock exposed to atmospheric influences, among which the accumulation of snow in the crevice thus formed is one of the strongest, combined with the more or less direct pressure which is experienced by the rocks on either side of this fissure, will result in rendering the walls very unsafe—so much so, perhaps, that great expense must be incurred hereafter if operations are pushed farther downward in the same mines.

As stated above, Mr. Briggs has kindly furnished me with some data regarding price of labor, conditions of contracts, &c. This was in May and June, 1873. The wages of a miner per day are $3 to $3.50 for work in the mine, lasting ten hours during the day, nine during night. Brakemen receive $3.50 for twelve hours' work. When leasing a mine, the

PLATE .V.



lessee usually gives the owner a certain percentage either of brutto or netto. In leasing the Gregory extension, which may be regard ed as a typical lease, the following conditions were agreed to: Briggs furnishes the steam or horse power; the lessees, the brakeman. One-quarter of the cost of crushing is paid by Briggs, unless they crush any mill but his own. In the latter case they pay the entire cost. Briggs supplies drills, shovels, hammers, &c.; they replace hammer-handles, &c. On ores up to 6 ounces per cord, they pay Briggs 25 per cent.; over 6 ounces they pay from 40 to 50 per cent. Of the smelting-ore of $100 per ton, they pay 25 per cent.; over $100 per ton, they pay 50 per cent. On a six months' lease they must sink 30 feet. Briggs has the right to retain 30 per cent. of the profits as a guarantee that this shall be done. Briggs furnishes the timber, and the lessees are required to timber the mine and keep it in good order. A foreman usually receives but low wages, but has a small percentage of the net profits, however.

Subjoined is the statement of Mr. Mills, the data of which are taken from the Monte Cristo mine:

Monte Cristo Mine, on Quartz Hill, Nevada, mining-district, owned and worked by James Mills, Central City, Colo.—Statement for one year, 1872, having two miners at work, engaged per day.

EXPENSES.		RECEIPTS.	
$25\frac{1}{2}$ cords, or 204 tons, of mill-ore, and $14\frac{579}{2000}$ tons smelting-ore	$67 67	Yield of $25\frac{1}{2}$ cords, or 204 tons, mill-ore	$3,132 66
Wages for miners	2,040 00	Yield of $14\frac{579}{2000}$ tons smelting-ore	1,158 17
Hauling	175 50		
Milling	704 50		
			4,290 83
	2,969 67		2,969 67
		Balance	1,321 16

Milling-ore:

Yield of $25\frac{1}{2}$ cords @ $122.88 per cord, (204 tons @ $15.36 per ton) $3,132 66

Smelting-ore:

Yield of $14\frac{579}{2000}$ tons @ $81.05 per ton 1,158 17

Total 4,290 83

GROSS COST.

Running mine-expenses, wages, hauling, and milling: Milling-ore, $25\frac{1}{2}$ cords, $110.60 per cord ore; 204 tons milling-ore, $13.82½ per ton.

Average assay of smelting-ore, (returns from Boston Colorado Smelting Company:) $14\frac{579}{2000}$ tons ore: gold, $2\frac{3}{4}$ ounces per ton; silver, $5\frac{5}{8}$ ounces per ton.

PROFIT.

Milling-ore: $25\frac{1}{2}$ cords, $12.20 per cord; or, 204 tons, $1.52½ per ton.
Smelting-ore: $14\frac{579}{2000}$ tons, $70.67½ per ton.
Profit on total expense of $2,969.67, $1,321.16, or 44½ per cent.
Improvements overground as well as underground were made during the time, and the mine kept in good condition.

PART II.

Differing from the lodes of the Gilpin County mining-district are those located near Georgetown, in Boulder County, the most extensive silver-mining district working at present in Colorado.

Traveling upward along South Clear Creek in a westerly direction, the cañon, which has been narrow for some distance, suddenly begins to open out into a wide, fertile valley of triangular shape, bordered on every side by steep mountains rising abruptly from it. In this valley, in its upper, broadest portion, the mining city Georgetown is located, almost as if selected for the beauty of the spot more than for the metal riches surrounding it. Unlike Central, the mines are not located within and all around the town; the mountains have not been deprived of their timber, have not had every stone on their slopes overturned in the search for treasures; nothing reminding too strongly of civilization has marred the natural harmony of this secluded valley. Steep, rocky slopes of the mountains, with deep-cut ravines, set off to advantage the peaceful appearance of the town they surround.

Two branches of South Clear Creek unite a little below Georgetown, and it is on the sides of the cañons that they have formed that the greater portion of the principal silver-lodes are found. A number of veins have been claimed, and temporarily worked, east of Georgetown, on the northern slope of Bald Mountain and several others, but little progress had been made there.

The main rock of that locality is a granitic gneiss, a curious mixture of the two, at times shading into each other very gradually, at times showing an abrupt line of junction. Slides and local faults have disturbed it to a considerable extent; noteworthy it is, however, that the lodes have been affected thereby but very little. Local contortions have taken place in the schistose gneiss, which appears as such in a great many places, but within it can be found masses of greater or less dimensions that would be regarded as granite. Characteristic of that formation may be regarded the almost entire absence of mica in those granitoid portions, while the gneiss is very abundantly supplied with it. Besides this granitic gneiss, a typical granite occurs in these mountains, which I have become accustomed to associate with the appearance of the main lodes. It is of a brownish-gray to light-brown color, rising up in steep bluffs parallel to the trend of the mountains on their slopes and sometimes crests. Harder and more compact than the surrounding material, it has better resisted the destroying agents of atmospheric influences. Frequently the line of demarkation between the granitic gneiss, which I am inclined to regard as older, is sharp and well defined for some distance, while at other points the two gradually change, one into the other, similar to the fusing together of two differently-colored glass rods in high temperature. In several instances, bands of white and yellowish quartzite accompany the junction, or local accumulations of mica alter the rock into a mica-schist near those places, while the feldspar is then represented but very sparingly, quartz more abundantly. Black mica is a prominent constituent of this granite that belongs to the porphyritic varieties; oligoclase, quartz, and orthoclase making up the rest. At the time of my visit, early in June, almost all the mountain-tops were still covered with several feet of snow, so that examinations regarding the horizontal extent of this granite could not be made so carefully and comprehensively as I might have wished it, although more time would have been required than I could spare. One of the most typical points of exposure is to be found on Brown Mountain, at the Terrible lode, where this material rises considerably above the granitic gneiss, presenting a long line of steep, smooth surface toward the cañon. Going farther westward, the granite seems to partake more of its normal character, until that of Mount McClellan, about nine miles from Georgetown, cannot be identified with the one just mentioned. So large is the number of varieties presented by the granitoid rocks of this region that local observations of this kind can give but a very poor conception of the great changes that take place and repeat themselves within comparatively limited areas. I will, therefore, take the liberty of referring to Mr. Marvine's report for a more connected and comprehensive discussion of these interesting features.

Similar to the conditions observed at Central, the lodes here have mainly two strikes, approximately east to west and northeast to southwest, the former being the more numerous of the two. They show great uniformity in dip, which is mostly near the vertical, and are rarely disturbed. But few of the mines have reached any considerable depth, so that not much can be said as yet about their character of persistency, unless inferences might be drawn, judging from their formation, analogous to that of other well-known localities.

With reference to the relation that these lodes bear to the adjacent rocks, it will scarcely be possible to apply a single rule covering all cases. It may be said, I think, that the majority of them follow in their course approximately the course of the porphyritic granite, are sometimes contact between it and the granitic gneiss, sometimes have their course within it, and in other cases stand in no connection with it. This granite may probably be considered intrusive, although its age will be by far prior to that of the Central City granite, possibly even not much more recent than that of the surrounding rock. If the hypothesis of filling the fissures with their mineral-matter by the agent of heat mainly were proved, the view expressed regarding the relative age of these lodes would find some support, inasmuch as the metals mainly found in them all have a lower temperature of volatilization than those occurring chiefly at Central; consequently would have been dismissed first from the common reservoir. Porphyry-dikes not infrequently occur, sometimes intersecting veins, but in no instance, so far as could be observed, occasioning any disturbance. Usually the lodes traverse the gneiss at some considerable angle to its dip; only in rare cases do they strike and incline parallel with it. In the latter case they seem to be younger than in the former, judging from their mineralogical and geognostic character.

Dikes of hornblende-rock, with epidote, resembling diorite, are quite frequent in the gneiss, and are almost invariably accompanied by a narrow seam of minerals, mostly galena and blende. Their strike is at right angles to that of the ore-veins, as at Central, running from north to south.

Due west of Georgetown, 8,412 feet above the sea, Leavenworth Mountain rises up about 1,200 feet above the valley, and it is on the south side of this mountain that a number of very valuable lodes were found. The Colorado Central, having a course about east 10° north, is located on the south side of this mountain, about 700 feet above the creek. It is a very rich silver-mine as far as the character of its ore is concerned, and has paid well ever since it was worked. Between walls the vein is very wide, no wall-rock having been found on the south side as yet, although nearly 30 feet of vein-matter have been cut through. The north wall is granite and well defined; dip slightly to the north. Ore traverses the entire gangue-rock, mainly in the direction of east to west, branching off, however, at several points into seams of one-fourth inch to an inch in thickness, which, nevertheless, pay following, owing to its rich character, but these spurs consolidate at places, and form a solid vein of ore $1\frac{1}{2}$ feet thick. Near the surface of the lode, a mass of float-ore occurs, of the same mineralogical character as that found at lower depths, although its position there seems somewhat out of place if it is from the same vein. Quartz and feldspar compose the gangue-rock—the latter mostly decomposed—both occurring in small particles as well as in larger pieces, and they were probably derived from the surrounding rock.

As yet no very great progress has been made in the development of this mine. A shaft of 85 feet has been sunk, and several short levels started in both at the bottom and before reaching it. The large percentage of silver contained in the ore renders it advisable to follow almost every spur, which can readily be done in the soft gangue-rock, so that, although but little headway is made in the working of the vein, it yields large profits. At the western extension of the Colorado Central, a narrow dike of porphyritic obsidian crosses the vein at right angles, without, however, occasioning any dislocation.

Constituting the ore, the following minerals are found: galenite and sphalerite, containing an appreciable percentage of silver; antimonial fahlerz, stephanite, argentite, and pyrargyrite; the latter two intimately associated with the galenite, the fahlerz occurring in masses of more than several pounds in weight. None of these minerals are crystallized, however, but occur massive. Galenite is found from the very fine-grained variety, passing through every phase, to the coarse-grained, breaking in large cubical fracture.

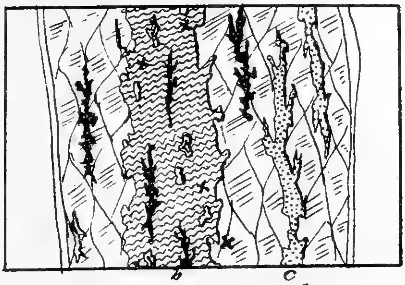
On the same hill, within a short distance eastward of the Colorado Central, is the Saco, in which operations had been taken up again but a short time previous to my visit. It strikes almost due east and west. A tunnel of 320 feet leads to the vein, the main ore of which is sphalerite with galenite. As at the Colorado Central, the south wall had not been found, allowing a very considerable width for the fissure.

The Star mine is close by, striking parallel with the Colorado Central with an almost vertical dip. At the time, the body of ore was small, mainly on the south side of the lode.

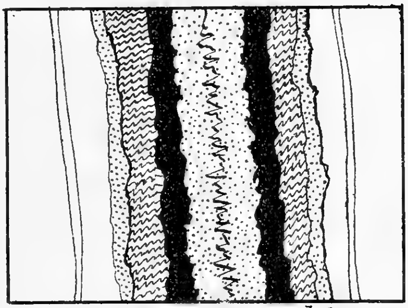
The Equator lode was not worked during my stay; it has a strike of approximately northeast to southwest; formerly it was worked, and yielded good pay.

On the hill opposite Mount Leavenworth, to the south, quite a number of small lodes have been found and temporarily worked, rarely yielding sufficient pay, however, to warrant a continuation of operations. They seem to be local infusions of ore between the strata of gneiss.

To the northwest of Georgetown, on Mount Sherman, a number of remunerative lodes are located, undergoing active working. One of the largest and richest there is the Pelican lode. As far as could be determined, considerable local attraction interfering, the strike of the Pelican is about north 16° east, with a vertical dip. The vein is from 4 to 10 feet between walls, widening somewhat the deeper it goes. Another lode, the Elkhorn, has a strike of north 35° east, dipping on an average 20° to the north. This Elkhorn approaches the Pelican both on a horizontal and vertical projection, and while in the third level it is yet 30 feet distant from it, 80 feet deeper they have joined; the Pelican keeping its true course and dip, while the Elkhorn accommodates itself to it. Between these two lodes, the intervening rock is gneissic, the same forming the entire south wall of the Pelican. Although there is a semblance of a wall on the north side, its character could not be determined; but, judging from surface-outcrops, it seems to be partly granitic, partly gneissic. A dike of porphyry is said to cross the vein in one of the lower levels. Blende and galenite mainly constitute the ore, mixed with small quantities of pyrite, chalcopyrite, argentite, fahlerz, and pyrargyrite. At the point where our section was taken, (Plate VI,) in the lowest east level, the vein was 6 feet thick, containing almost in the



Pelican 80 ft. below shaft



Pelican

Terrible

center a body of galena-ore of about 18 inches, intermixed with blende, pyrite, and the silver-ores proper. The gangue-rock is composed of quartz and feldspar partly decomposed.

Another section of a central portion of the vein was obtained, (Plate VI,) given in varying succession layers of the minerals composing the ore, and thus showed a combed texture. The single layers were from one-half to one inch in thickness, and not all of them could be given in the sketch.

Minerals found are those mentioned above, none of them presenting any very fine crystals, mostly massive. Their character is such as to insure a very rich yield of silver wherever they occur, if even only in small quantities.

A tunnel 325 feet in length leads to the vein, which is worked upward and downward from it, having reached at the time a depth of 82 feet below the tunnel-level. Every indication of persistence is shown by the lode at that inconsiderable depth, and also upward as far as it has been worked. In consequence of the advent of the Elkhorn, this mine shows more complicated workings than most of that section. Near the Pelican are quite a number of other lodes, some of which were not in operation, while a lack of time forbid a visit to any but the principal ones. West of it still, on Mount Sherman, is an interesting vein, the Cold Stream lode, striking north 67° west, into a dip to the north, varying from 10° to 25°. The foot-wall on the south side is gneiss, while the hanging-wall is composed of porphyritic granite. This is one of the few instances where the vein showed itself to be a true contact-vein between these two rocks. Some distance from the tunnel, probably 60 feet, the vein is suddenly cut off by a strip of gneiss running across it at right angles, but appears again on the other side without being deflected the least in its course. Galenite, with sphalerite, compose the main ore of this lode; the former occurring in a heavy body, coarse-grained, breaking into large cubes. Owing to the foot-wall, the vein wavers slightly, forming a sort of scalloped line. West of the tunnel, a dike of ash-gray porphyry, 6 feet in thickness, crosses the vein, but after working through it was found to continue in its regular course.

Of minerals, the following are found: galenite in fine cubo-octahedra, sphalerite, argentite, fahlerz, pyrargyrite, wire-silver, with the exception of the latter all occurring massive; the pyrargyrite and fahlerz intimately associated with the galenite; quartz and light-red feldspar, mostly decomposed, make up the gangue-rock.

One of the largest and best known lodes of the district is the Terrible, located about four miles west of Georgetown, on the south slope of Brown Mountain. It strikes north 82° east; an abnormal course, compared with the others. In speaking of the relation of these lodes to the formations surrounding them, it has been stated above that the porphyritic granite formed a steep bluff, running almost parallel with the local trend of the mountain. It is within this granitic bluff that the Terrible vein lies. A tunnel of about 340 feet has been driven at right angles to the lode from the south side, and on the north of it the rock has been examined for the distance of 60 feet. The entire tunnel, as well as the 60 feet beyond it, were found to be within the limits of the porphyritic granite. Keeping its course quite regularly, the ore-vein runs along within the heart of this immense granite dike, varying in thickness and local dip, without any well-defined walls to limit its extent. Numerous little slides have evidently occurred, occasioning the formation of slickensides and breaks in the granite, but no distinct wall could be observed. Clay selvages at some places border the ore-vein, but the rock on the outside may contain numerous spurs of that same vein. It is altogether one of the most interesting mines. I did not succeed in discovering any distinctly differing gangue-rock; it appeared throughout to be the porphyritic granite that filled the places between the single veins and spurs. At certain points, circumstances had favored decomposition, and the gangue, therefore, was soft enough to break with the fingers. Quartz and feldspar were its main constituents; but the black mica, characteristic to the surrounding granite, was just as plentiful as in the gangue itself, so that the conclusion presented itself that, although this gangue must be regarded as younger than the surrounding rock inasmuch as it is decomposed, its ingredients were formed contemporaneously with those of the granite. From 3 to 20 inches in the thickness the main vein varies, sending off shoots and spurs to either side; sometimes they return again, sometimes they pinch out. In several instances, a number of smaller veins were observed to run parallel to each other, continuing so for a considerable distance. This was the case at the extreme north and of one of the lower levels, and at this point our section of the lode was taken. (Plate VI.) Granite forms the gangue-rock, somewhat decomposed in the central portion, perfectly sound and hard outside, containing within it four distinct parallel veins, the largest one 5 inches thick. Toward the southeast the veins seem to become more irregular.

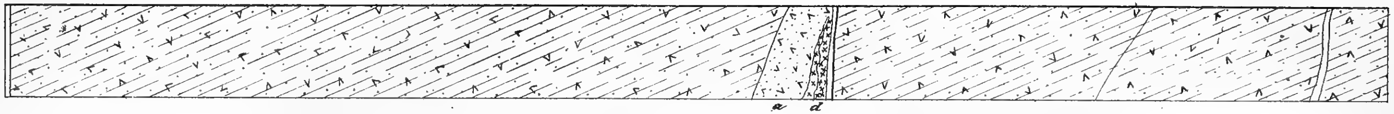
Galenite forms the greater portion of the ore; associated with it are sphalerite, pyrite, (rare,) argentite, fahlerz, and pyrargyrite.

A larger number of mineral species occur in this mine than in any other I have had occasion to visit in Colorado. Galenite is found in almost every variety; very pretty crystals (combination of cube with octahedron, the latter predominating) of it occurring in small cavities near the veins; sphalerite, pyrite, and chalcopyrite, massive; pyrargyrite, in minute crystals; argentite, stephanite, polybasite, in tabular crystals; stibnite, rare; silver in form of wire, and leaf-silver; fluorite, in light-green transparent cubes; baryte, orthoclase, oligoclase, caolinite, biotite, and quartz occurring between the single veins.

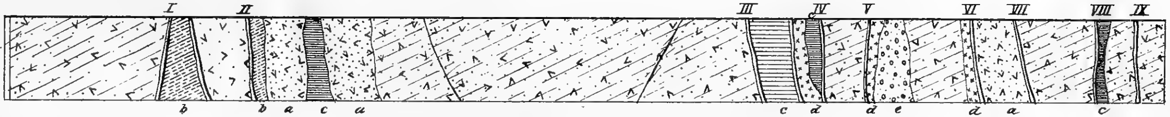
As stated above, a tunnel of 340 feet leads at a right angle to the vein; thence levels are driven on either side, and a shaft sunk. The mine is renowned for its rich ore, which, as I was informed, is sometimes regarded by strangers as a favorite souvenir of Georgetown. Besides the lodes spoken of, a very large number have been claimed, and are worked to some extent. Several of the larger ones were not in operation during my stay at Georgetown; others were in litigation, so that no data regarding them could be obtained.

The Payrock mine, situated on Republican Hill, northwest of Georgetown, I will now mention. Striking nearly due east, the vein pitches downward from the north at an angle of about 20° below the horizontal, and suddenly takes a turn of 45°, (Fig. 2,) so that its dip southward is only 25° instead of 70°. Porphyritic granite forms the foot-wall, gneiss the hanging, although at several points they seem to shade into each other.

About nine miles west of Georgetown, McClellan Mountain is located, immediately opposite Gray's and Torrey's Peaks. On the western slope of this mountain, the Baker and other mines are located; on the eastern, the International and Belmont. The International strikes about north 30° west, and is a contact-vein between gneiss on the north and granite on the south side. Its location, about 500 feet above timber-line, causes the ore to be frozen almost constantly; while, on the other



Burleigh Tunnel 1490 ft.



Marshall Tunnell 1147 ft.

hand, it has the benefit that provisions can be kept in the mine for months without deteriorating. Between walls that are well defined the vein is 5 to 6 feet wide, dipping from 12° to 20° to the north.

A considerable quantity of ore is taken out of this mine, and transported down the wagon-road by axle. It is mostly galenite, with sphalerite, some fahlerz, pyrargyrite, and native silver. From the east a tunnel has been driven in on the vein, about 140 feet in length, and there by overhand and underhand stoping ore is being taken out, while the driving of the tunnel continues. Parallel to this lode, and apparently similar to it, is the Belmont, situated a short distance to the north.

Besides these mining-operations, two great tunnel-enterprises have been undertaken, and are still being carried on. The one is the Marshal, the other the Burleigh tunnel, sections of which are given on the accompanying plate. (Plate VII.) The Marshal tunnel, pushed to its present state by the energy of General Marshal of Georgetown, is located on the southern slope of Mount Leavenworth, a short distance below the mines spoken of before. It is driven at a course of north 43° west, and has continued in a straight line. The proposition is to drive through Mount Leavenworth, strike all the lodes which it would cut at some angle, and thus let the tunnel serve to facilitate transportation of ores and regulation of waters. At the time I visited it, the work had progressed to a distance of 1,147 feet from the mouth, and a careful section was taken.

At 175 feet from the entrance, the first lode was struck, crossing the tunnel at an angle of about north 69° west. This is the Bulldog, or No. 1; contains a small amount of black blende, not sufficiently rich to yield any pay. Thirty-six feet of loose gangue-rock (*b*), quartz, and decomposed feldspar follow the narrow vein of ore, and a selvage of clay more than 2 feet in thickness separates this lode from the following gneiss. Arriving at 234 feet from the tunnel, lode No. 2 is reached, dipping off to the north, bordered on the north side by porphyritic granite (*a*), 20 feet in thickness. Following is a long stretch of granitic gneiss, with several slides dipping to the north, the rock being partly decomposed, partly sound. In several instances white mica occurs in this gneiss locally, but the black always predominates. Six hundred and ninety-five feet from the mouth of the tunnel, a lode was cut, supposed to be the Equator, and the strike approximately corresponded with that of the Equator. Two more veins follow at intervening distances of about 20 feet, edged on the north by granite of 25 feet thickness. Vein No. 5 then set in, followed by 8 feet of gray quartzite (*d*), and then by 22 feet of a light-gray compact porphyry (*e*), which strikes parallel to its course. After this 73 feet of the granitic gneiss follow, when vein No. 6 is cut, at a distance of 880 feet from the mouth of the tunnel. The north wall of this vein is formed by 46 feet of hard porphyritic granite (*a*), identical with that of other localities. From the end of this portion of granite to the present terminus of the tunnel at 1,147 feet, the rock remains granitic gneiss, with local accumulations of mica or quartz, changing the character somewhat. Two more veins were found, and 20 feet from the end of the tunnel a third occurs, striking across it. These nine lodes that are thus cut by the tunnel contain more or less blende, more rarely galena, and as far as could be ascertained neither fahlerz nor pyrargyrite, as the veins higher up on the mountains do.

Differing from this is the Burleigh tunnel, situated northwest of Georgetown, at the base of Sherman Mountain, about half a mile east of the Terrible. In June, 1873, it had reached a length of 1,490 feet, a considerable portion of which was driven by hand. The tunnel is wide, well graded, entering the mountain in the course of north 20° west. At a distance of 797 feet from the mouth of the tunnel, a dike of porphyritic granite occurs, 38 feet thick, (Plate VII, *a*,) striking at right angles to the course of the tunnel, with a southerly dip. Contact between this granite and the following gneiss is a vein striking parallel with the former, containing a body of blende 18 inches in thickness. From that point to the end of the tunnel, no further veins have been cut. About 450 feet from the end of the tunnel, a break occurs in the gneiss, parallel in dip to the porphyritic granite; a small vein of quartzite, 4 feet thick, is found about 320 feet farther toward the end. At the eastern end of Georgetown, the Eclipse tunnel has been driven in a southerly direction; it is claimed quite lately, with good success.

From the few words that have been said about the working of the Georgetown mines, it will have become evident that the plan of operations differs slightly here from that followed at Central. The silver-miners of this section usually drive a tunnel into the side of the mountain containing their lode, and, having reached it, sink a shaft. At the level of the tunnel, drifts are made, and the ore extracted by means of overhand stoping. Sometimes a shaft is sunk from the surface, connecting with the tunnel or one of the levels.

A number of works have been put up in Colorado to smelt the lead and silver ores from this and other regions, the greater portion of which are doing well. Eventually the concentration of ores will have a regenerating influence upon mining and smelting enterprise, if the flush produced at present by the extraction of large masses of rich ore should pass away.

PART III.

High up in the mountains of Boulder County, another district of silver-mines remains to be commented upon. Caribou is the mining camp, located in the center of a number of mines that have attracted considerable notice. Situated near the timber-line, with snow within three minutes' walk from the hotel-door in the latter part of June, the report of rich lodes has attracted several hundred miners to the spot. As my time was very much limited just then, I can only speak of the two main lodes which I visited, and must again refer to Mr. Marvine's report for notes on the geognostic formations.

Predominating is a granite, with accidental admixtures of hornblende, so that at certain localities it may be termed a syenitic granite, and it is therein the Caribou lode is located. The strike of this lode, that a short time ago was sold to a Netherlands company for $3,000,000, is almost due east and west, and it has a dip to the north that on an average is slight—in one or two points increasing however—never varying more than 20° from the vertical. Entering above, the dip to the north is found to be about 20°, continuing for 40 feet; then follow 70 feet almost vertical, and after that a northerly dip of 15° again. With increasing depth the vein grows wider, so that it is 14 feet thick between walls at the depth of 210 feet, while it is 4 feet at the surface. Both walls are beautifully defined, having an almost polished appearance. On the north wall, the granite seemed to be of a different variety, but it could not be decided with certainty in the mine. A thin clay selvage separates the vein from either wall. In the distribution of the ore, a symmetrical arrangement may be observed, ore being found near either wall, and again in the center. It consists mostly of galenite, sphalerite, argentite, pyrargyrite, and native silver; quartz mainly forms the gangue-rock, small amounts of feldspar also occurring. One of the western levels shows a very curious dike of granulite of 12 feet thickness, running across the vein at a right angle, without occasioning any disturbance or dislocation, however. The Caribou is intersected by the No Name on the east, and the Seven-Thirty on the west side, at an angle of about 30°. In both these interesting lodes, the ore is of a similar character, and they show no dislocations.

Of minerals the following were found: galenite, sphalerite, argentite, in small crystals and massive; fahlerz, massive; pyrargyrite; native silver, in wire form and leaf form; chalcopyrite, cerussite, and malachites; the latter two as the result of decomposition.

Two shafts are sunk on the lode, connected underground by levels and drifts, and at present a tunnel 700 feet in length is being driven in from the north to strike the vein. This will greatly facilitate the extraction of ore. Thus far the greatest depth reached in the mine was 370 feet.

The No Name lode, striking north 20° east, intersects the Caribou east of the shafts, showing a considerable dip to the north. Walls are well-defined, granitic, and the thickness of the vein between them from 3 to 6 feet. Galenite and sphalerite, with argentite and fahlerz, constitute the main body of ore. Besides these minerals, chalcopyrite, wire-silver, cerussite, azurite, and malachite are found. At the time of my visit, a depth of 117 feet had been reached.

A large number of other lodes, highly spoken of, were being claimed and opened at the time, but the expected opportunity of visiting the place in October again did not afford itself, and no information regarding them has reached me.

PART IV.

Annexed is a report of Dr. A. C. Peale upon the mines which he visited during the summer of 1873, and he has kindly permitted his notes upon them to be placed in connection with the above report.

MINES NOTED BY THE SOUTH-PARK DIVISION OF UNITED STATES GEOLOGICAL SURVEY, 1873.

BY A. C. PEALE.

TARRYALL CREEK.

There has been considerable mining done along Tarryall Creek, but at present little work is in progress. One great disadvantage is the scarcity of water. It is only during the spring and early summer that there is sufficient water for mining purposes. Above Hamilton the gravel rests on sandstones for the most part, and is from 10 to 20 feet thick. The following are two of the principal claims:

Tarryall, Hubbard, and Snafferd.—They have two flumes, the average yield being from $5 to $6 per day. There are four men working, at from $2.50 to $3 per day.

Little French, or upper claim, has two men working on it.

Near Hamilton there are two claims, worked by Hawkshurst & Foote. There are five men working, at $2.58 and board per day. The average yield is about $100 per week. While I was there they cleaned up $75 for five days' work. In 1860–'65 there was in Hamilton a population of about 5,000 inhabitants; to-day there are not more than about half a dozen families.

SILVER HEELS MOUNTAIN.

The following are some of the lodes that have been opened on the mountain:

Uncle Sam lode.—The crevice is 8 feet in width and dips to the northwest. It was discovered in 1868 by Sargent & Greene, who are still its owners. But little work has been done. The gold and silver are found associated with pyrites in a quartz-gangue. The walls of the lode are gneissic. The ore is said to assay from $10 to $45 to the ton.

Black Eagle lode.—Four-foot crevice discovered by Hawkshurst & Foote in 1867, who still hold it. Associated with gold and silver, magnetic iron and pyrite are found. It is said to assay from $100 to $600 to the ton. The lode is in gneiss, and dips to the southeast. Other lodes are the Black Warrior, Republic, Slater, and Mineral lode. Very few, if any, are worked. In the Republic, the ore is galena. The general angle of dip of all these lodes is about 30°.

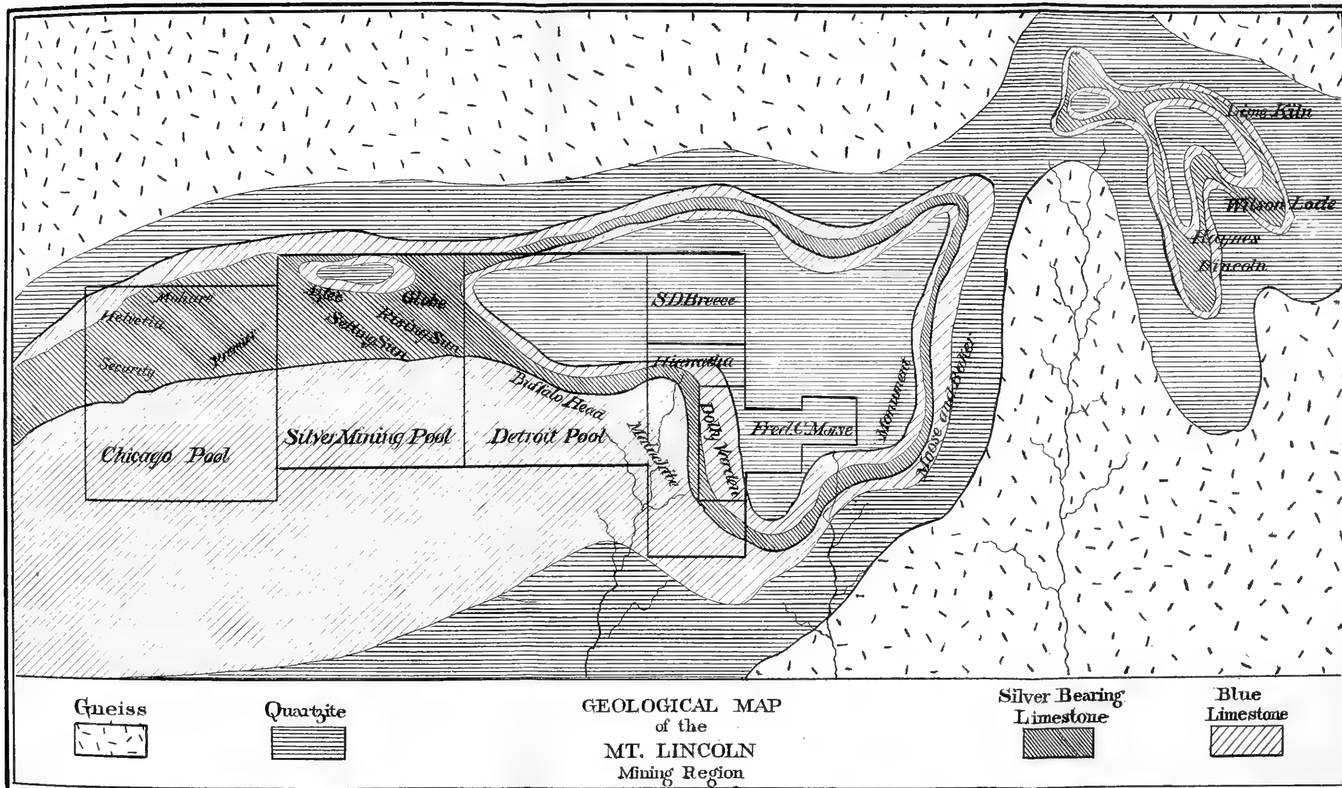
FAIR PLAY, COLORADO.

Further notes in regard to the mines in the vicinity of Fair Play than are given below will be found in Dr. Hayden's report. Placer-mining was formerly carried on very extensively on the South Platte River, and on all the streams tributary to it rising in the range that lies between South Park and the Arkansas River. In almost all the gulches we may find the ruins of what were once active and thriving towns. There is still some mining going on on the Platte. The gravel on the river opposite Fair Play is about 70 to 100 feet in thickness. There are several claims being profitably worked here. The principal mining interest, however, centers in the silver-bearing limestones of Mount Bross, Mount Lincoln, and Horseshoe Mountain. The following section of Mount Bross was made by Mr. Stevens, of Fair Play, and shows the geological position of the argentiferous belt. The section corresponds with the illustration shown in Plate XV, (map).

1.	Gneiss.	
2.	Yellow quartzite and sandstone, about	400 feet.
3.	Blue limestone	350 feet.
4.	Light-colored limestone, 100 feet	
5.	Blue limestone	
6.	Quartzite	10 to 20 feet.
7.		100 feet.
8.	Black quartzite slates	75 feet.
9.	Sandstone	
10.		200 feet.
11.	Limestone	20 to 30 feet.
12.	Sandstone	150 feet.
13.		500 to 600 feet.


Lime Kiln
Wilson Lode
Haynes
Lincoln
-er Bearing
-imestone
Blue
Limestone

PLATE. XV.


Lime Kiln
Wilson Lode
Haynes
Lincoln
Mohave
Helvetia
Premier
Security
Aztec
Globe
Setting Sun
Rising Sun
S.D.Breece
Hiawatha
Buffalo Head
Malachite
Dolly Varden
Fred.C.Morse
Monument
Moose and Baker
Chicago Pool
Silver Mining Pool
Detroit Pool
Gneiss
Quartzite
Silver Bearing Limestone
Blue Limestone
GEOLOGICAL MAP
of the
MT. LINCOLN
Mining Region

This last bed reaches to the summit of the mountain. It is in bed No. 2, which is probably the equivalent of the Potsdam sandstone, that all the gold, or most of it, in the region has been found, especially in the lower part, where there are dikes of volcanic rock. The gold-mines of Mosquito and Buckskin Gulches are found here. All the sandstone contains gold, but not in sufficient quantity to make it profitable to mine. It is in bed No. 4 that the silver-bearing galena is found. This limestone is lighter-colored than that on either side. It is probably a part of the Quebec group. The ore occurs in segregations and impregnations, and, as far as has been ascertained, is confined to the belt of limestone represented by bed No. 4 in the section given above. The accompanying map or diagram was made by Mr. Stevens, who has kindly allowed me to use it. It is not drawn on an absolutely accurate scale, but will give a good idea of the various claims on Mounts Lincoln and Bross. The principal ones are the Moose, the Baker, and the Hiawatha. The ore, as has already been intimated, is galena, which, according to the assays of Mr. Peters, carries from $3 to $200 in silver and as high as $120 in gold, the coarser-grained galena always being the richer. The gangue of all the mines in the limestone is barytic, both in massive and crystallized form. The mines at Horseshoe Mountain are similar to those of Mount Lincoln and Mount Bross. They occur in the same belt of limestone, and their mode of occurrence is the same. The ore is taken to smelting-works at Alma and Dudleyville, near the base of Mount Lincoln.

ORO CITY.

Oro City is at the head of California Gulch, a branch of the Arkansas River heading in the Park range. California Gulch has been the seat of extensive placer-mines. At present, however, very little is done. There are three or four claims being worked near Oro. The principal mining, however, is done at the Printer-Boy lode. The following notes were obtained from Mr. C. L. Hill, superintendent. The mine, of which a diagram is shown in the illustration, is owned by the Philadelphia and Boston Gold and Silver Mining Company, (J. Marshall Paul, of Colorado, and H. M. Paul, of Philadelphia.) The discovery was made in 1868, but no work was done until 1869. It was first worked by a company in 1870. As shown in the diagram, there are two shafts, a main one, 275 feet in depth, and a boundary one, 145 feet deep. These shafts are 367 feet apart, and between are two levels. Above the upper one there is a third level. From November, 1872, to the latter part of September, 1873, $75,000 was taken out; the average yield per week being 100 ounces. In September twenty-six men were employed, at $3.50 per day. The company owns a mill near the mine. The expenses of mining and milling per week are $800. Besides the Printer-Boy, there are the American Flag and several other lodes at the head of California Gulch.

HOMESTAKE LODE, ETC.

The Homestake lode is situated at the head of a small western branch of the Arkansas River, west of Tennessee Pass. The district is called the Homestake district. There is a small settlement, to which the name of Lake City has been given. It is just at the timber-line, which here is about 11,500 feet. Besides the Homestake, which gives its name to the district, there were at the time I visited the place some forty claims, very few, however, of any importance as yet.

This lode was discovered in July, 1871, by W. A. Crawford and two other men, while trying to find a trail across the range. It was first worked in September, 1872, by Archer & McFadden, the present owners. The lode strikes south 65° west; dip, north 25° west; angle, 75° to 85°. Two levels were commenced in the fall of 1872. The east level, in September, 1873, had penetrated 150 feet. It is 5½ feet high, 4 feet wide at the bottom, and 3½ feet at the top. It is propped with timber, being but 30 feet below the surface. The lode is from 2 to 3 feet in thickness, and is in gneissic rock. The west level had been carried in 150 feet, and the average width of the lode here was 2 feet. This level penetrates the solid rock some distance below the surface, and propping is rendered unnecessary. Below these levels, two tunnels have been started to strike the lode. One is 100 feet below, and the other 300 feet. Assays made by M. M. Hayes, assayer, for the Homestake district, vary from $100 to $800 to the ton. One picked specimen assayed 738 ounces to the ton. The ore is principally argentiferous galena in a gangue of baryte and calcite. There is also a trace of gold. The complete list of minerals found here will be seen in the catalogue of minerals. In September there were nine men employed, at $3.50 per day. From Mr. J. A. McFadden, one of the owners of the mine, I learned that the expenses from May to September, inclusive, had been something over $3,000. This included building of cabins, supplies, &c. The mine having been just opened, of course the expenses were heavier than they would be afterward. Up to September, 30 tons of ore—about half the quantity taken out—had been shipped to Denver.

ARKANSAS VALLEY.

On the Arkansas River, in the vicinity of Granite, there are quite a number of placer-diggings, and also in Colorado Gulch, one of the western branches of the Arkansas. During the season of 1873, there were two or three claims worked in the latter place, yielding about $5 per day to each man. This gulch, in 1863, was one of the richest in the Territory, yielding $75 per day to the man.

ELK MOUNTAIN DISTRICT.

This is a new district in the Elk Mountains at the head of Rock Creek, and little has been done beyond the locating of claims. There are about thirty claims situated on the south side of Rock Creek. The discovery was made in 1871 by Messrs. Brennan, Brant, Graham, and others, but nothing was done until 1872. The lodes are all in the beds of Cretaceous age—black metamorphosed slates, containing quantities of *Inocerami*.

The following are the principal lodes:

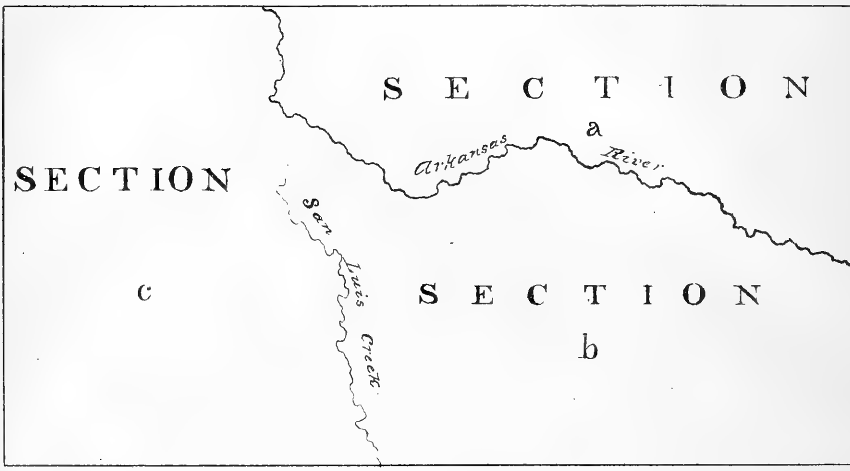
Buckeye.—This lode was discovered July 29, 1873. It is from 5 feet to 6 feet in width, and dips 12° south 35° east. It is well defined for at least 1,000 feet. The one is principally argentiferous galena, associated with pyrite, cerussite, chalcopyrite, malachite, and a little hematite in a quartz gangue. Blow-pipe analyses, made by Mr. Kirker, yielded 75 to 100 ounces of silver per ton.

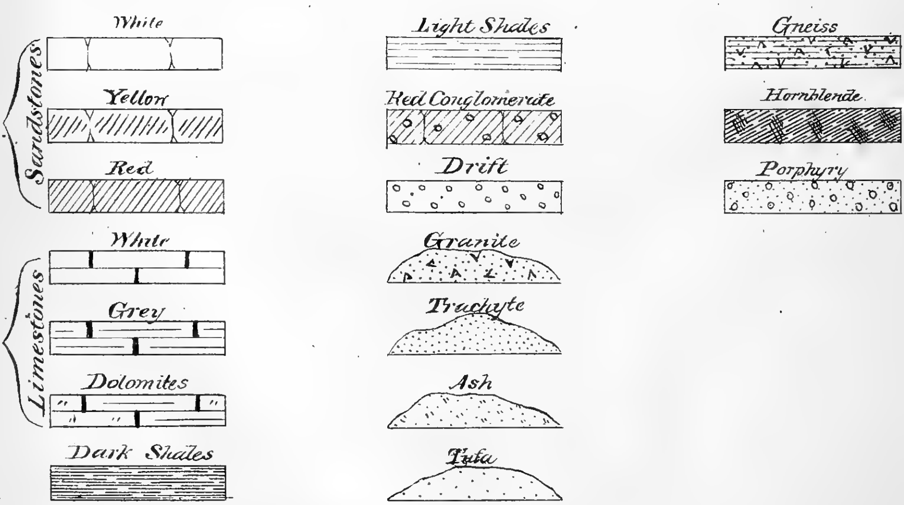
D. P. lode.—This was discovered July 29, 1873. It is 4 feet in width, and its direction is southeast and northwest. Ore and gangue as in the Buckeye.

Fair Play.—The discovery was made July 20, 1872. Its width is about 6 inches. The ore is similar to that in the other mines, and is contained in a gangue of quartz associated with calcite.

Liverpool.—This lode was discovered August 1, 1872. It is 2 feet

Sheet showing the division of the District as used in the Report and also the conventional signs used in the Geological Sections.





wide, and its direction north 55° east. In all other points it resembles the other lodes.

Rover State.—Discovered July 24, 1873. Its width is about 2 feet and strike north 65° west. Connecting this lode with the Pacific, there is a smaller one, 6 inches wide, called the Sidney.

Pacific.—This lode was discovered in July, 1872. The strike is east of south. It has seams of different widths. The ore has assayed by blow-pipe about $10 per ton.

Helena. This lode was located in July, 1872, and is from 6 to 8 inches in width ,striking north-northeast and southwest.

Cape Horn.—This lode is from 10 to 15 feet in width, and has been tracedm ore than 1,000 feet. It strikes north 65° west, and dips east of north at an angle of about 75°. The ore is said to assay 150 ounces per ton. Connecting the Cape Horn with the Anna is the Erie, about 6 inches in width.

Anna and Washington.—The Washington lode is a continuation of the Anna, the extent of both being 3,000 feet. The discovery was made July 25, 1873. The strike is north 55° west, and the dip southwest. It is in a very black shale, and between it and the Cape Horn there is a bed of quartzite. The width is about 5 feet, which increases in places. The ore is of the same character as in the other lodes. Mr. Kirker, one of the company owning the claims, assures me that as far as he has traced the lodes, they seem to converge toward the Anna and Washington. He says also that west of these there is another set, of which the following are the principal ones: Montreal, 15 feet in width; Bear Hole; New Chicago, 3 feet wide; Deep Hole, 1 foot 6 inches; St. Louis; Wisconsin; Superior; Tempest; Lily; Hoosier; Lookout; Cashier and Silver Wing. These, he says, seem to converge toward the Montreal, as those in the other group do toward the Anna and Washington. All the lodes are owned by the Rough and Ready Company, composed of the following members: R. A. Kirker, William Gant, Samuel McMillen, Benjamin Graham, Louis Brant, James Brennand, and C. M. Defabauch.

CHAPTER II.

REPORT UPON THE GEOLOGY OF THE SAN LUIS DISTRICT.

Section a—The district assigned to the San Luis division for topographical and geological survey for the summer of 1873 is bordered on the north by a line running east to west six miles south of Pike's Peak, on the west by the one hundred and seventh meridian, on the south by a line running east to west twelve miles south of Saguache, and on the east by the eastern slope of the Front range.

It can be appropriately divided into three sections, as shown by the accompanying diagram. Section *a*, comprising the northeast portion of it, separated on the west, southwest, and south from the others by the Arkansas River. Section *b* contains the southeast portion of the district, terminating westward with the western border of San Luis Valley, and from there northward with the well-known Poncho Pass. On the north it is bounded by the Arkansas. Section *c* represents the remainder, the western part of the district.

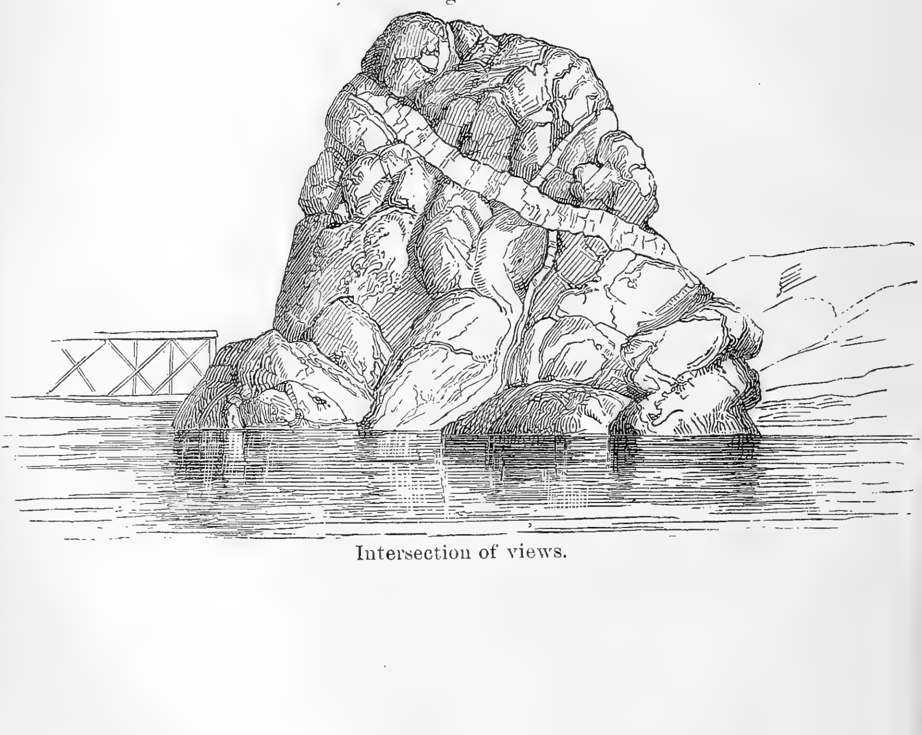
Along the eastern portion of section *a* we notice the heavy masses of mountains, cut by deep cañons and gorges, showing that characteristic appearance that is imparted to any landscape by the predominance of archæan formations. Westward from the edge of the great plains the mountains rise abruptly, particularly so in the vicinity of Pike's Peak, the summit of which is more than 8,000 feet above the valley. In the pure atmosphere of that region, the deception in distance allows the traveler to be even more strongly impressed with the grandeur of the scenery that has given the "Pike's Peak country" so much of its justly-deserved celebrity. Along the eastern border of these mountains, where they gradually taper off into the plains, stretched for many miles before them, the sedimentary beds reclining against the granitic mountains have at times been greatly disturbed, and now form at several points very grotesque groups along their base.

Going westward from the border of this Front range, more into the interior of the mountains, unmistakable cones appear, denoting former volcanic activity, changing with their introduction the general aspect of the country. Instead of densely-wooded hills, covered either by living or dead timber, areas of grazing-lands are frequently found, frequently also marshes. In many cases the prominent cone-shaped peaks, the probable points of volcanic outflow, present a more desolate appearance, being covered with innumerable fragments of rock, rarely large, but sufficiently so to prevent any extensive growth of vegetation. A variation from this general character of the country occurs along Oil Creek, where a comparatively low tract of country extends northward for the distance of about twelve miles, with a width varying from two to four miles. To the west of this little valley the granitic rocks are no longer the predominating, for the volcanic increase so largely in bulk and extent as to change the face of the country. High, grassy plateaus appear, differing in vegetation to such an extent from the older rocks that may be outcropping that this difference alone may frequently furnish useful hints to the geologist regarding the distribution of the formation. Quite frequently the creeks have worn deep, rugged ravines, although it would undoubtedly be erroneous to attribute all the cañons and gorges to erosion exclusively. Farther toward the northwest, the character of the country again changes; it becomes more rolling, supplied with frequent cones; the valleys are broader, less deep.

In the western portion of section *a*, the mountains are no longer so high, and their slopes are more gradual on the northern side, although often quite rugged on the opposite; the influence of comparatively little disturbed sedimentary formations is perceptible. Bordering upon the Arkansas, the hills of this western portion are less massive—less so than those farther east—owing to the lower relative and absolute altitude and consequently smaller depth of the cañons.

Granite forms the heaviest masses of section *a*, although not covering the greatest area. On the western part of the section it occurs as the main rock, presenting a dark-red or brown color, showing but little variation in the character of its texture and structure, and usually weathering in heavy bowlders; it frequently forms bold and prominent faces on the mountains. Toward stations 89, 90, and 91, it is mostly covered by the overflowing trachorheites, outcropping only in the deeper cañons and gorges that are in a great part due to erosion. Owing to its coarse texture, it readily decomposes, but, dependent upon the more or less accidental percentage of its constituting minerals, does not decompose uniformly throughout. At station 95, the granite becomes very coarse-grained, so much so as to show a perfect separation of the three minerals, feldspar, quartz, and mica; only the latter, however, follows its inclination to crystallize. At this locality, the feldspar (orthoclase) is of

Fig. 6.



Intersection of views.

a bright-red color; the quartz, yellowish or white; the mica, gray to brown. Another point where the granite assumes a similar character is immediately west of Cañon City, which may perhaps partially account for the deepening of the steep cañon from which that city has derived its name. This cañon forms the bed of the Arkansas River for a distance of about six miles. Station 11 is located directly north of this cañon, in an air-line about three-quarters of a mile distant, and about 2,000 feet above the river-bed. Allowing all due consideration for the immense effect produced by erosion, it still seems improbable that the Arkansas should have forced its way through almost six miles of solid granite, when a slight deviation to the northeast would have afforded it a by far easier passage, unless some existing favorable condition induced this course. It seems reasonable, and warranted by the facts observed, to suppose that, by some agency or other, possibly by the gradual rising of the granitic area and consequent cracking or splitting of strongly-tensioned portions of it, some facility may have been afforded to the river in shaping its course. This view may receive some support in the fact that the line pursued by the Arkansas through that section of granite is a comparatively straight one. The suggestion that the river may gradually have cut through during the continuation of the rise along the former coast cannot be entertained, because at the time before that took place the now Cretaceous portions must have been so low as to compel it to flow out over the area they at present occupy.

To the northwest of station 11 the granite is mostly covered by the trachorheites, and only exposed in depressed localities. Along the Arkansas, westward, toward station 10, it maintains its character, weathering in more or less angular masses. At the west side of the bridge built across the river, a short distance south of station 10, is stationed an isolated granitic sentinel, dark red or brown, with a very large percentage of feldspar, but little quartz, and still less mica. This monument-like rock shows a pretty illustration of the intersection of two veins; a narrow quartz-vein running up and down has been broken and displaced by a broader younger one, crossing it at an almost right angle. Speaking more correctly: the two halves inclosing the smaller vein have been displaced by the formation of a broad fissure, in which the material composing the younger vein was deposited. North of station 10 granite mainly crops out in the valleys, as in those of Currant, Cottonwood, and Tallahassee Creeks, the beds of which are mostly formed by it. Proceeding in this northerly direction, we find the lithological character of the granite undergoing some change; the feldspar more frequently shows yellow and flesh-colored tints instead of the red and brown; the quartz turns from brown and reddish to rose-colored and yellow, even gray and white; black mica begins to predominate over the white, gray, and brown. At the upper end of Cottonwood Creek, near station 68, the texture of the granite begins to resemble closely that of gneiss, and this change is carried out also in the appearance of weathering, although it characterizes no newly-entering formation, but merely an increase and accumulation of the micaceous constituents. North of this station the granite widens out, being exposed over larger areas as the trachorheites recede. West and southwest of station 10 it forms lower hills, considerably cut by the drainage. The western portion of section *a* bordering on the Arkansas is formed by granite again, appearing this time in a strip of about twenty-four miles in length and three to four miles in breadth. It is coarse-grained, and very similar, if not identical, with that of the eastern half of the section. Distributed throughout its southern half, although not occurring frequently, are small patches of fine-grained granite, distinct sometimes not only in their texture, but also in the character of their constituent minerals. A granite found near station 59 showed gray quartz, white feldspar, and black mica; was very fine-grained and compact. On Badger Creek, a short distance east of station 58, a small patch of porphyritic granite crops out that shows differences of texture within a very limited distance. It contains oligoclase, orthoclase in Carlsbad twins, gray quartz, black mica, and chlorite.

In the southern and western part of section *a* the granite is frequently traversed by dikes of hornblendic rock, resembling to some extent diorite. Although they will be spoken of under the title of "dikes" hereafter, they form a very characteristic feature of the granite, and as such must be mentioned here.

Distribution.—Immediately at the eastern slope of the Front range the granite begins, extends westward to station 91, and a few miles beyond stations 93 and 94, bordering the east side of Oil Creek Valley. At the northern boundary of this valley it sets in again, separating two large volcanic areas by a band of three to six miles in width. West of Oil Creek it is found in all the deeper cañons, while trachorheites cover the high plateaus. Along Currant Creek it is exposed in a strip from one and a half to two miles wide, increasing this width toward stations 71 and 72. The greater portion of Cottonwood Creek runs in granite; also a part of Tallahassee Creek. On the Arkansas, granite appears again about half a mile west of Canyon City, and continues westward to station 6, with a single interruption opposite station 10, where Cretaceous rocks form the bed of the river for a short distance. Small patches of it appear at stations 58′, 58, and 57. West of Badger Creek several such patches occur. The second extensive mass of it runs approximately parallel to the Arkansas, forming its eastern bank. From station 52 southward it continues until a point is reached within two miles of station 5, where the volcanic rocks cross the river.

Resting immediately upon the granite, we find the Silurian characterized by but a few fossils and the well-known quartzitic formations. From a distance these beds, situated in the western portion of section *a*, may easily be mistaken for the prevalent trachorheites, as they form steep, although not high, bluffs, rising abruptly from the granite, capping some of its highest points along a line of about 15 miles. Their quartzitic constitution allows them to resist atmospheric influences for a greater length of time than the under and overlying rocks, so that, taking all these points into account, they form a well-defined characteristic horizon. At times the rock partakes more of the character of a limestone, but in that case segregations of siliceous matter, mostly in the shape of chalcedony and hornstone, afford a welcome lithological feature of distinction. Wherever the Silurian formation occurs in section *a*, it conformably underlies the Devonian and Carboniferous as far as could be ascertained. Beginning in the northwest corner of this section, we find a narrow strip of strata belonging to the Silurian period, running from about one mile north of station 53, down in a southeasterly direction, until it reaches the Arkansas, forming by its course the approximate representation of a large S. At station 53, which is located on a dark-gray limestone, with hornstone segregations, ascribed to the Silurian, the strata dip at an angle of 9° to 12° almost due east, gradually lessening the degree of their dip as they extend eastward. A section running through station 53, at north 27° east, shows the following strata, which I have referred to the Silurian.

Resting immediately upon a coarse-grained red granite, we find a bluish quartzitic limestone, weathering, in heavy strata, very hard and compact, containing numerous crinoid remains, closely resembling the plates of *Heterocrinus*. Besides these, a few specimens of *Orthoceras* were found, but in too poor a state of preservation to admit of any specific identification. From these beds, (section A*a*,) the next strata, of hard gray limestone, are separated by a thin layer of dark-gray slaty shales, as it is underlying the limestone (*b*) that formed the top of the plateau upon which station 53 was located. The upper stratum of this limestone contains a number of corals and *Spongidæ*, and upon it follow thick beds of white, yellow, and pink quartzites (*c*) weathering into angular fragments, not at all conducive to the comfort of travelers. This pink color seems to be of some importance, as it recurs in several localities, and probably affords a good constant geognostic horizon. Its color is usually a delicate pink, sometimes stained with yellowish or reddish streaks and blotches. Higher up, the character of these quartzites changes; they turn into a light-red sandstone, much less compact in texture. With this sandstone I close the Silurian of that locality, as the lithological character of the strata changes radically, and a little higher up Carboniferous fossils are found.* It is obvious that no careful detail-studies of these formations could be made at the time, and therefore the paleontological part must necessarily appear meager.

Extending to the south for a distance of seven to eight miles, the Silurian retains very well the character above given. Again, we find all along that the quartzitic limestones rest directly on the granite, forming a sharp, very distinct boundary. But little change is noticeable in the dip of the strata, both as regards direction and angle of dip, which at places rises to 15° to 16°, rarely falling below 10°, however. Station 55 was located on the same strata as station 53, and a comparison of their features and succession leads to the same result as before. About one mile south of station 55, the Silurian, and with it all the sedimentary beds, suddenly change their course, making an angle of about 90° to the eastward, instead of following their main course in a southerly direction. With this turn the dip changes, swinging around more to the north, so that we find it a little north of east. Probably the cause of its having been changed may be looked for in the eruption of trachorheites directly south of the deflected line. The edge of the Silurian, which has narrowed down considerably, is at some places most likely in contact with the trachorheites, although I did not succeed in finding any point where this was distinctly shown. Going eastward, as we approach Badger Creek, we find a patch of coarse-grained granite appearing, which, as usual, directly underlies the Silurian on the west side, while on the opposite it underlies the volcanic rocks. A section carefully taken from station 56, in the direction south 45° west, running for a distance of ten miles, until it reaches the volcanic strata south of the sedimentary, may serve to illustrate the formations here.†

Proceeding from the southwest, we find the granite partly coarse-grained, partly fine. It is the same patch referred to in discussing the granite of section *a* as porphyritic granite. A series of yellow to light-brown, hard quartzites are deposited upon it, weathering in tabular fragments. At first these quartzites (Plate IX *b*) show a steep dip to the northeast of 35°, but it decreases with increasing distance from the granite. Above these strata we find white and pink quartzites of very

* The remainder of the section given will be treated of when speaking of the Carboniferous formation.

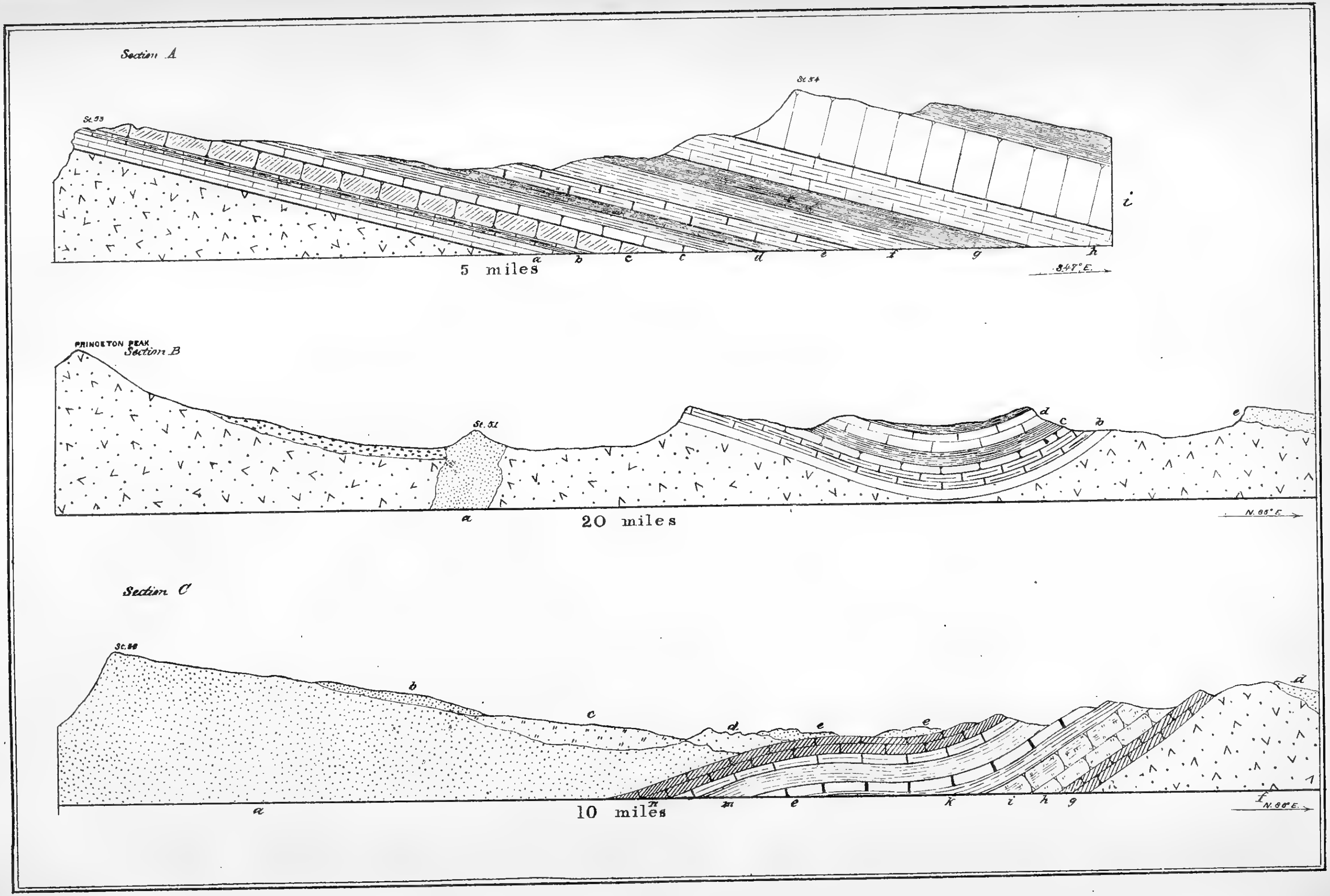
† For convenience only that part containing the sedimentary beds has been taken out. The entire section will be given when speaking of the volcanic rocks.

fine texture, which are in turn covered by yellowish shales (*f*) that can be referred to the Carboniferous, as in section A, Plate VIII, preceding. It seems probable that the Lower Silurian blue limestones underlie these quartzites, although they were not found.

Scarcely a mile east of this part of Badger Creek, a little north of station 58′, the Silurian makes a second turn; this time from west to east toward north to south, again running parallel to the first line of outcropping mentioned above, thus completing the S-shaped figure. Station 58′ is located on the quartzitic strata. A few miles south of this station the limestones appear, and remain either entirely or partially exposed during the remainder of the line followed by this formation in section *a*. The dip is not steep; never much exceeding 15° to 18°, and is a little north of east. Three or four miles south of station 58′ the band of sedimentary rocks becomes very narrow. A third turn is taken east of station 57′ of about 28° to the west, from which point the Silurian runs down to the Arkansas, bordering the east side of the trachorheites. It is exposed on the Arkansas for a short distance. On the south side of the river this formation appears again, but no direct connection between the two sections can be traced.

Only about eighteen square miles are covered by the Silurian, because its breadth is very inconsiderable, although the meandering-line running from station 53 to the Arkansas is almost thirty-two miles in length. Orographically, the Silurian is of slight importance in the formation of plateaus of small extent, sloping off gently to the north, northeast, and east. Farther north, beyond the limits of our district, this formation is found occurring in much greater bulk, and it seems that southward the conditions for its formation in Silurian ages may not have been at all favorable. Whether any of the strata above the ones just spoken of should be referred to the Devonian, I am unable to say. The poorly-preserved relics of paleontological testimony that could be obtained were so few and so unsatisfactory that I can have no decided opinion upon the subject, although I am inclined to think the Devonian, if represented, is no formation of great extent, either vertically or horizontally.

The Carboniferous formation of section *a* shows some very interesting features. In the eastern portion of the section no rocks were observed that could be referred to this age; it was found only in the western, in connection with the Silurian just spoken of. From station 53, a belt of it stretches along a little east of south, from three to four miles wide, bordered on the east by the familiar coarse-grained red granite, on the west by the Silurian. Northwest of station 54 it forms a small synclinal valley, dipping from either border toward the center at an angle of 7° to 9°. Adapting its course to that of the underlying Silurian, it makes the sharp bend below station 55, and then, running in an easterly direction, gradually pinches out until it becomes very narrow. Owing to the overflows of trachorheites, only small patches of it are exposed on that easterly line, large masses apparently being covered. Remaining in a conformable position to the underlying rocks, the Carboniferous follows the second bend north of station 58′, and thence continues southward in a very narrow strip for about six miles. At that point then the lower limestones are deflected a little to the west; the sandstones, farther north of no great dimensions, are enormously developed; and the upper limestones make their appearance. Of the latter, a spur branches off to the east and runs through a granitic country for a distance of about seven miles, dipping northeast to east, and then comes to an end without connecting again.


Section A
St. 53
St. 54
a b c c d e f g h
i
5 miles
S. 47° E.
PRINCETON PEAK
Section B
St. 51
a
d c b
e
20 miles
N. 85° E.
Section C
St. 58
a
b
c
d e e
n m e k i h g f
d
10 miles
N. 80° E.

The sandstones extend down to the Arkansas, form the bed of the river for some distance, and are again found on the other side. Proceeding to the consideration of the stratigraphical and lithological conditions observed in this formation, I refer to section A, Plate VIII. Reclining upon the reddish Silurian sandstone, and conformable with it, is a thick stratum of yellow and brown sandy shale (*d*) covered by light-yellow and gray shales. These two strata weather very regularly, forming a gentle slope, which is broken by the overlying limestone, (*e*,) giving occasion to the formation of a gradually-rising bluff. On exposure, this limestone weathers white, while its color on a fresh break is grayish blue. Quite near the top of the eminence formed by it, a few fossils were obtained, representing *Orthis*, *Productus*, and *Orthoceras*. Overlying the limestone, we find shales of a gray and brown color, (*f*, *g*,) which in turn are succeeded by other shales, more sandy, however. All of them weather quite dark, and produce a gently undulating surface, which is brought to a close by a series of heavy strata of dark-blue limestones, (*h*,) capped by brown sandstone, (*i*.) The latter is middle-grained, partly argillaceous, and contains small aggregations of magnetite crystals.

To show the position of the Carboniferous with reference to surrounding formations, a section may serve, running from station 46 in a course of east 6° north for a distance of about twenty-one miles. (Section B, Plate VIII.)

Station 46 is located on the west side of the Arkansas, on a mountain of probably Post-Silurian granite. Descending from that into the valley of the Arkansas, we find the base covered with drift. On the east bank of the river, a bluff of light-colored trachyte (*a*) rises abruptly, forming a small cone, the edges of which partially overflow the succeeding red granite, which forms low hills, until the steep Silurian ledge is reached. In detail of the Silurian I may refer to section A, Plate VIII. It has a dip of 16° to 12° eastward, underlying the Carboniferous strata. For the latter the character given in section A is applicable. Descending to an elevation of about 9,360 feet, (camp 46,) the trough of a shallow synclinal valley is reached, and from that point the strata begin to rise again toward the east, gradually at first, increasing, however, to a rise of 15°. The sandstone upon which station 54 was located does not extend far enough north to be cut by this section. It was impossible to determine whether the Silurian again outcrops at this eastern junction of Carboniferous with the granite, but it seems highly probable. Granite that is lithologically identical with that between stations 51 and 53 appears east of the edge of the termination of sedimentary beds. Trachorheites (*e*) form the last member of this section, having overflowed a large portion of the granite, and not unlikely also some of the sedimentary beds.

Nearing Badger Creek from the west, the Carboniferous narrows with the Silurian, while the sandstone of station 54 pinches out entirely. About five to six miles southwest of station 56 a very interesting and instructive point is found demonstrating the position taken by the volcanic rock to sedimentary. The section, a portion of which has been used in to illustrate the geognostic features of the Silurian, is taken so as to cut the points referred to. Overlying the yellowish shales, interstratified with quartzites, which have been referred to the Upper Silurian, are a series of blue limestones (*l*) irregularly alternating with gray shales containing *Orthis* and crinoids. Possibly these shales might be regarded as Devonian, but the absence of any typical fossils by which a correct classification could be made, allows them to be placed either in that position or as the oldest Carboniferous, which I prefer in this instance for stratigraphical reasons. Bluish shales (*m*) that have been eroded considerably follow, forming the bottom of a narrow valley, and are covered in turn by a gray saccharoidal limestone (*n*) rising steeply from them. A gentle dip, about 7° to 10°, pervades throughout, gradually lessening toward the northeast. Proceeding onward in that direction, the red sandstone, which has not appeared for four or five miles along the line of Carboniferous outcrop, is again found, forming bluffs of the classical "hog-back" shape. On the summits of these low bluffs innumerable fragments of yellow, red, and brown jasper were found, a circumstance which I have observed in several instances in the same formation, although many miles distant, thus affording probably a slight hint for the parallelization of strata. Following along the section-line, a small quantity of rhyolite is found to have overflowed this red sandstone, (*e.*) It appears again, however, probably owing to erosion, about three-quarters of a mile farther on, (*e.*) The rhyolitic bluff in question is about 80 to 100 feet high, weathering in grotesque forms. Andesitic tuffs and rhyolite again cover the sandstone, so that the line of junction can be traced for several hundred yards. A slight folding seems to take place at this second exposure of the sandstone, possibly owing its formation to the lateral pressure coming from north and northeast during the period of massive volcanic eruptions. To facilitate the ready comprehension, both of locality and distribution of the formation, a diagram has been prepared, the dotted line indicating the course of the section.

South of the points just under consideration, the Carboniferous again follows the Silurian in a very narrow strip, on its sudden turn, until it reaches a locality about five miles east of station 57′, where it suddenly widens out, covering a comparatively large area of land. Of the lower limestones, a portion follow along the Silurian, conformably overlying it, and are in turn covered by the red sandstone mentioned above. An immense development of vertical dimensions is attained by this sandstone, which covers an area of more than twenty-five square miles, and dips at an angle of 15° to 17° to the northeast. In respect to stratigraphical conditions as well as lithological character, its strata present a very uniform appearance. Taking the thickness of the combined strata, it amounts to more than 5,000 feet, while the development in section *b* seems to be still greater. To this sandstone, characteristic not only as an excellent geognostic horizon, I give the name of Arkansas sandstone, from its proximity to that river. Running parallel with the main direction of the formation just spoken of, is a spur of Carboniferous limestones, west of stations 60 and 61, separated from the remainder by a strip of granite. A well-marked line of sharp bluffs, the strata of which dip steeply to the eastward, faces the western border of this spur. *Favosites* and a few other fossils that were found afford no reliable clew to their position, but for stratigraphical reasons it must be considered as properly belonging above the Arkansas sandstone. Gray and bluish limestones compose the entire mass.

As a rule, the Carboniferous beds form a continuation of the grassy or wooded slopes initiated by the Silurian; and having suffered but little, scarcely at all, from disturbances of various kinds, usually present gentle outlines, varied, however, by the more sterile sandstone areas. Possessing a dark-red color and singular uniformity in features, the latter make a less pleasant impression than the timbered limestone hills inclosing well-waterd valleys.

Between the formation last spoken of and the next one following, a wide gap occurs in the adopted succession of geological epochs. Next in age to Carboniferous, progressing from old to younger, we find in section *a* a series of beds that I combine under the term Mesozoic.

It remains to be stated that in the subsequent pages this word is used to denote a formation, or a series of formations, younger than the Permian, older than the Cretaceous; so that its age will rank with that of the Triassic and Jurassic. Although strata that must be referred to this group cover a large extent of ground throughout Colorado, the paleontological evidence that has been furnished, by which its relative age might be determined, is very scant—too scant altogether to admit of any thorough or strict identification, and it is necessary therefore to assign to them the position indicated with some reserve.

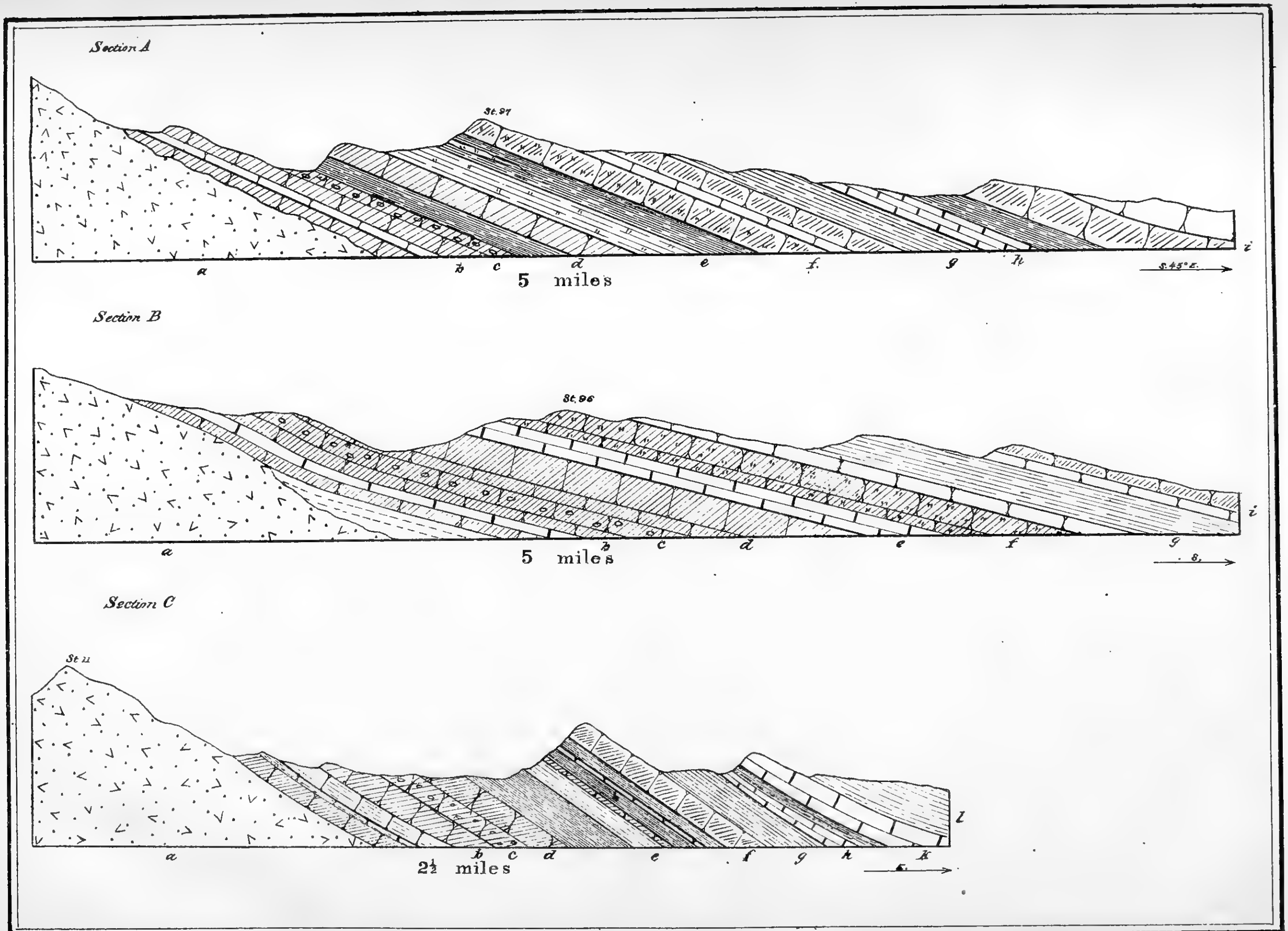
Interrupted at a number of places, this formation is found all along the eastern slope of the Front range in section *a*. Following up Oil Creek, we find that a bay existed there as late as the Cretaceous period, and the Mesozoic beds are exposed at a number of points. West of Canyon City the same beds are exposed, but do not extend into the Cretaceous bay that there runs parallel to the Arkansas River. The strata composing the lower portion of this series are usually termed the "red beds," and form more or less steep bluffs, standing out boldly from the underlying granite, and frequently weathering in grotesque groups. Although not so strikingly picturesque as the Garden of the Gods near Colorado City, farther south of that locality a number of small "gardens" may be seen that owe their singular scenery to the presence of these red beds.

Beginning at the north end of the Front range, as far as it is inclosed by the limits of section *a*, and traveling southward, the average thickness of these beds is found to undergo but comparatively slight changes. A series of sections comparing the succession of formations was taken along several points of the eastern border of the range. The first one runs through station 97, the second at station 96, the third a short distance west of Canyon City through station 11. All these have been taken at right angles to the local trend of the range, thus varying from east to south in direction. First examining the section through station 97, (Plate X, section A,) we find coarse-grained red sandstone resting immediately upon the granite, dipping at an angle of 18° to 20° to the southeast. Throughout the entire section, the angle of the dip decreases as the distance between the point of observation and the junction with the granite increases; therefore, no further mention will be made of it. The sandstone just mentioned is covered by a stratum of white, also coarse-grained, sandstone, which in turn underlies red. Upon this is deposited a stratum that presents a good, well-defined horizon throughout section *a*; it is the coarse-grained red conglomerate, (*c*,) varying somewhat in thickness. It may be observed that toward Canyon it gradually increases. Small bowlders are its component parts, usually well rounded, quartzitic in character, but not sufficiently well identified to assign them to any one of the observed formations as their original place of deposition. Argillaceous material cements them, and it can be said that from the character of the single fragments found it may be inferred that they formerly belonged to some stratum or strata deposited by mechanical action. A series of red shales (*d*) cover, this conglomerate, very sandy in places, so that they might almost be considered as highly argillaceous sandstones, easily yielding to atmospheric influences. Thick strata of red sandstone follow, overlaid by white and yellowish shales, (*e*,) partly dolomitic, interstratified with banks of limestone. Rising up from these beds in a characteristic bluff is a yellow sandstone, (*f*,) sometimes shading over into brown. Red sandstone overlies, and these two together probably form Cretaceous No. 1. White shales and limestones alternate, producing Cretaceous fossils, and after they have continued for some time, after the bluffs reach far into the prairie, another sandstone bluff makes its appearance, which may be regarded as the lowest, or one of the lowest members of the Tertiary, (*i*.) Throughout the red beds no fossils were found. Proceeding in a southwesterly direction, the section (B) taken through station 96 presents the following aspect:

Reclining against the granite of the Front range we find a red sandstone, dipping off to the southeast at an angle of about 22°, covered by thin stratum of bluish limestone and then white sandstone. Above these red sandstones occur again, underlying the red conglomerate (*c*) mentioned above, which bears the same character throughout. Red shaly sandstones are found above the conglomerate, becoming more compact as they go higher, (*d*.) Overlying these there are bluish and white shales, (*e*,) partly dolomitic, covered in turn by a brownish-red sandstone (*f*) that is mostly quartzitic. This sandstone forms the bluff upon which station 96 was located, and contains numerous remains of leaves. White sandstones, and higher up white marls, shales, and limestones, are found above it. Analogous to the preceding section, a new bluff is eventually formed by white and yellow sandstones, (*i*,) belonging perhaps to the Tertiary.

Through station 11, about a mile west of Canyon City, the third section is located, running almost due east. (Plate X, section C.) Granite again underlies the red sandstone, dipping at an angle of about 24° to the east. The succession of strata is almost identical with that given in the preceding sections; but the red conglomerate (*c*) occurs in greater thickness than heretofore noticed, and also the beds overlying it are more developed. Again, the high bluff is formed by a yellow to light-brown sandstone, (*f*,) overlying the upper Mesozoic shales, (*e*,) underlying the succeeding Cretaceous ( ). By giving these three sections in tabulated form the constancy in the succession of their strata will become more evident. In the subjoined table the strata are arranged without reference to their thickness, which, as a rule, increases slightly from section A to B and to C.

Section A, Plate X.	Section B, Plate X.	Section C, Plate X.
White sandstone.	Yellow sandstone.	Yellow and white sandstone.
White sandstone and marls.	White sandstone.	Brown and yellow shales.
Yellow and brown sandstone.		Lignite formation.
Yellow shales.	White and yellow shales, interstratified with limestones.	White, gray, and yellow limestone and shales.
White limestones and shales.	White sandstone.	White and gray limestone, with *Inoceramus*.
White limestone and marls.	Red quartzite.	White limestone.
Yellow marls and shales.	Reddish sandstone, with plants.	White shales.
Red quartzite.		Yellow sandstone.
Yellow sandstone, with plants.		


Section A
St. 97
a
b
c
d
e
f.
g
h
i
5 miles
S. 45° E.
Section B
St. 96
a
b
c
d
e
f
g
i
5 miles
S.
Section C
St. 11
a
b
c
d
e
f
g
h
k
l
2½ miles
E.

Yellow shales and limestones.	White and gray quartzitic sandstone.	Yellow shales.
White shales and marls, dolomitic.	White shales and dolomites.	White sandstone.
Red sandstones, partly shaly.	Red quartzitic sandstone.	Grayish and greenish shales.
Red shales, sandy.	Red sandstone.	Red and brown shales, sandy.
	White sandstone.	Red sandstone.
	Red sandstone, shaly.	
Red conglomerate.	Red conglomerate.	Red conglomerate.
Red sandstone.	Red sandstone.	Red sandstone.
White sandstone and shales.	Bluish shales and limestones.	Wihte sandstone.
		Red shales.
Red sandstone.	Red sandstone.	Red sandstone.
Granite.	Granite.	Granite.

Around the eastern and northeastern base of station 11 the red beds are found at almost every point varying to some extent in the angle of their dip; although, taken all in all, the disturbance producing the never-missing dip in the Mesozoic beds must have been quite a considerable one; but, strange as it may seem, it was certainly one that extended over a large area of country, for I have not noticed a single instance along about seventy miles of the eastern slope which came under my observation in which these beds were not conformable with those overlying them, and, as far as could be judged, also with those underlying. Undoubtedly, the action producing this effect must have been of a very simple and uniform character, although probably continued for some considerable length of time.

On the eastern border of Oil Creek Valley, the red beds are exposed only at a few isolated points; but along the western side, they form one almost continuous line, and it is there that the general rising of the heavier masses of land west of it seems to have been stronger. In connection with this formation, a number of investigations must be mentioned that have been made in Oil Creek Valley, from the nature of which this stream has received its name. In 1860, examinations were carried on at this locality with a view to finding oil, small quantities of which had been noticed floating on the creek.*

Several shafts were sunk, yielding more or less oil during the past ten years, a heavy quality of which seems to be existing in the higher Mesozoic strata. Apparently the shafts were started on Cretaceous ground, and were continued through a series of shales, sandstones, and limestones, with some yield of oil, until the red conglomerate was reached

* The information upon this subject I owe to the courtesy of A. Rockfeller, esq., of Canyon City, who kindly supplied me with the data, for which I wish to express my thanks.

at a depth of about 240 feet. No careful record was kept of the strata through which the drill passed, but it struck a "rotten red sandstone" above the conglomerate. That the hard bowlders contained in the conglomerate would be very injurious to the chisel can readily be imagined. In order to carry on boring-operations, a derrick of 64 feet in height was erected, and the chisel and drill used weighed, together with socket, &c., 2,500 pounds. At present the works are not in operation, owing to a temporary absence of the operators.

Judging from evidence obtained in Doctor Peale's district, as well as from a point in section *b*, it seems altogether probable that older formations underlie, frequently conformably, those we find upon the surface. As far as determinable, no red conglomerate crops out in Oil Creek Valley, although the evidence of its existence there, at a depth of 240 feet, is afforded by the results obtained, and this existence may furnish hints for inferences to be drawn at other localities, where similar circumstances occur. A section through Oil Creek Valley, running nearly north to south, (Plate XI,) will show the relations of the strata. Analogous to the Mesozoic sections previously given, the red shaly sandstone (*c*) is overlaid by whitish and greenish shales, (*e f*,) separated from those superincumbent by a thin stratum of brownish sandstone. Above this sandstone remains of saurians were found, fragments of bones, but too poorly preserved to admit of any identification. Whether they are *in situ* or not at that point I am unable to say. Overlying the Mesozoic, we find in this valley the Cretaceous, beginning, as usual, with a yellow to light brown sandstone. A number of box-shaped bluffs are formed by the upper shales and capped by this sandstone. Taking a section through one of them, situated a short distance north of station 88, we find the following succession, (Fig. 1, Plate XII:)

a. 60 feet red sandstone.
b. 40 feet white and greenish shales.
c. 8 feet brownish sandstone.
d. 35 feet white and yellow shales and marls.
e. 10 feet light-brown sandstone.
f. 25 feet white sandstone.
g. 40 feet light-brown and yellow sandstone, interstratified with dark-gray slaty shales.

Only a very small area is covered by the Mesozoic formation in section *a*, as it is exposed mainly along the eastern edge of the Front range, merely in a narrow, sometimes broken, line. With the exception of those occurrences along Oil Creek, in the mouth of the Cretaceous bay, west of Cañon, and at a point north of station 95, the remnant of some small bay, section *a* shows no strata removed from mountain-slope that might be referred to this group. Careful investigation, perhaps the discovery of some fossils in these beds, may lead to a recognition of their proper position in the adopted scale of geological ages; and until that is accomplished, it will be necessary to speak with reserve when parallelizing these formations with Triassic and Jurassic of other regions.

Continuing in a conformable series, we find the formation referred to the Triassic and Jurassic overlaid by the Cretaceous. The character of the Cretaceous formation in the western Territories has been so well established that it is comparatively easy to identify its various members and refer them to an adopted schedule. As seen in the sections of Plate —, a very distinct horizon is formed by a stratum of yellow or brownish sandstone, quartzitic at times, usually capping a row of bluffs. This sandstone contains numerous remains of plants in different stages of pres-

PLATE. XII.

Fig. 1.

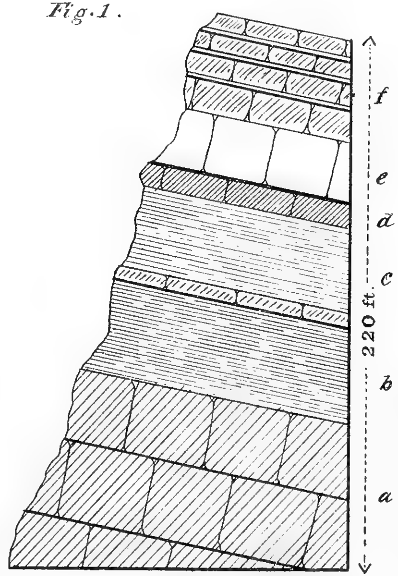


Fig. 2.

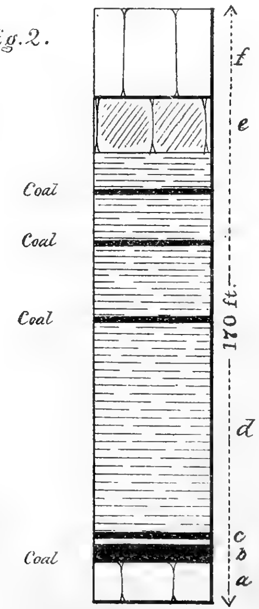
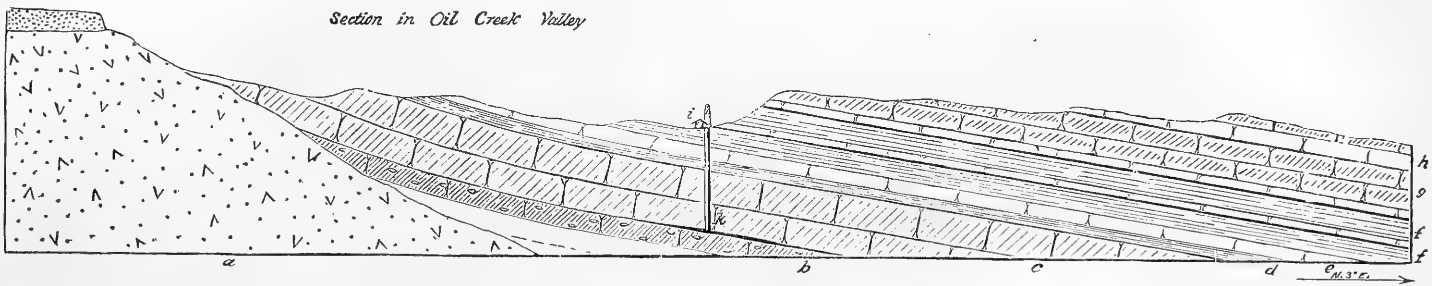


Fig.

Section in Oil Creek Valley



ervation, and forms the lowest stratum of the Cretaceous. It is Cretaceous No. 1. At Canyon City, the sequence of the strata can be well seen by ascending one of the bluffs north of the Soda Spring, and looking eastward.

Retaining the same curves that are followed by the underlying strata, the Cretaceous skirts the east and southeast slope of the mountains throughout section *a*, dipping more steeply near them, approaching the level toward the plains. At Oil Creek it forms a bay of about eleven miles in length and from two to six miles in width; another smaller one, of about three to four miles in length, is found a short distance west of Oil Creek. More gently rolling surface characterizes these bays with their low bluffs. West of station 11 another bay, about as long as the one up Oil Creek, occurs, but very narrow. Opposite station 10 this bay forms an oblong arm, crossing the Arkansas. Throughout the Cretaceous strata are conformable with those underlying, so far as could be determined. The beds show very little variety, and but few fossils were found in them, *Inoceramus* and *Ostrea* being among the most numerous. At Canyon City a spring rises in the Lower Cretaceous beds that attracts considerable attention on account of its agreeable taste and freshness, in consequence of a liberal supply of carbonic-acid gas. This spring is located about a third of a mile west of Canyon. A qualitative analysis is given by Mr. P. Fraser, (Report United States Geological Survey, 1869, p. 218,) showing the following constituents:

$NaO\ CO_2$
$MgO\ CO_2$
$CaO\ CO_2$
$Al_2\ O_3$
Fe, trace.
I, trace.

A comparison of the sections given on the Plate will show the uniformity existing in the Cretaceous strata sloping off from the Front range Above the yellow to brown sandstones follow series of white shales and limestones, forming a row of hog-backs north of Canyon City, filled with fragments of *Inoceramus*. Westward, beyond station 10, Cretaceous Nos. 2 and 3 appear, with *Ostrea complexa* in light-gray to yellowish shales. They have a gentle dip eastward, varying several times on account of small local changes in the *niveau* of the valley. A sandstone that may belong to No. 4 or 5—no fossils were found in it—overlies some of the limestones of that region. Apparently Cretaceous Nos. 2 and 3 rest immediately upon granite, and it seems doubtful whether any considerable thickness of older strata would be found below. On the south side of the Arkansas, No. 1 rests upon the granite, so that it is likely to extend northward far enough to underlie the succeeding strata.

Along the Front range it becomes a matter of interest to determine the end of the Cretaceous and the beginning of the Tertiary. It seems that the age of the Lignitic group following the Cretaceous can only be settled by very careful and accurate observations. It is possible that the coal-beds farther north and those of Colorado may not be the same geologically; and while the determination of their exact position is at present based upon paleontological evidence, it does not seem to confirm either their Cretaceous or Tertiary age. In section *a* we found no coal, although some of the bluffs showed dark shales resembling those farther south of Canyon, where the coal occurs.

Some distance from the mountains a number of bluffs occurs along the eastern slope of the Front range, among which probably the Eocene must be looked for, but our work did not take us near enough to make any satisfactory observations. No unconformability was noticed, although, if there was really one, it would be somewhat obscured by the very small angle at which the strata dip off into the plains.

This will close the discussion of the sedimentary formations of section *a*, and only the volcanic rocks and the "removed" material remains.

South of Pike's Peak, beginning within a short distance of it, we find a large isolated mass of volcanic material. Orographically, this portion of the country is characterized by a number of pointed conical peaks, the recognized type of volcanoes, although it is not to be understood that they are all cones formed by volcanic eruption. Their elevation is generally so high as to let them be commanding points, and several of them were for that reason selected as topographical stations. High plateaus, covered with grass and quaking asp, usually denote the extensive flows of lavoid material, and precipitous cliffs, mostly of dark color, frequently show curious freaks of weathering. This one mass seems to be perfectly isolated from all the rest at present, but probably at some former time a connection existed between it and the more westerly portions. Going westward, another area covered by it is found after crossing Oil Creek. The character is almost identical with that just described, only that the plateaus extend for longer distances. Currant Creek forms the western border of one portion and the eastern of another. Near station 56, the country becomes more rolling, more like high prairies, with isolated, prominent peaks of volcanic rock. From there, this material extends northward and spreads considerably. A fourth portion is located immediately northwest of the heavy mass of Arkansas sandstone spoken of above. Granitic outcrops occur in several points throughout that portion. To the south it crosses the Arkansas, forms a few low hills, and disappears. The western boundary is nearly parallel with the river-course, following that sharp bend made by the Arkansas about eight miles south of Centreville. Stations 51 and 52 are located on a little spur of a volcanic ridge. As a rule, the volcanic rocks of section *a* overlie granite, but in several instances they cover sedimentary beds. Erosion, perhaps not without the help of some other agent, has carried away portions of them in such a manner as to leave the beds of the largest creeks in granite. Interesting studies could be made by attempting to trace the direction and extent of every flow of these lavas, and to determine what percentage of them are volcanic eruptive, what are massive eruptive.

Upon entering into any description of the volcanic formations of any locality, it becomes necessary to define the basis upon which it is done. Discrimination in nomenclature of volcanic rocks has been sadly neglected, and a number of terms have been applied without any acceptable justification. Innumerable varieties, including texture and structure as well as mineral constituents, increase the difficulty of arriving at any definite conclusions, without a comprehensive knowledge of the entire western volcanic products, while, on the other hand, the great variety of specimens tends to mislead.

Richthofen, in his very able monograph On a Natural System of Volcanic Rocks,* refers the name trachyte to a definite order of rocks, comprising within that order two families. The limitation of this term that has previously been used indiscriminately for a number of trachoid rocks was undoubtedly a step toward that improvement which is so much

* Memoirs of the California Academy of Science, 1868, vol. i, part ii.

needed in petrography. Propylite, andesite, trachyte, and rhyolite are very closely related in lithological character as well as in the mode of occurrence, &c., and almost invariably are found in close proximity to each other. It seems impossible to trace, while in the field, the boundaries of each one of these orders, although propylite perhaps may be more readily separated than the rest, and I shall, therefore, speak in this report of trachorheites, which term comprises the four above-mentioned rocks. Propylite does not occur in our district, so the term will indicate only andesite, trachyte, and rhyolite, the definition of which is accepted as Richthofen gives it.

The patch of formations belonging to this group occurring immediately south of Pike's Peak presents as its most prominent feature lighter colors than ordinarily, varying in color from light red and gray to yellowish brown and bluish gray. Several very regularly-shaped cones indicate the points of outflow in this portion; Mount Pizgah being one of the most prominent among them. Layers of more or less thickness have overflowed the underlying granite, forming high plateaus, with quite frequently steep edges. Farther west we find a second large mass of trachorheites, upon which stations 69 and 70 are located. Andesite forms the main bulk of this portion, accompanied by a series of breccias and tuffs. Richthofen says, (*ibid.*, p. 25,) "Andesitic mountains are characterized by monotony in scenery. They form continuous ranges, which are often of considerable elevation and extent, but exhibit gentle outlines in their summits as well as in their slopes. Breccias only, which accompany the solid rock ordinarily in vast quantities, cause local interruptions of the monotony by their more rugged forms. They appear in castle-shaped rocks on the crests of andesitic mountains, and form high walls, naked and steep along their slopes." Long and narrow plateaus run out a considerable distance, falling off steeply on several sides, usually on those farthest distant from the point that supplied them with volcanic material.

Frequently a stratified structure is noticeable, giving the bluffs a very unique terrace-shaped form. It would be of importance to establish the mineralogical and chemical nature of these terraces relatively. At some points, strata of white ashy material, that probably did not reach its place of deposition in a liquid state, occur among the trachytes and rhyolites, and can be traced for a considerable distance. As far as could be determined, andesite forms the heaviest masses of hills and mountains, but immense quantities of tuff and breccia, the latter appearing sometimes as if it might have been redeposited by water, cover the greater part of the andesite, and allow it to outcrop only at comparatively few places. True trachytes are by no means wanting. Station 69 is located on sanidin-trachyte, having a maroon-colored cryptocrystalline paste, containing a large number of sanidite and oligoclase crystals, with here and there a crystal of bronze-colored mica and of a hornblende prism. The tuff frequently forms cliffs of 100 to 150 feet in height, thereby imparting a very characteristic appearance to the country. The trachorheites farther west scarcely vary in character. Andesite seems to be the oldest rock among them, and forms the bulk of almost all the higher peaks. Station 72 is located on a bluish-gray andesite, with microcrystalline paste, with small crystals of oligoclase and some of andesite. Narrow needles of hornblende are scattered throughout, and a small quantity of black mica is found. Upon being pulverized, magnetite can be extracted from the powder. Hot vesicular breccia, that has been covered again by a subsequent flow, and baked to a jaspery hardness, occurs throughout, changing sometimes with a fine-grained ash. One feature I will not omit here, as it is constant in the entire western part of section *a*. The long, stretched plateaus, having for a basis either andesite or tuff, are almost invariably crowned with a highly vesicular flow of the lava, showing andesitic composition. The color is dark, almost black; the paste very even in texture, only a few mineral segregations have taken place. In most cases, the vesicular cavities have an approximately oval shape; but some were found in which these cavities were elongated to the extent of over half an inch, probably owing to the fact that the material was moved, or moved on farther, after having partially hardened. The cavities are frequently filled with carbonates of lime. Oligoclase and sanidite are contained as small crystals in the paste. Hornblende and mica are rare. Magnetite occurs quite abundantly. It seems, from the position this material has, that it must belong to the andesite, and, therefore, I refer it to that order, supposing it to be the youngest member. Between the older andesite and the one in question a large mass of material is deposited—breccias, tuffs, and ash—this vesicular lava covering them all; but I did not observe a single instance where true trachyte was covered by it. Reference to the section may show the position of these formations. Station 56 is a prominent point, sloping off gently to the south, and having a steep slope on the northern side. It is composed of andesite of a dark color, whence its name, "Black" Mountain. The paste is fine-grained and dense, not vesicular; small crystals of oligoclase, sanidite, and brown mica occur throughout. Hornblende is rare; magnetite comparatively abundant. Although the color of the rock is dark-gray, the weathered surface is always reddish-brown. Proceeding toward the southwest, we find the vesicular andesitic lava overlying this andesite, but a cut which exposes about 120 feet vertically shows that the vesicular material also rests immediately upon a very thick bed, probably over 200 feet of volcanic ash. This ash is of a white, light-greenish, light-brown to pink color, very soft, so that it will crumble in the hand, or may be cut with a knife; it weathers in very picturesque groups, that are well set off by the variation of color. Farther down, along the slope, the tuff sets in, probably underlying in part the ash. Wherever this tuff outcrops, it forms grotesque groups of rocks of a light-grayish or yellowish color. After that the character changes; several small hills are formed by rhyolite along the base of the mountain, forming to a considerable distance small bluffs parallel to it, and partly overlying the tuff, partly the Carboniferous sandstone. It is at first red, of jaspery texture, with crystals of sanidite and oligoclase, also scattering particles of black mica. Free quartz can be noticed, but there is not much of it. On the second bluff, the rhyolite is white; the paste is not quite so compact as that of the red, but the minerals contained in it are identical. In some of the rhyolites and tuffs it may be noticed that the sanidite has a blue light, like the labradorite, with which it may be readily confounded. On the west side of the sedimentary formations, trachorheites are also found. In the main, they seem to consist in tuffs with an andesitic nucleus. True trachyte is not wanting in either the section east or that west of the Carboniferous and Silurian. Its appearance is more local, however, and it apparantly did not flow to such an extent as the rhyolites or tuffs. Station 68 is located on such trachyte. Isolated patches of granite are distributed throughout the trachorheitic area just mentioned; but the granite that appears is rarely the well-known coarse-grained red variety surrounding all these volcanic formations; it is always more or less metamorphosed. Stations 51 and 52 are located on a narrow strip of trachyte running down from the northeast. It is of white color, with sanidite, oligoclase, black mica, and isolated crystals of hornblende.

The trachorheites in section *a* have a main strike of about 10° north of east. They form numerous little volcanic islands, owing to the weathering of their own and the under-lying strata.

Besides the trachorheites, and perhaps one or two points of propylite, which are doubtful to me, however, I have not been able to observe any other volcanic rocks in section *a*. There remain to be discussed yet the dikes, drift, and ore-deposits.

A large number of dikes, running from north to south, traverse the granite of the section under consideration, varying in breadth from 2 to 100 feet. In most cases they present a dioritic composition, consisting mainly of feldspar and hornblende. The latter occurs either disseminated in fine grains throughout, or radiated or segregated in long, poorly-developed crystals, or, particularly toward the two outer sides of the dike, the hornblende assumes a schistose character. Mica is rarely wanting. Quartz occurs quite frequently, although not entering into the mineral composition sufficiently to change its character. Epidote almost invariably occurs in small light-green crystals, lining small fissures and cavities that may have formed. It seems probable, from the comparatively small extent of these dikes, that they owe their existence to infiltration and segregation in preference to injection, although in some cases the latter may be true. They will be found more frequently on the crests of mountains and hills than at any other part. Drift we have none in section *a*, except a few very small patches along the Arkansas River—merely a deposition of pebbles. No deposits of ores were found in this section.

Résumé of Section A.—As far as could be determined, little if any disturbance took place in section *a* before the closing of the Carboniferous period. The eruptive activity that upheaved the Sangre de Christo range in section *b* reached over into section *a*, occurring probably at a period shortly after the deposition of the Carboniferous formations. The Arkansas sandstone in the western part of the section, as well as the limestone under- and overlying it, owe their northeasterly dip to the action above mentioned. At the adopted end of the Cretaceous period the entire Front range began to rise very gradually, not rising equally in the entire mass, but faster along a line well marked by the present boundary of the granite. During that rise a sufficient amount of land was exposed to allow the formation of the lignitic group to go on at favorable points. This gradual elevation seems to have been accelerated at certain points a little more than at others, although it was comparatively very uniform. By this means the beds reposing on the granite were gradually raised; they may have been partly broken, so as to be carried away more readily by erosive action, but probably in no instance did they cover much more of the granite than at present. During the deposition of the older Tertiary beds this gradual rise seems to have been still going on, so that an unconformability that might be expected is more or less obliterated. The extent of the motion was not very far inland, but, as mentioned above, occurred along a line running parallel with the present boundary of the granite. Although anticipating, I will state a feature observed in section *b* that may serve to illustrate this view. From the Cretaceous bay that runs westward past station 11, a small arm of oblong shape extends southward, crossing the Arkansas. The dip all along the granite boundary in the bay is toward the east to northeast, very slight—only 3 or 4 degrees in the western end of the bay—but the southern arm, which is west of the line of rising, shows a dip to the west and southwest throughout of about 7 to 10 degrees, increasing toward station 11. No merely local cause could be found to explain this; and as all the evidence obtained points to the fact that the main mass of the mountains partook but slightly of the tendency exhibited by the portion nearer to the ancient coast, this fact may be considered as arguing in favor of the adopted view. In the western portion of section *a*, a gradual rise also took place, which gave the Silurian and Carboniferous their northerly and northeasterly dip. I feel inclined to ascribe this to the eruptive activity going on in the sections farther south, and shall have occasion to speak of it again in discussing the dynamical geology thereof.

Perhaps contemporaneously with, certainly not very long after, the elevation of the granitic masses, occurred the immense eruptions of trachorheites. In quantity, probably the tuffs and breccias exceed the other forms of volcanic rocks in section *a;* next are the andesites; then the trachytes; and rhyolite seems to be represented by the smallest quantity. The eruptions were mostly massive, not volcanic, although quite numerous cones and craters exist that have preserved their characteristic shape very well, and usually present commanding points. A large quantity of the ejected material must have been in a liquid state, while part of it may have been deposited analogous to the deposit of ash covering Herculaneum and Pompeii. After "ash" had been thus deposited, frequently subsequent flows of lava covered it, and produced a metamorphic state. The general aspect of the country at the time of these eruptions was probably a very monotonous one; comparatively, but small effects had been achieved by erosion, as is shown by the very extensive and numerous plateaus formed by the trachorheites. It seems quite likely that the disturbance caused by all these eruptions had a tendency to upheave the main mass of granite, which no doubt occurred; but it seems further that, in section *a*, the uplifting of the sedimentary beds of this Front range was not owing to any eruptive action, because in that case local variations from the more general features would be more frequent and more evident. I may here refer to Plate . Yet a word may be said regarding these sedimentary formations. All along the line of granite, the action was so uniform that almost throughout the same beds rest upon it apparently, with the exception of the two Cretaceous bays. From evidence obtained farther north by Dr. Peale, as well as from a local feature observed in the southern part of section *b*, it may be conclusively inferred that older formations underlie those that are exposed; that the Carboniferous and Silurian are not wanting, although they do not outcrop at even a single point throughout the entire Front range of section *a*. Wherever the rise of the granite has progressed sufficiently, the older formations can be and are found. Reversing the sentence, it will be seen that, wherever they have been identified, the mean relative altitude of the underlying granite is greater than the mean of other points.

The two Cretaceous bays were probably never invaded by Tertiary waters. When the increase of water occurred that we must accept for the Tertiary period of that section, they had already risen too high to be touched by it.

CHAPTER III.

GEOLOGY OF SECTION B, SAN LUIS DIVISION.

Section *b* covers considerably more ground than the preceding one. The eastern boundary is formed by the easterly limits of the district assigned; the northern one, by the Arkansas River; the western, by Poncho Pass and the western borders of San Luis Valley; the southern, by the southern limit of the district. Orographically, this section is separable into four natural divisions: 1. The heavy massive granite mountains, with the Wet Mountains to the east; 2. Wet Mountain Valley, at the western border of them; 3. The Sangre de Christo range, dividing it from; 4. San Luis Valley. The character of the southern continuation of the Front range presents but little variation from that given in the preceding section. Some differences are occasioned by the thickening of the Mesozoic beds farther south, and the range is devoid of those characteristic little groups exhibited farther north in the Garden of the Gods. As a rule, the bluffs rising east of the termination of the granitic range are higher and more bulky; their appearance remaining very similar to those farther north, however. Although never rising to any very considerable altitude, the granitic mountains of the Front range present a heavy aspect; deep, and frequently quite rough, cañons intersect the country.

Toward the western and southwestern portions of this bulky range, a long narrow strip of trachyte occurs, varying somewhat the character; single high peaks appear, accompanied by the well-known high narrow plateaus. Little parks are dispersed throughout these mountains. Wet Mountain Valley might be called one of the larger parks, extending along the east base of the Sangre de Christo range. This range rises abruptly from the valley to an altitude of 12,000 to 14,000 feet absolute height, giving it a relative one of 3,000 to 5,000 feet. Following in its course an almost straight line for forty miles, it presents altogether a very imposing sight. The average width of the Sangre de Christo range is not much over ten to twelve miles, which, compared with its length and relative altitude, is small; and as the color of the rocks composing the mountains is dark, the range appears to very good advantage.

A naked and sharp appearance is presented by the peaks of this mountain-range. Extending beyond the timber-line, their highest slopes are composed of loose rocks, usually with steep descent into one of the cañons formed at the side of the highest points.

San Luis Valley slopes off gradually west from the Sangre de Christo until its lowest point is reached almost in the middle; then it rises again just as gradually to the westward.

Granite, as in section *a*, forms the chief bulk of the mountains in section *b*. It occurs mainly in an immense wedge-shaped mass, beginning at the Arkansas River and extending onward to the southeast until at last it pinches out there. Its eastern boundary is determined by the boundary of the Front range, its western partly by the base of the Sangre de Christo, farther south by the border of Wet Mountain Valley. At Poncho Pass, the northwestern limit of section *b*, the granite is found extending over from the west.

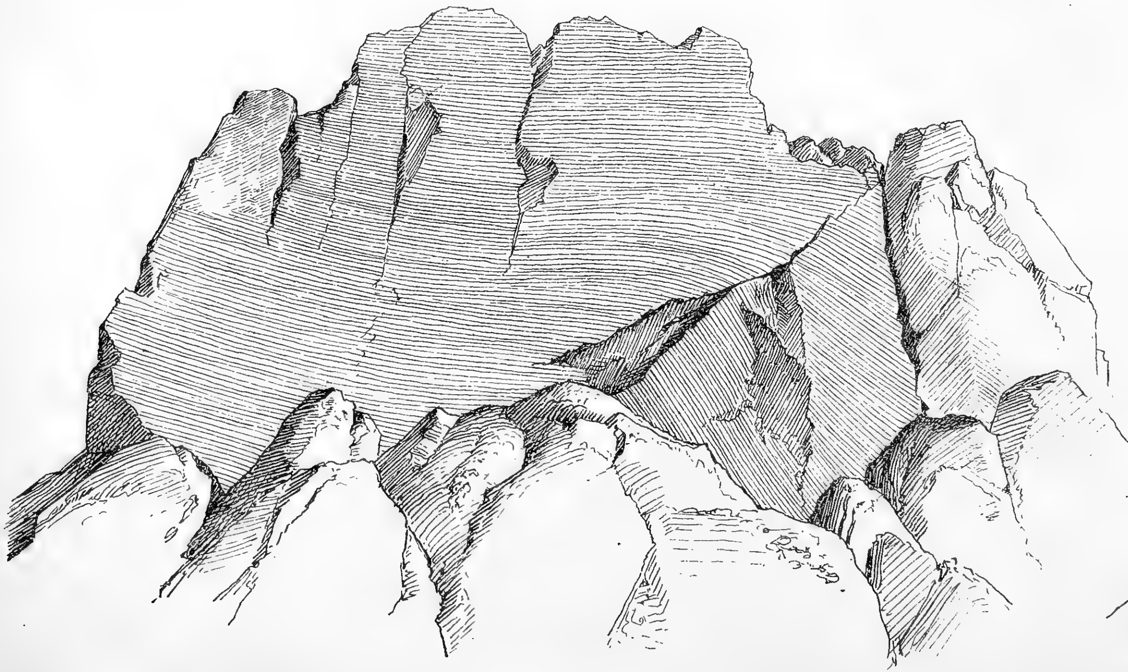
Granite of a different character and different appearance forms the center of the Sangre de Christo. It crops out all along the crest of the range, so far as could be determined, with the exception of a single place between stations 19 and 20, where the sedimentary rock making up the greater part of the range forms a bridge. Almost throughout, with the exception of the eruptive, the granite preserves a very uniform character, very similar, if not identical, with that of section *a*, a type that I am inclined to regard as the oldest of that portion of the Rocky Mountains. There is but little variation in the granite of section *b*, with the exception of local accumulations of mica, whereby a more or less stratified appearance is obtained, and of numerous dikes—partly schistose, with mica, partly hornblendic—that have some influence upon the character of the surrounding rock. In the Sangre de Christo range the eruptive granite is very similar throughout, but totally distinct and different from any other granite found in the section.

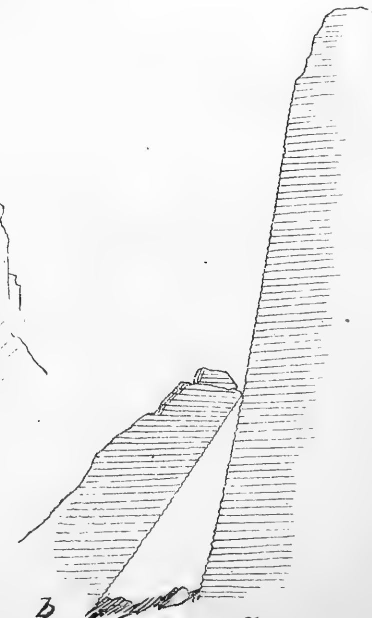
Beginning in the northwest corner of section *b*, we find the granite identical with that north of the Arkansas, gradually changing, however, in texture toward the south, where it becomes a little finer in grain, has, perhaps, more mica, and therefore alters its structure somewhat. Where Hardscrabble Creek flows out into the more open country immediately east of the granite, the latter assumes nearly the character of gneiss, becoming more lamellar, and showing a decided tendency to stratification. The color of the feldspar, too, usually is a little lighter than farther north, and the mica black. In its main outlines, however—in the weathering and formation of cañons—there is but little difference. On station 13, near Oak Creek, a very curious phenomenon was noticed. Naked rocks compose the crest of a narrow ridge running approximately east and west, upon which the station was located. On the north side the rock was perfectly planed, about 100 feet in length and 50 feet high. This planed surface was striated horizontally with striæ varying from 1 to 4 inches in width. Toward the west they bend off from the horizontal direction, falling downward. A good idea of it can be obtained from the illustration. At first a vision of glacial action presented itself; but upon examination it was found that the large slab reclining against the base of this rock was striated on its under surface in precisely the same way. It is evident, therefore, that this striation must have been produced by a friction of these two portions of rock upon each other, and that the motion must have been first a horizontal, then a declining one. As to the cause producing this phenomenon, I am unable to give any positive statement. I merely wish to remark that glacial action must be out of the question entirely, being precluded by the orographical character of the surrounding country.

Toward the northwest of the great wedge-shaped mass of granite, it becomes very coarse-grained, is of dark color, and frequently shows apparent stratification. Having observed the structure of granitic masses throughout the country surveyed during the last season, I have thought to observe that wherever the feldspar is very predominant in the granite, particularly as regards its occurring in continuous pieces, the granite presents a more or less stratified appearance, owing to the influence of the planes of cleavage. Upon weathering, this becomes more apparent still.

An entire change is noticed, however, in the character of the granite as soon as the Sangre de Christo range is reached. Almost throughout the entire length of this range, the core of it, the tops of the higher peaks are formed by this new variety. It occurs as a central mass of the range, anatomically speaking as its backbone, and is only bridged over at one single point as far as could be determined. On either side of it lay the heavy strata of Arkansas sandstone, dipping off from the granite at steep angles. At first sight this rock might be mistaken for

Illustration A.





syenite, as it resembles it quite closely in its lithological character. The color is gray, the texture fine to middle-grained, and very uniform. The feldspar is light gray, white, yellowish, and small crystals of white oligoclase are dispersed throughout the mass. Quartz is colorless to white, the mica black, sometimes in crystals. The position that this granite occupies with reference to the superincumbent sedimentary strata, renders it of the highest interest. In the *résumé* of section *b*, this will be spoken of at more length. Over to the northwest, toward station 1, the granite assumes a slightly gneissic character, owing to a considerable quantity of mica contained therein.

Gneiss occurs at one point in section *b*, but has changed its character to a considerable degree. Hunt's Peak, at the northwest end of the Sangre de Christo range, is composed of gneiss, and from there it extends for about six or seven miles to the northwest. A thorough metamorphosis has taken place, and the micaceous parts have agglomerated in such a manner as to appear like concretions, and are contained between the planes of feldspar. In weathering, the quartz, feldspar, and smaller mica particles fall off, leaving these button-shaped nodules protruding on the faces of the rocks, thus presenting a very peculiar appearance. Besides the white micaceous portions, black mica is disseminated throughout the rock. The quartz is white, in small particles, the feldspar in very small quantities, besides the large buttons, mica, both black and white predominating throughout. Although having stratified structure, the rocks, thanks to metamorphosis, weather more like granite.

Hornblende-rock may be the general name for a group comprising several distinct species of rocks. It has been a question how the hornblendes of the Rocky Mountains are to be considered, because mineralogical differences frequently cannot be found between specimens from narrow local dikes and specimens of a rock that builds up mountains. All that are found in section *b* are merely crystalline aggregates, without any distinct paste, therefore must be excluded from the category of volcanic eruptive rocks. In the eastern portion of the section, hornblendic material occurs only in the form of dikes, and will be treated of under that head; but at station 15, toward the west, we find these rocks in more considerable masses; several hills of 500 or 600 feet relative elevation are composed of it. The structure is that of a stratified rock, not infrequently inter-stratified with bands of granite, mostly having a gentle dip, in this instance to the eastward. It is composed of small crystalline particles of hornblende and oligoclase, joined together rather loosely, without the slightest intimation of a *magma*. Small rounded nodules of a green mineral that seems to be pargasite are dispersed throughout it. Although, mineralogically, there would be no objection to calling this rock diorite, lithological features do not correspond. This point is perfectly isolated, located near the beginning of a long, narrow patch of trachorheite , at first suggesting its being propylite. On the western slope of the Sangre de Christo range more hornblendic rocks are found. Immediately west of station 16 they begin, forming a narrow belt near the base of the mountains, and there they are dioritic. Hard and tough, they resist alike the influence of atmospheric conditions and the geologist's hammer, while the scaly plate-like fragments produce an uncomfortable ascent. Farther north in the range, near Hunt's Peak, another mass of these rocks occurs, forming some of the high peaks of that neighborhood. Again they differ in character, however, and instead of a diorite we have hornblende-schist. Thin narrow crystals of hornblende, in immense quantities, are mixed with a small quantity of quartz and still less mica. The color is a dark brown to black. At a few points the mica predominates, changing it into mica-schist. From those high localities the hornblendes come down northward into the foot hills, until near station 4 they disappear again. In speaking of section *c* we will have occasion to dwell upon these rocks at more length.

With this the Antizoic rocks of section *b* are exhausted, and we go on further to the sedimentary. The Silurian is again found, although in small quantities. It skirts the foot-hills bordering upon the Arkansas valley in section *c*, and a small continuation of this belt has reached section *b*. Southeast of station 4 a narrow strip of but a few miles in length appears, dipping off toward the north. Of the Carboniferous, however, section *b* contains more than the two others. That mass of Arkansas sandstone described in section *a* changes its course slightly to the southeast when crossing the Arkansas, and forms the main bulk of the Sangre de Christo range, where the thickness of its strata is remarkable. The lower limestone that we have farther north also appears immediately south of the Arkansas, near the junction of the South Arkansas, and accompanies it for the distance of about fifteen miles, uniformly dipping off from the mountains toward the river. As no fossils at all were found in its strata, it was simply determined by its relative position to the Arkansas sandstone and its petrographic features. Another little patch of it appears about five miles northeast of station 16, where the dip of the strata is inverted. Opposite station 5, the Arkansas sandstone forms the bed of the river for several miles, and crosses over on the south side. A flow of trachytic lava, coming from the north, reached this point south of the river after the sandstones had already been disturbed, and showed a considerable dip to the northeast. By means partly of atmospheric, but mainly in consequence of the irrigation, this ridge of sandstone was cut into several small hills, five or six of them, each one provided with a trachytic cap, growing thinner in proceeding eastward. Two cuts annexed will serve to illustrate this point. At the northern end of the Sangre de Christo range, the sandstone again appears, and spreads as it continues on southward. At first, north of Hunt's Peak, its dip is nearly north, but soon, upon going south, turns to the northeast. From the apex of the range downward, the angle of the dip diminishes; but quite a number of local slides and disturbances create exceptions to this rule. All along the range, with the exception of one point, at station 20, the granite comes up through and separates the sandstone; but at this place a bridge of very considerable thickness, probably about 800 to 1,000 feet, is formed by the sandstone, extending horizontally about two miles. Here the sandstone forms an arch, that is exposed upon almost its entire section, with the granitic bowlders, in the deep cañon immediately aside and in front of it. As these bowlders cannot have been brought there from any point outside, it may be concluded that they are there either in position, or very nearly so. The strata overlying this arch form steep smooth peaks of very considerable altitude. Upon the edge of one of these station 20 was located; on another one was station 19. A section drawn through the arch will give an idea of the relative position of the strata. In the center the eruptive granite (*a*) shows, while the strata directly above it are obscured by *débris*. Farther up we reach the bridge, dipping off on either side, (*b*,) with the strata lying across unbroken. Heavy beds of red sandstone dip off on either side, with steeper precipices and slopes on the western than on the eastern side. Interstratified with the sandstones are beds of dark-

Illustration B.

Fig. 1.

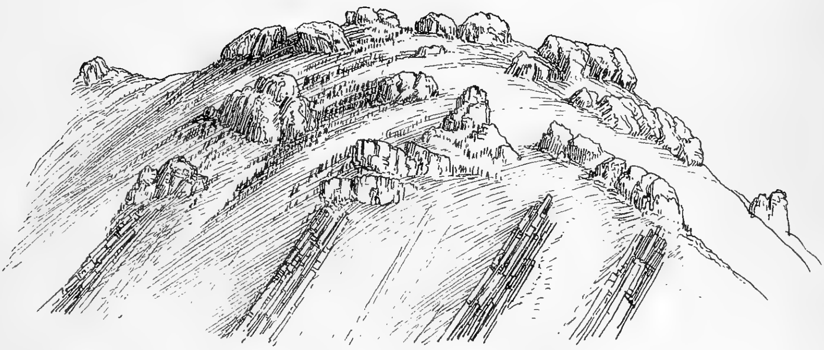


Fig. 2.

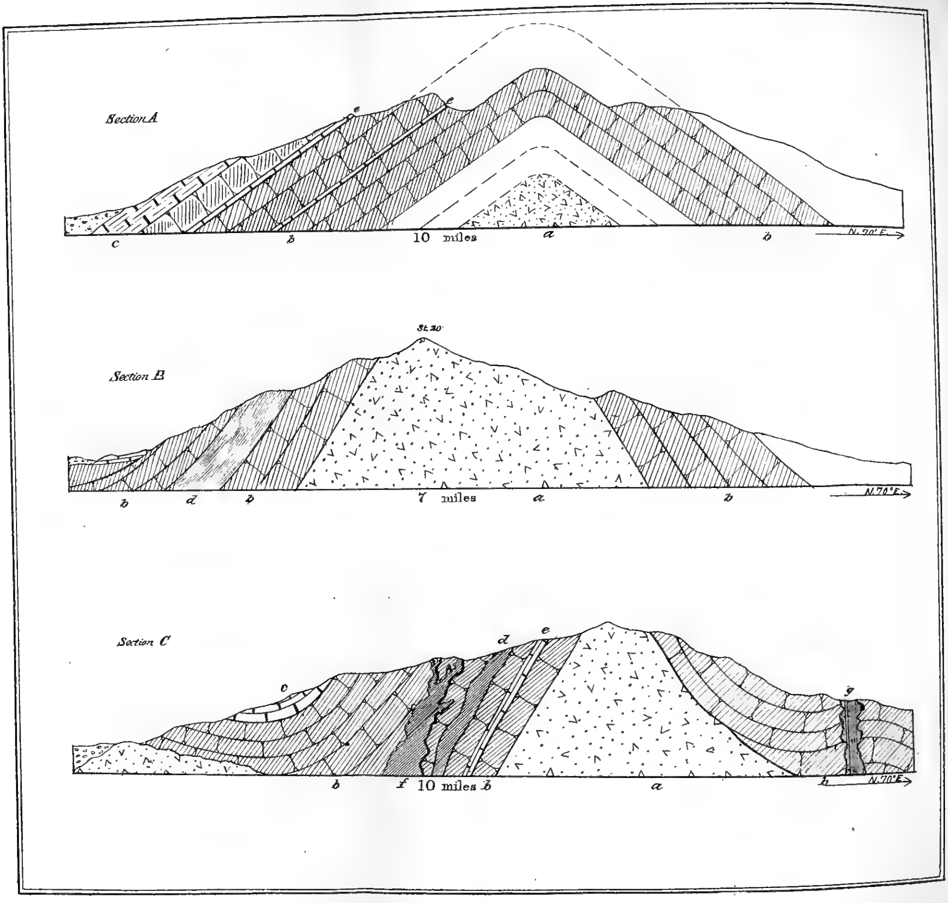
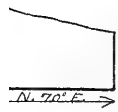
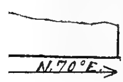
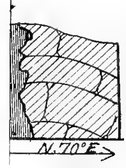

Section A
e
e
c
b
10 miles
a
b
N. 70° E.
St. 20
Section B
b
d
b
7 miles
a
b
N. 70° E.
Section C
c
d
e
g
b
f
10 miles
b
a
h
N. 70° E.

PLATE. XIII.







brown argillaceous shales and isolated strata of limestones, (*e*,) with fossils. Near station 19 one of these was exposed, and crinoids were found. The remainder is made up again by Arkansas sandstone and a few limestones, all Carboniferous, the combined thickness of which, with those underlying, probably exceeds a mile. Although it was possible to see over to the east side of the slope for some distance, but little detail could be observed, and the section, therefore, shows nothing but the lower strata. The course of the section is about north 70° east. Proceeding farther northward, to station 20, it was found (Plate XIII, section B) that the granite (*a*) had again appeared, and forms the highest peaks at that locality. As far as could be determined, the Arkansas sandstone (*b*) rests upon the granite for about 2,000 feet, although I have but little doubt that it is underlaid by still older formations even at that point, but the amount of *débris* that is deposited at the base of the mountains obscures the line of junction. In ascending the west slope to reach station 20, the boundary-line between the granite and sandstone was found to be well-defined, the latter ending with a little swell in the outline of the mountain. At that point its dip is almost vertical, but soon diminishes; a section may serve to illustrate the conditions observed. A heavy bed of dark, almost black, shales (*d*) overlies the sandstones, and is in turn covered by a series of sandstone strata, (*b*.) Toward the base of the mountains some limestone makes its appearance, slightly disturbed, but originally conformable with the sandstone. The eastern slope is mainly composed of the latter. In speaking of this station, 20, it may not be out of place to mention a phenomenon which, although not strictly appertaining to geology, may be of some interest. During our trips in the higher mountains we had several times noticed evidences of the presence of comparatively large quantities of electricity, but on this station anything thus far experienced was surpassed. It was found that as soon as a sufficient amount of electricity was contained in the atmosphere, any metal instrument or weapon that may have been about would produce a buzzing sound, like the hammer of an induction-coil. When the supply of electricity in the lower strata of air was exhausted and the buzzing ceased, it could be renewed by holding the instrument up higher into the air. On this particular instance, a heavy gale was blowing from the north, driving a storm toward us with great rapidity. The wind came in single puffs, and while a rifle that was carried along would not buzz during the short lull of the wind, it would do so quite strongly as soon as the gust reached the point of observation. At one time the quantity of electricity grew so large and intense, that I received from my rifle a shock sufficient to paralyze me momentarily. The weapon dropped out of my hands, and about half a minute after a discharge of lightning took place very near by, by which the electric phenomena were quieted for a time. Soon, however, electricity accumulated again; its manifestation again became intenser, until every hair on the head was rising upward; every finger buzzed when held up into the air, and every pointed rock hummed with a sonorous sound. As soon, however, as the next discharge took place, this time some distance off, it again subsided. From personal communication it has been found that these occurrences have been noted by a number of persons, who perhaps either had no opportunity of making them known, or deemed them of too little importance.

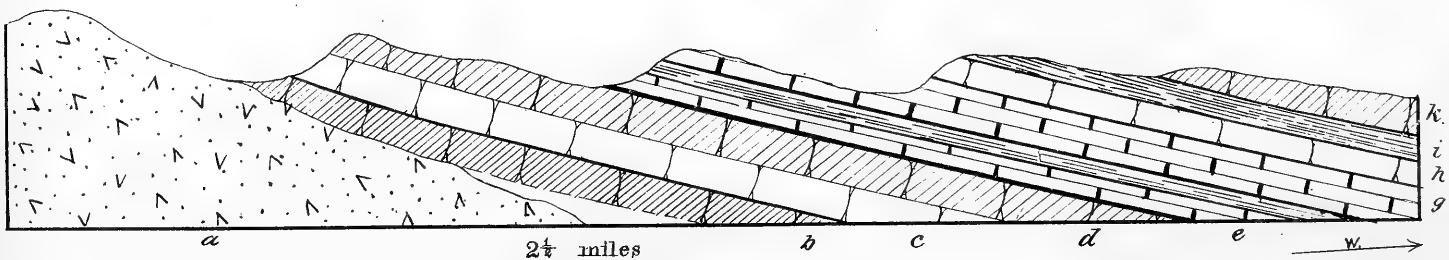
As the diluvial and alluvial material begins right at the basis of the west slope of the range, it could not be determined with certainty whether the Carboniferous strata extend to the westward for any considerable distance; but about eight miles west of the termination of the sandstone it crops out again, leaning up again at Granite, on the west side of the valley, with a dip to the east. It is very probable, therefore, that the Carboniferous strata extend across that northern end of the San Luis Valley. This western outcrop is small, about five or six miles in length, but very narrow, dipping gently under the diluvial deposits. East of Mosco Pass the sandstone seems to extend across the lower portion of Wet Mountain Valley, as it was found a little west of stations 83 and 84, on the western slope of the mountains, and the aspect of the valley at that place indicates a crossing of the sandstone. Limestone accompanies the sandstone at several places in a long patch west of station 19, dipping conformably with it, with the exception of one small local fold; but besides this occurrence there are several beds of limestone, interstratified with the sandstone, one of which afforded a few fossils. On the western side of Homan's Park, where the sandstone crops out again, limestone is also found with it, analogous to the limestone of section *a*, overlying the Arkansas sandstone. In connection with this formation I have to mention a very peculiar conglomerate, found only once at a high elevation. The Christones, upon the highest of which station 17 was located, are entirely composed of a conglomerate, containing fragments of granite, gneiss, hornblende-rock, mica-schist, pink porphyry, garnet-rock, epidote-rock, and quartzite. These fragments are not rounded by action of water or atmospheric influences, but have perfectly sharp, angular outlines, and are cemented by a hard, gray quartzitic paste. Their size ranges from half an inch to several feet in diameter. In weathering they resist longer than the matrix does, thus studding the almost perpendicular walls of the mountain similar to the ornamentation of Gothic spires. A little south of station 17 a dike of pink porphyry has broken through the conglomerate, and makes its appearance near the top of a peak. Stratification can be noticed to some extent in the arrangement of the conglomerate, and the strata dip off very steeply to either side from the crest of the range. Besides these more connected masses of Carboniferous rocks, an isolated point of exposure was found near Boggs's ranch, in the southeast corner of section *b*, where the rise of the main granitic body seems to have been sufficient to bring out this formation besides the Mesozoic beds. It is of but small extent, identified by fossils found in the grayish limestones and shales. As in section *a*, the Carboniferous here, too, is succeeded by the Mesozoic formation.

On Plate XIII, section *c*, an ideal section through the Sangre de Christo range is given, showing at once all the various occurrences throughout the entire range, and its general character. Resting immediately upon the granite are the Arkansas sandstones on either side, interstratified with limestones, (*e*,) and shales, (*d*.) Dikes of hornblende-rock, (*f*,) with a strike of north to south, traverse the sandstones. Toward both east and west the dip gradually decreases. As in section *a*, the Triassic and Jurassic beds occur along the eastern edge of the granitic Front range. Directly south of the Arkansas they begin, occurring in isolated patches all the way southward until Hardscrabble Cañon is reached. From this point they cover more ground, until a short distance below Bogg's Ranch, where they entirely cease. Station 78, southeast of Hardscrabble Creek, is located upon such a sandstone, of dark-red color, lithologically identical with that farther north. The dip throughout is to the east and a little north of east, steeper at the base of the mountains, more gentle nearer to the plains. South and southeast of station 78 they increase considerably in thickness, forming bluffs of nearly 1,000 feet in height. Deep gorges, at times narrow, sometimes wider, in the latter case forming fertile areas, are cut into them. The shales, of a dark-red to a brown color, seem to increase considerably in thickness, and southeast of station 79 compose the soil of a valley that is well cultivated. As stated under the head of Carboniferous, a portion of this latter formation is exposed at the western ascent of this valley, indicating a more considerable rise of the granitic country immediately west than is found anywhere along the old shore-line. White sandstones and single dolomitic strata interchange with the red ones, while those beds referred to the Jurassic formation seem to decrease in thickness. A careful study of detail-stratigraphy and paleontological character of the formations of this region would probably lead to very interesting facts bearing upon age and arrangement of these beds referred to the Trias. South of Saint Charles River, no more Mesozoic beds were found, which can probably be accounted for by the fact that the granite in its horizontal exposure pinches out at that point, and, as far as could be seen, does not appear again for considerable distance. From that point southward, as far as section *b* extends, it was found that the Cretaceous formation rests immediately upon the granite. Cretaceous No. 1 is very distinctly defined throughout the southern portion of this section, forming abrupt bluffs of a yellow to brownish sandstone, in which a number of plants are found. In the vicinity of station 33 and northward, its dip to the eastward is not very considerable, and remains comparatively small for some distance north, at the same time conformable with the underlying Mesozoic strata. At this southern end of our section the Cretaceous rest immediately upon the granite, and probably a little farther south the Tertiary beds succeed it in this position; while north of the South Saint Charles River, the Cretaceous is considerably removed from the granite, having, at that point, but a very slight dip. Undoubtedly erosion has had a very appreciable influence in this, by carrying away large portions of the readily disintegrating sandstone. Low bluffs characterize the formation north of Hardscrabble Creek, dipping to the eastward at an angle of frequently 15° to 20°, retaining the same character down to the Arkansas. At several intermediate points, it seems to rest immediately upon the granite, as no red beds were noticed between, and as seen at most places the yellow sandstone is succeeded by a white one. Both time and the character of the country forbade our spending many days in the plains east of the mountain-range, so that the terminus of the Cretaceous area could not be accurately determined there, but it seems to have only a limited extent, and that the Tertiary beds set in very soon and continue. In the vicinity of Canyon City, the Upper Cretaceous formations make their appearance, and the sandstones are covered by a series of limestone and shale strata, both containing fossils, and running out into the plains at a gentle dip. Low bluffs are formed here, as a little farther north, by the limestones and sandstones, while the softer shales, more readily yielding to atmospheric influences, manifest their presence by forming shallow ravines and narrow valleys. A little southwest of Canyon City, a warm spring of about 100° Fahrenheit has its origin in the Lower Cretaceous limes and shales; like all warm springs, it is said to have a very beneficial influence upon persons affected by rheumatism, gout, &c. Besides this continuous stretch of Cretaceous, section *b* includes another portion connected with the Cretaceous bay west of station 11. This is an arm of the bay of almost oblong shape, presenting a series of long, low bluffs, striking a little east of north. As mentioned in the *résumé* of section *a*, the dip of the strata composing these bluffs is to the west, thus varying from that of the remaining Cretaceous. A narrow stratum of red sandstone, reclining on the eastern side upon the granite, is a local variation of the yellow and light-brown usually found in Cretaceous No. 1. A section running east to west will give a better idea of the arrangement of the strata in this locality. Resting upon the granite (*a*) we find the mentioned red-brown sandstone (*b*) underlying a white one, which in turn again is covered by a brown; between the western slope of this bluff and the rise of another one, a white limestone (*e*) occurs, overlaid by a white, shaly limestone, with *Inoceramus*, forming the apex of a low bluff, and dipping westward at an angle of about 10°. It is covered by white sandstone and a light-greenish shale, (*i.*) A yellow to light-brown sandstone (*k*) finishes the western extent of the valley. Cretaceous waters have probably never intruded far inland to the west in these localities, as at present no trace of them is found, unless coming either from the north or the south.

At this place, between the Cretaceous and the succeeding Tertiary, the Lignitic formation may find its position. As the entire district of the San Luis division shows a good development of these Lignitic beds at but one point south of Canyon City, and the opportunity for making detail-studies of the geological relations of this group did not offer, I take the liberty of referring to Mr. Marvine's report for observations regarding its age and relative position, and also to Professor Lesquereux's work. A section will show the position of the coal-beds. The foot-wall is formed by white, middle-grained sandstone, upon which a coal-bed, varying from 3½ to 5 feet, rests, which is separated from a narrow seam of 1 foot to 16 inches by a stratum of gray shale, of 10 to 14 inches in thickness; 60 feet of grayish-brown argillaceous shales, with small particles of mica, follow, containing indistinct remains of plants, terminated by a narrow coal-seam, above which 45 feet of the same shale follow, intersected by two similar thin seams of coal. Fifteen feet of yellowish sandstone rest upon this, separated from the overlying 25 feet of white sandstone, which form the top of the bluff, by a thin stratum of shale. The three upper seams are not used, but the lower ones are worked for coal by the Denver and Rio Grande Railroad Company. Canyon City coal-mines is the usual appellation given to these deposits. A tunnel has been run in on the main vein in a southerly direction for the distance of about 1,400 feet, and drifts from this serve to work the coal, of which both the 4 foot bed and the 1-foot seam are utilized. The main bed dips at an angle of 2° to 4° to the westward, remaining constant in this as far as worked thus far, but to judge from the stratigraphy exposed on the surface, this dip will change farther west, reversing its direction. At the time of my visit, September, 1873, the mines had been worked for fifteen months, and, according to a statement kindly furnished by Prof. R. N. Clark, at Labran, Col., the production of the mines in 1872 was 4,956 tons, to 12,909 produced in 1873. Mineralogically considered, the coal would be termed a compact bituminous coal.

From all that could be learned with reference to the relative position of the larger coal-vein mentioned above, it seems that those worked farther eastward are underlying it. Probably beginning with the first rising sandstone-bluffs, a little east of the coal-mines, we find the Tertiary formation. As in section *a*, our investigations did not carry us through the Tertiary portions of the beginning plains for a length of time sufficient to make careful comparisons, and consequently to admit of strict and correct discrimination. It is quite likely, however, that the higher bluffs, composed of a yellowish and brownish sandstone, rising up beyond the light-colored and gray shales, should be ascribed to the Tertiary period. As far as could be observed, no unconformability exists between them and the underlying strata, although it dare not be denied that any such existing unconformability would have been greatly

Section from east to west near Station XI.



obliterated by the slight dip occurring there. As a rule, it may be noted that wherever the Cretaceous rocks are in close proximity to the granite westward, the Tertiary bluffs will also be relatively close, and in the reverse case their position will be regulated by that of the Cretaceous. At the southeastern end of section *b* it comes up very close to the granite, and probably at some points farther south rests immediately upon it. Near Dobson's Ranch several bluffs yielded fossils that indicated their Tertiary age, belonging probably to the late Eocene period. From there eastward, the bluffs cease to be numerous as soon as some distance from the mountains is reached, and the gentle slopes stretch over the plains. As well as the Cretaceous, no Tertiary flood seems ever to have reached far into the interior of section *b*, but to have remained east of it throughout; south of it, however, coming in more closely upon the higher lands. Besides archæan and sedimentary, section *b* contains a limited quantity of volcanic rocks.

Trachorheites.—Opposite station 4, to the north, a portion of the trachytic material has crossed the Arkansas, extending into section *b*. Mostly it is trachyte and tuff of a light-gray to yellowish or brownish color, flowing to the south and southeast. As stated, when speaking of the Arkansas sandstone, a number of bluffs composed of it are capped by the tuff, appearing on the maps as islands. To the west of station 4 several small isolated hills are composed of trachyte, that probably at one time were in connection with the main mass north of the river. On Texas Creek, about a mile west of station 8, volcanic activity was manifested by trachytic rocks on a small scale, and thereby a number of small hills have been formed, flanked by ashy material. Granite surrounds this little patch of trachyte on every side, which may be regarded as the sentinel of a larger, horizontally, quite extended eruption and flow of trachorheites. From station 15 onward, in southeasterly direction, we find a strip of these rocks about thirty-five miles in length, and on average from two to four miles in width, bordered on either side by granite. Station 83 is located at the southeastern extremity of section *b*, on Mount Greenhorn, having an elevation of 12,341 feet, which is composed of a compact andesite. Although of comparatively rare occurrence, this mountain seems to present one of the volcanic andesitic eruptions. The rock weathers in slabs from one-half an inch to more than a foot in thickness, the thinner ones of which give a submetallic sound when struck. A more massive eruption of the same material continues to the northwest, beyond station 84. Proceeding in the same direction, the character of the eruptive rocks is found to become more trachytic, and, toward the lower hills bordering the range, decidedly rhyolitic. Usually the color of the rock is a light-gray, with a pinkish tinge, representing the type in which the Kosita mines are located, becoming almost white and very compact to the north. In accordance with the general character of rhyolite, the foot-hills show gentle outlines, are of rounded form, gradually sloping off toward the valley, and are accompanied in the higher lands by the well-known grassy or swampy plateaus. West of station 15 the lithological character of these rhyolites changes somewhat, as they become very compact, show scarcely any crystallization of minerals contained in the paste, and present a more or less stratified appearance. White ash sets in, loose in texture, and of a feldspathic composition. Besides the trachorheites, we have basalt in section *b*. A little southwest of the warm spring, near Canyon City, two small hills occur, composed of a black basalt, weathering in rough outlines. To the south of these, at station 12, at an elevation of 7,026 feet, a cone of basalt is found, which is very hard, of black color, and contains numerous inclosures of olivine.

Another small mass of basalt occurs in the Sangre de Christo range, among the foot-hills, east of station 16, where several small hills of it were ejected, somewhat disturbing the superincumbent sandstones. Looking off to the east and southeast from station 84, a number of cones were noticed among the Tertiary formation, that are probably basalt, but no examination of the locality could be made. Altogether, this occurrence of basalt is very limited, compared with that of other districts; but it seems probable that the presence of such large quantities of trachorheites might account for it.

Dikes occur in large number and considerable extent in section *b*. By far the most numerous are the hornblende-dikes, with a usual strike of north to south and almost vertical dip. While they are not quite so frequently met with in the northern portion of the granitic mass, they abound in the southern, sometimes traceable for several miles, but almost invariably of limited lateral extent. Ordinarily they carry a considerable amount of quartz and hornblende, mostly mica, and in some instances feldspar, garnets, and epidote; the two latter either as crystals or massive. Their texture is frequently that of gneiss, owing to the hornblende, to the mica, or both, whereby they are distinctly offset from the surrounding granite. When variations of texture take place, these rocks resemble a schist more closely, and may give rise to misinterpretations. In the Sangre de Christo range we find a large number of such dikes, with the usual strike passing through the sandstones, and farther north through the granite that is exposed at the base of the range, but never, as far as I have observed, through the eruptive granite. Differing from the eastern ones, these retain their mineralogical and lithological character more uniformly throughout, and resemble diorite. In some instances, when the quantity of mica accumulates to a considerable extent, the texture becomes more like that of a schist, the structure more stratified, and the hornblende not rarely is segregated in single prismatic crystals of about an inch in length. It is possible that the hornblende-schists, occurring at the northern end of the range in question, should be regarded merely as immense dikes of this character, as in their mineralogical composition there is no essential difference. The presence of feldspar in the dikes of the range, compared with the scarcity in the eastern ones, is a point worthy of notice, and it does not occur in the same manner again to that extent in any of the dikes throughout the district. What the geological relations of these dikes are seem a little obscure, but they may perhaps justly be regarded as segregations in the greater number of instances.

Section *b* includes a large drift-area. Along the south side of the Arkansas, a narrow strip of drift-deposit occurs, the deposition of which was facilitated by a widening of the cañon. Wet Mountain Valley is covered entirely by drift, originating from the mountains on either side of it. Drainage has cut a number of steep gorges into the loose material, of no very considerable depth, however. The grandest mass of drift-material, or, perhaps more correctly speaking of fluvial deposit, is found in San Luis Valley. Over thirty miles long, to the southern limit of section *b*, and at that point nearly thirty-five miles across, stretches an uninterrupted plain, the soil of which is made up entirely of drifted material. On the western side of the valley, the bluffs of gravel rise to probably more than 100 feet above the ordinary level; but eastward nothing of the kind is observed. Toward the center of the valley its greatest depression occurs, and there San Luis Creek flows southward, emptying into the small San Luis Lakes. A large portion of the ground is swampy and impassable. At the eastern border of the valley the gravel bluffs are not so prominent as on the western, but a very curious and interesting formation of dunes takes place. At the west opening of Mosco Pass a considerable area of ground is covered by bluffs, 500 to 600 feet in height, composed of very fine light-yellow sand. In form these dunes do not vary from the celebrated ones on the Baltic Sea, and like those shift onward to the higher land. This phenomenon is a very good illustration of the fact that westerly winds prevail to a considerable extent, because none are found on the western side of the valley, and these have selected the very locality where wind would have the fullest sweep through a low pass of a high mountain-range. The area covered by the sand-dunes is about twelve square miles, but the fine sandy soil extends for some miles northward. A fact that finds its explanation in the nature of the soil may be mentioned here. More than twenty creeks, heading in the Sangre de Christo range, flow down westward into the valley, but have, however, a short existence, as they are absorbed by their porous beds before running any considerable distance. Some of them run farther in the morning than in the evening, so that, camping on a quite large creek with a plentiful supply of water in the morning, by evening it may be necessary to walk half a mile before finding water. The melting of snow in the neighboring mountains and the rain-fall that seems to be quite frequent during the day-time in that region account for the change.

Ore-deposits.—There are several in section *b*. A short distance up Grape Creek Cañon a deposit of magnetic iron-ore occurs, which is being worked at present. On the western slope of the Sangre de Christo range, not very far from station 19, a large mass of hematite was observed, which is not yet worked. In the higher mountains of that range quite frequent indications of silver-bearing lodes were noticed, although none was found. A number of mines were started in 1872 in the Hardscrabble mining-district, located in the rhyolitic mountains, about three or four miles east of Wet Mountain Valley, near the head of Hardscrabble Creek, the settlement being called Rosita. At the time of my visit there, September, 1873, several mines had been opened, and smelting-works were in course of erection; but I have been informed since that the expectations of the efficacy and cheapness of the smelting-process were not fully realized, and discouragement took place. All the lodes are found in a rhyolitic rock, forming a system of regularly-striking parallel veins, with a course of about south 25° west, *i.e.*, at right angles with the strike of that long, narrow strip of trachorheites running from station 15 to station 83.

The Senator lode has the above-given strike; is 7 feet wide at the surface and 12 feet at the bottom of the shaft, which has reached a depth of 40 feet; dip to the northwest about 120°. The vein can be readily traced on the surface by the quartz-ledge appearing there. The names of some of the other mines opened on average about to the depths of 20 feet are: Virginia ledge, of about 10 feet in width; Gem mine, parallel to the Senator, 6 to 5 feet wide, mostly furnishing galena ore; the Keystone, 4 feet wide; the Steven & Leviathan, with a width of 15 feet; the Del Norte, 4 feet wide, and several others. A number of quite small veins run parallel with or connect some of those mentioned above, thus forming a sort of net-work. The fact of their existing in this rhyolite associates them with considerable interest; but although I had expected to find in them some rare minerals that frequently associate in similar places, I was disappointed. As the rhyolite there is of comparatively small thickness, probably not much over 1,000 feet, it seems probable to me that the fissures extend through it, and probably continue down into the granite below. Only a few minerals were found in these mines, all of which, however, seemed to contain more or less silver: quartz, feldspar, galenite, sphalerite, cerussite, argentite, stephanite, malachite, and azurite; the latter two the result of decomposition of fahlerz. The elevation of Rosita is 8,827 feet.

Descending Hardscrabble Creek, several mines were found located near the upper end of Hardscrabble Cañon. In speaking of the granite of that region, it was stated that a number of variations took place, caused by local accumulation of one or the other mineral constituent. Parallel to these accumulations, sometimes of hornblende, appearing in the form of dikes, more frequently of mica, sulphuret-ores have segregated, and are being worked to some extent. The strike of the lodes is parallel to that of the gneissoid strata; the dip also conformable. The Silver Hills mines are of that character, furnishing quite a considerable quantity of fine-grained galena, with argentite and cerussite. Another of similar character, but less ore, is the Barton mine. Of these mines but little can be said, as they are not deep enough yet (35 feet) to warrant any definite assertion, but it seems probable that they will not hold out very long.

Résumé of section b.—We find along the eastern line of the Front range the same phenomenon of a gradual rise that characterizes the corresponding portion of the preceding section, only having gone on to a greater extent in the southern part. Here we have, analogous to the occurrence near Pike's Peak, the Carboniferous strata, although at one locality only appearing upon the surface, indicating a greater activity of the rising, or a more thorough erosion. It is of importance to know that these older formations underlie the beds referred to the Mesozoic period. One of the most interesting and instructive portions of the section is the Sangre de Christo range. A series of sandstone-strata of more than a mile in thickness have been lifted up in one continuous, almost straight, line of forty miles in length; and while the strain has been too great for most of the strata, while they have broken, and allowed the granite to be forced out to higher relative altitude than they reach, at a single point this strain has been resisted and the sandstone-arch remains entire. Comparative regularity in the arrangement of strata in their tilted position shows that but few, if any, disturbances took place in, or had any effect upon, the immediate vicinity of the Arkansas sandstone. It seems probable that this latter extends across the San Luis Valley, perhaps over its entire width, perhaps only partly. As trachorheites reach over eastward to the very base of the gravel-bluffs, and neither granite nor any sedimentary beds make their appearance to form a transition, it is quite possible that the sandstone may extend a short distance up into the higher lands. Its stretch across the southern part of Wet Mountain Valley seems to me pretty certain, although it could not be determined definitely from a distance. The trachyte has taken in section *b* a course almost parallel with that of the granite forming the heart of the Sangre de Christo range, and instead of appearing, as in section *a*, as the result of massive eruptions, it seems in this instance to have been volcanic, accompanied by flows of considerable extent. Besides this difference, there is little resemblance in the general character of these trachorheites to those of the northern section; they are, as a rule, more compact, with less tendency to segregate crystallized minerals. San Luis Valley, that probably in late geological times contained a lake of very considerable extent, seems to owe its formation to the gentle slope of the underlying sandstone. Sangre de Christo seems to have contributed a large amount of the drift-material of which the bottom of this valley is made, also the country to the northwest of Poncho Pass.

CHAPTER IV.

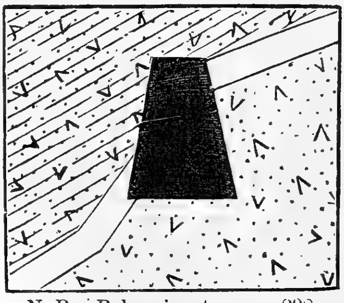
GEOLOGY OF SECTION C, SAN LUIS DIVISION.

Section *c* is bordered on the east by the Arkansas River, Poncho Pass, and San Luis Valley, while the southern, western, and northern limits are the same lines that inclose the entire district. Altogether the country of this section presents a mountainous aspect, containing, with a high average elevation, a number of our highest peaks, and those portions of the main continental divide that fall within the boundaries of our district. The southwestern portion, to an extent of more than 1,400 square miles, is one continuous mass of trachorheites, with all their characteristic orographic features. Toward the foot-hills, and near tne few wider valleys that occur therein, frequent formations of table-mountains are found, sometimes only small, sometimes of considerable size; and the different flows of trachoid rocks have produced mountains with well-marked steep terraces. To the northeast of this immense volcanic area we get into granite and hornblende rocks again, forming massive, heavy mountains, skirted by lower foot-hills composed of sedimentary rocks, which lead off into the valley of the Arkansas. West of this valley steep masses of granitic mountains rise to an altitude of over 6,000 feet above valley-level, almost ideal in shape, certainly presenting an imposing sight. These sharply-cut mountains vary somewhat in the character of the material of which they are composed, much less in their general outlines, however. Northwest of them is the deep cañon of the Gunnison, bordered on either side by steep, high walls, with a usually very narrow surface in the valley itself. Leaving the cañon at the western terminus of our district, we find the aspect of the country has suddenly grown much more gentle; the influence of sedimentary beds is again noticeable. A long valley, about five to seven miles in width, extends over about eighteen miles to the southeast, fairly studded in its upper half with small box-shaped bluffs, composed of Cretaceous strata.

Granite covers a large portion of the area in section *c*, but is surpassed in quantity by the trachorheites. In the northeastern part it runs parallel to the Arkansas, keeping about five miles distant, borders Poncho Pass, and extends southward for eight to ten miles, but is soon covered by volcanic rocks, and appears in the southwestern corner only in small isolated patches exposed by erosion. In the northwestern extension from the Arkansas it is the main rock, but is covered partly by sedimentary strata, partly obliterated by volcanic eruptive rocks; probably it underlies quite a considerable portion of the trachorheites of the southwest, and, as far as could be judged from a very distant view, comes in again farther westward. In this section, as in the preceding, there are also two distinctly defined varieties of granite, one evidently younger than the other. Beginning with the granite immediately west of Poncho Pass, we find it to be very much of the same character as given in the preceding section; it is subject to a number of variations and modifications, caused by local accumulations of one or the other constituent mineral. If the mica predominates, in proportion it will change the structure of the granite, and all varieties from typical granite to equally typical gneiss can be observed. In texture it varies from a very fine-grained granite loosely put together to one yielding tablets of feldspar over a foot in length. This general character of the granite is retained all the way westward to the boundary, but changes in Gunnison Cañon and its immediate vicinity. There we have granite analogous to the one found at Badger Creek in section *a*, a middle- to coarse-grained porphyritic granite, with white to yellowish oligoclase, gray, white, and pink quartz, black mica, and large Carlsbad twins of orthoclase, continuing through the whole cañon, with a few exceptions. On the heights inclosing this cañon, the granitic rocks weather in bold but rounded outlines. It was here that a good opportunity was offered to observe the often-asserted fact that even without the action of moving water, without any motion on part of the rocks, bowlders and rounded cliffs will form high up in the mountains, sometimes on their very summits. As one of the most effective agents, expansion by heat has been mentioned, the result of which would be a scaling off of the outer crust, and, in course of time, an approximation to the spheroid form. It seems to me, however, that the action is more easily explained, and in itself is certainly simpler, if we take into consideration the mechanical retention of water by the mica and by the frequently-cracked feldspar, combined with the expanding action that cold temperature has upon water in causing it to freeze. Thus scales of the rock will gradually be carried off comparatively rapidly, as in the high altitudes of that country frost occurs almost every night for the greater portion of the year. Other atmospheric influences certainly have their share in producing the noticed effect; and sudden changes of temperature, even without freezing, cannot occur without leaving their traces in the course of time. An interesting point to study the behavior of granite occurs at station 2, Mount Ouray. This mountain is composed of hornblendic rock, but at a distance shows a stratified appearance on its eastern side. Approaching closer, however, it is seen that this is owing merely to the fact that narrow and some wider seams of granite are interstratified, *i. e.*, intruding between the strata of the hornblende-rock. The affixed cut will illustrate this phenomenon, having been taken from a point near the summit of the peak, where a seam of pegmatitic granite about one foot in width intruded between the hornblende-strata, continuing for a considerable distance. Numerous occurrences of this kind were noticed on this mountain; rarely, however, was the granite-seam as small as in this instance. The very top of the peak is composed of granite, containing reddish feldspar, white to gray quartz, and white mica, at several points changing to a true pegmatite, with its agglomerated quartz-crystals contained in the orthoclase-matrix. Invariably the junction between the granite and hornblende-rock is perfectly clear and sharp, without any transition of one into the other. In the *résumé* of section *c*, the relation of these two rocks, as regards their age and, partly, genesis, will be considered. Entirely different from all the granites thus far treated of as occurring in this section, we find those of the southern end of the Sahwatch range, the granite of the high range bordering upon the Arkansas Valley. Generally it is of a light-gray color, middle-grained, with either one or two kinds of feldspar, and, as far as noticed, always black or dark-brown mica. As a rule, this granite weathers in sharp, well-defined fragments, which character is imparted to the whole mountains composed of it. Mount Princeton, situated a little north of Chalk Creek, at an elevation of 13,997 feet, tapers off to a very fine point, as do a number of the other peaks in that range. Its granite presents a stratified appearance. The steep descent toward the valley is rather surprising, inasmuch as the comparatively low land on the east side of the river is composed of an entirely different granite.

Fig. 8.

F



N. B.—Belonging to page 298,
Payrock mine.

Until the hornblendic rocks near station 3 are reached, the Sahwatch range retains its own peculiar kind of granite, and then the older predominating one again appears. On Chalk Creek, one of the two feldspars (oligoclase) decomposes quite readily, and the bluffs are consequently of a white, almost chalky appearance, whence the name of the creek. This decomposition appears to be only local, extending not very far, and only on the northern side of the creek. Two warm springs are found near the bluffs, bubbling up through the deposit of drift-material, and, as long as we remained encamped there, observations of their temperature were taken.

August 27, 1873, the smaller one, farther from the granite-bluffs than the other, within about 80 yards of the creek:

6 a. m.	12 m.	7 p. m.	9 p. m.
108°.5 F.	112°.0 F.	111°.0 F.	109°.5 F.

It remains to be stated that the waters of this spring were exposed to the action of the sun's rays during the entire day, which may account for the rise of temperature during noon and its gradual cooling toward evening. Two observations of the larger one were taken, which is located nearer to the granite-bluffs, farther removed from the creek. One was taken at 6 a. m., the other at 12 m., and in both cases the temperature was found to be 130° F.

Besides these younger granites, we have still another one in section *b*, at station 38. Analogous to the granite that has given cause for the formation of the Sangre de Christo range, station 38 presents a small granitic cove, very similar to the former in lithological character, with Silurian and Carboniferous strata dipping off from it on all sides. This is the only instance of the kind that we have here, but it is certainly a very striking one. A section cutting through station 38, given under the head of Carboniferous, will more clearly show its position.

Closely related to the granites we find a rock composing the mountain upon which station 45 was located, at the head of Chalk Creek. A crystalline aggregate of orthoclase, oligoclase, quartz, chlorite, and hornblende, (very sparingly,) constitutes the rock. Orthoclase is contained in it as Carlsbad twins, reaching an inch and a half in length, of light flesh-color, inclosing laminæ of white, transparent oligoclase. The latter is dispersed throughout the rock in small portions, of white color, but not so transparent as when in the orthoclase. Quartz is colorless, transparent, not very plentiful; sometimes found as rounded grains. Chlorite of a pale muddy green to dark green and blackish green occurs in small crystals and crystalline masses replacing mica. Hornblende was observed rarely in thin prisms. For this rock I use the term Porphyritic Protogine.

Hornblendic rocks are found at several localities in section *c*, invariably forming peaks of considerable elevation. The masses are never continuous, but occur in isolated patches, in every instance serving as topographical stations—stations 2, 3, 43, and 44 being located on them—and, without exception, they are surrounded by granite. A stratified structure of the rocks will always be found, at times parallel to the stratoid texture, again making various angles with it. On station 2, Mount Ouray, we find the granite breaking through this rock; find it interstratified in a most characteristic manner; and find on the most precipitous side that the very interior of the mountain must be made up to a considerable extent of granite, which is coarse-grained, of light-red color, with but little mica. The shape of the mountain is approximately that of a huge amphitheater, the sides of which slope down steeply toward the center, a little more gently toward the periphery. Upon first sight, the rock composing this mountain might be called a coarse-grained hornblende-schist; but examination shows that the gray to dark-green mineral is not hornblende, but probably diallage; the white crystalline feldspar occurring interstratified with the diallage, is oligoclase; small quantities of a dark grayish-green chlorite are accessories; also an admixture of magnetite, containing probably a little chromic iron. In this instance, therefore, we have a rock that is quite widely distributed in the southern series and northern Italian Alps, characteristic in its structure, although in texture closely related to some others—euphotide. Considerable variation takes place in the texture, owing to changes in the relative quantity of the different minerals, and to the introduction of hornblende, whereby a more slaty structure is effected as through mica. The weathered surface is sometimes brown, although more frequently a dark-green, almost black. Station 3 is composed of the same material, and subject to the same variations mentioned above. Besides these points, we find a similar rock farther to the north and a little west of Mount Ouray—high black peaks of pyramidal shape, with clean-cut outlines, presenting faces with steep slopes. Here, however, the rock is more schistose still; mica occurring in more considerable quantity produces this effect. Stratification is also existing there, although the curious peaks in which the granite of station 2 indulges do not occur. At stations 43 and 44 mica occurs in such considerable quantities that the rock might seem more like a very fine-grained mica-schist, with little quartz and radiating hornblende and epidote as accessories. It seems that with these variations it would scarcely be advisable to refer this occurence to the same group to which Mount Ouray belongs; it seems to be more closely allied with mica-schists. Upon weathering, the rock scales off in single plates or tablets, that cover the sides of the mountain, and by their frequent sliding prevent the growth of vegetation. These schists stand in no such intimate connection with the granite as those spoken of above, and the boundary-line between the two is very distinct and sharp. All these points, with the exception of station 3, are located on the continental divide, and rise to considerable elevation. Besides these occurrences, there are no rocks of a similar character in section *c* except those dioritic ones forming dikes.

The Silurian formation is found in section *c* at several points along the base of the granitic mountains bordering the southern end of the Arkansas Valley, again surrounding station 38 and near station 42. Granite foot-hills slope off toward the valley of the Arkansas in rounded outlines, and immediately resting upon them we find the heavy Silurian beds, recognizable from their characteristic lithological constitution. Light-colored quartzites of yellowish, bluish, and reddish tints are conformably stratified with the superincumbent gray to bluish limestone with siliceous segregations, all dipping off uniformly at an angle of about 15° to 80° toward the north. Erosion has formed a number of bluffs along the lower edge of the Silurian rocks; but upward they recline in regular outlines upon the granite. As no fossils were found, I am not prepared to parallelize these formations with any occurring in the Eastern States; but lithologically they certainly seem to be identical with those found north of the Arkansas River. A section taken through Mount Ouray, running almost due northeast through station 55, may illustrate the position. The highest point of station 2 is composed of granite, (*a*,) and granite veins traverse the euphotide (*b*) throughout, which is represented by a series of granitic ramifications occurring

Section through Mount Ouray.

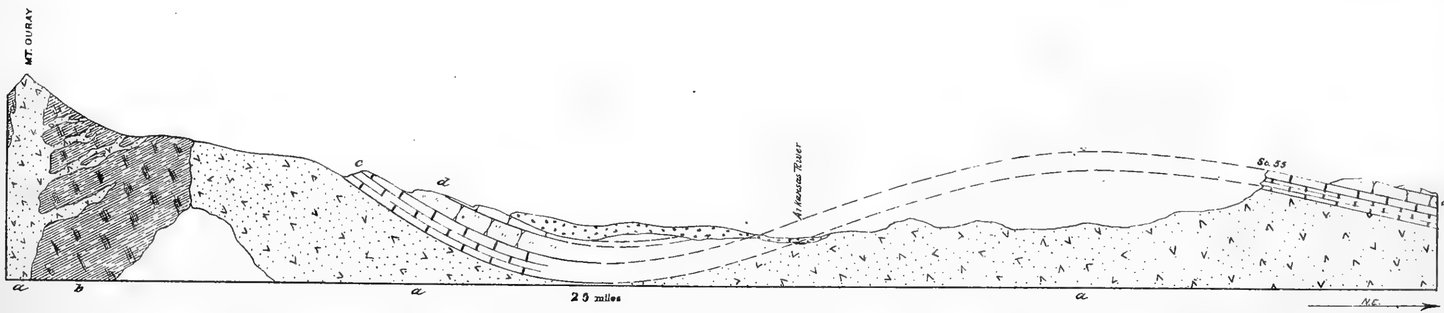
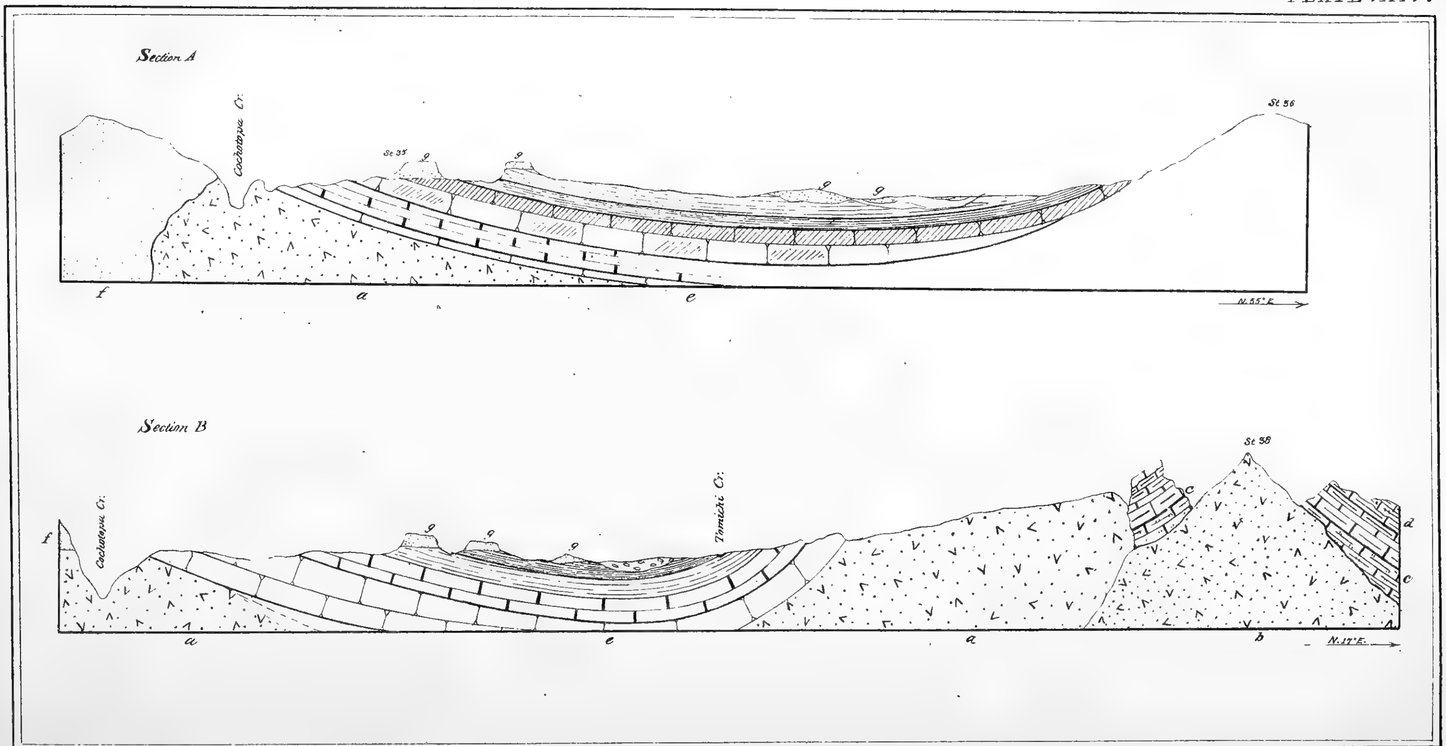


PLATE. XIV.


Section A
Cochetopa Cr.
St 35
g
g
g
g
St 56
f
a
e
N.55° E.
Section B
Cochetopa Cr.
f
g
g
g
Tomichi Cr.
St 38
c
d
c
a
e
a
b
N.17° E.

within the former, keeping approximately parallel with the westerly dip of the euphotide. Descending from the peak, this rock is suddenly cut off in an almost vertical, sharp line, visible for nearly 2,000 feet along the side of the mountain, and granite sets in, which continues until the valley is nearly reached. Here we find the Silurian beds, (*c*,) perhaps even Carboniferous, although that formation was not identified with certainty, dipping off toward the river. Drift-deposit (*d*) obscures the structure entirely, until the low rolling hills on the north of the Arkansas show granite exposed. Without much variation in altitude, this continues for about ten miles, until a bluff, rising rather abruptly, is crowned by the Silurian strata, (*c*,) upon which station 55 was located. The very formation of this bluff is probably owing to the hard, protecting cap of quartzites and limestones. It seems reasonable to suppose that the beds we found at the base of station 2 were at one time connected with those twenty miles farther to the northeast, and under circumstances whereby the construction of connecting-lines would indicate the formation of an S-shaped fold, which may have served to break up and destroy the connection. There seems to have been an inequality in the rising of the land on the two sides of the Arkansas at that point, which may account for the fold. This view of a former connection is strengthened by the fact that but fifteen miles below our section the Silurian of both sides approach each other within four miles. In the northwest corner of section *c*, the Silurian was also found, and identified again by its petrological character and its normal position to the Carboniferous. As it conducted itself, so far as could be noticed, throughout conformably with the latter, and no special stratigraphical studies could be made regarding it, I will refer to the description of the Carboniferous of that region. A doubtful point occurs at stations 36 and 37, where the quartzites closely resemble those of the Silurian formation; but the absence of Carboniferous in the line running from that point to the Cretaceous strata, without any inversion having taken place, prevents their exact identification, and therefore that point shall be left doubtful.

The Carboniferous formation occurs at one point only in the eastern portion of section *c*, unless it might be found overlying the Silurian, where it was not identified, however, lining the outer edge of the granitic mountains bordering upon Homan's Park.

In speaking of the Sangre de Christo range, reference has already been made to it, and the probability suggested, which is corroborated by this occurrence, that the Arkansas sandstone is persistent across the northern portion, and perhaps partially so across some of the middle and southern portions of San Luis Valley. The dip here is to the east, away from the mountains it rests upon. Of more importance are the Carboniferous rocks of the northwest portion of section *c*. Leaving stations 36 and 37 as undecided, we find farther northward the highlands north and south of the cañon of the Gunnison composed of Carboniferous limestones of considerable thickness. Ascending the steep granitic hills forming either side of the cañon, the stratified sedimentary rocks are seen crowning the top and gently dipping toward the cañon. Station 38 is located on a peak of eruptive granite, and surrounded on all sides by sedimentary beds. The northern portion of section B, Plate XIV, will show more clearly the position. After leaving the coarse-grained red granite, (*a*,) an immense dike of dioritic rock occurs, striking considerably out of course, almost east and west; but immediately after passing this dike, a heavy mass of limestones and quartzites (*c*) is found, upon the edge of which station 38′ was located. These strata have a dip to the south of about 20° to 25°, increasing, however, as we proceed farther north. Before reaching the granitic point, a stratum of hornblendic trachyte is found to cover the sedimentary rocks, the dip of which has increased at that point to about 30°. Standing on station 38, the highest point of the vicinity, at an elevation of 12,795 feet, the sedimentary rocks are seen to form a craterlike figure all around this cone, showing on all sides a strong radiating dip from it. On the sides nearest to the cone, the strata are exposed, presenting a face of about 1,200 feet in thickness, and falling off nearly vertically. The trachyte that partially covers the top shows itself in a distinctly-marked precipitous ridge capping the limestones, a large portion of which are changed to marble. On the south side, at station 38′, it was impossible to find that the strata there had any connection with those farther down the valley, while on the eastern and northern sides they slope off for some distance; on the southern decreasing their dip as they proceed. This point is so very characteristic and unique in its details that it is to be regretted that not more time could be given to a careful study of the changes that have occurred in stratigraphical and lithological conditions.

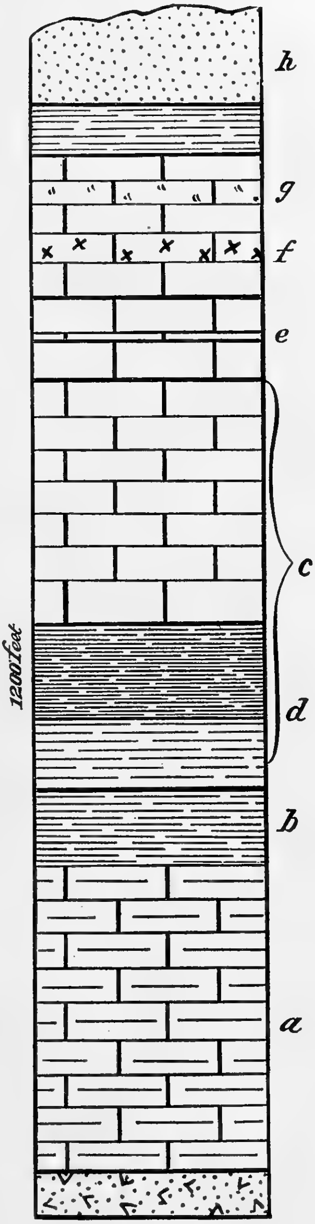
A section running through this wall of strata, with the thickness of beds estimated, shows the following arrangement:

The lowest members that can well be distinguished are about 320 feet of light gray to bluish to almost white limestones, (*a*,) with quartzitic segregations characteristic to the strata of that horizon, and sparse remains of crinoids. Although the identification is necessarily not a very thorough one, these beds have been referred to the Silurian. Above that follow 80 feet (*b*) of yellow and gray shales, regarded as Devonian; then 175 feet of variegated shales (*d*) partly sandy, with isolated banks of limestone, weathering smoothly, with a steep face; 260 feet of light-gray and yellowish limestones follow, interstratified with narrow bands of shale, and partly altered so as to appear like marble; the whole is covered by 40 feet of light shales, separated from 45 feet of the same material by a 20-foot stratum of dark-blue Carboniferous limestone (*e*) full of fossils; a short synopsis of which will be given at the end of the description of Carboniferous. This stratum is a well-marked horizon, and can be traced along for considerable distance, forming a narrow, dark line between the lighter rocks that over- and underlie it. Upon this follow 150 feet of light-blue and yellow limestones, (*f*,) dolomitic in part; a large portion of them altered into marble. Single bands of quartzite appear also, and almost all the strata contain a few fossils. Overlying there are 50 feet of yellow, reddish, and whitish shales without any fossils; 70 feet of a hornblendic trachyte (*h*) cover the whole.

About seventy square miles are covered by the Carboniferous at that point, but no connection is made with that on the north side of the cañon of the Gunnison. Ascending the heights north of the cañon, the same conditions are found to occur as on the south side; the sedimentary beds sloping down toward the river. At the point where the cañon opens into Taylor River Valley, the Carboniferous strata make a sweep down the hill, for a short distance form the bed of the river, and extend across it to the south, but only for a short distance. Station 42 is located on the north side of the cañon on a trachyte that covers the Carboniferous, which extends northward beyond the limits of our section. In thickness and stratigraphical relations, there exists an almost perfect identity between the formations on the two sides of the cañon.

Although the quantity of fossil remains occurring in that stratum of dark-blue limestone is very considerable, there are but few species, and

Fig. 10.



of those the preservation has been a rather inferior one. A number of crinoids, brachiopods, cephalopods, &c., were found. The aspect of several of the species reminds strongly of Upper Devonian types; but in determining here, the general character of things must be taken into consideration rather than the identification of any one single specimen be relied upon. Curiously enough, almost all the species found there are such as have very nearly allied forms in the formations preceding, so that discrimination becomes difficult. We have here a similar case to one that Professor Meek speaks of in the Report of the United States Geological Survey for 1872, page 432, in treating of the Carboniferous of Mystic Lake and vicinity: "They belong, without exception, to genera that are common both to the Carboniferous and Devonian, while a smaller portion of the genera is also represented in the Silurian." "Some of the *Producti*, *Chonetes*, and *Spirifer* have rather a Devonian look, while a fine striated *Hemipronites* is very similar to some of the Devonian types of that genus." "Notwithstanding the resemblance of some of these fossils to Devonian forms, and the fact that scarcely any of the species can be identified beyond doubt with forms peculiar to the Carboniferous, I must regard the whole as belonging to the lower part of the Lower Carboniferous." "The entire absence of any strictly Devonian and other types of corals, crinoids, lamellibranchs, &c., also favors the conclusion that this formation belongs to the Carboniferous, which conclusion is also supported by the specific affinities, if not even by the specific identity, of some of the species of *Spirifer*, *Productus*, &c." This quotation applies admirably to our present case. We find—

Numerous fragments of the columns of crinoids, not recognizable.

Large numbers of a delicate rimose *chætetes*-like coral, which is mostly weathered beyond recognition of outer structure.

An infundibular form of *Fenestella*, quite numerous.

Athyris, in one small specimen.

Spirifer, with the medial lobe finely striated longitudinally; the lateral lobes containing numerous stronger, simple, radiating costæ; varying considerably in size.

Rhynchonella, which has a decidedly Devonian aspect.

Orthis, a compressed resupinate form, with an extremely narrow area; probably a new species.

Hemipronites, closely related to *H. crenistria*, resembling some Devonian types.

Goniatites, in two very poor specimens.

Orthoceras.

Productus, in two specimens, that admit of some doubt, however; one fragment was found that seems to belong to a conoid univalve.

Mesozoic beds.—None are found in section *c*.

The Cretaceous formation is quite considerably developed near the central western portion of section *c*, following along Tomichi Creek. From the south and west, the predominating trachorheites have overflowed the sedimentary beds; and while a considerable portion is covered by them, erosion has broken through at several points, and thereby formed bluffs from 100 to 300 feet in height, composed of sedimentary strata and capped by volcanic material. All along the western side of the valley bordering on Coochetopa Creek this is the case, and on one of the bluffs station 35 is located. The greater part of the eastern portion of them seems to be made up of Cretaceous Nos. 2 and 3, while the western shows more of the lower sandstone strata. A section taken through a cut in a narrow gulch to be east of station 35 gave the following result, beginning from below:

22 feet, dark-gray shales, weathering a little lighter, containing *Ostrea complexa* and fragments of large *Inocerami.*
40 feet, of yellow shales, with white and yellow sandstones, full of *Ostrea* and *Inoceramus.*
17 feet, of light-yellow shales, of more marly character.
8 feet, of the same shale, traversed by plates of calcite from one fourth inch to one inch in thickness, of several feet in extent.
12 feet, brownish-gray shales, also with calcite.
40 feet, of gray shales, weathering lighter.
120 feet, gray shales, partly dark, partly light, weathering rapidly, containing toward their upper and lower limits pyrite and crystals of selenite.
30 feet, of light-gray shales.
20 feet, of yellow shales.

Above this there was rhyolite, having flowed from the southeast.

This thickness, of little over 300 feet, probably represents the average thickness of the Cretaceous beds of that horizon throughout that valley, as but small deviations from the general character were observed. In going up to station 36, these same strata were found again; but how they connect I am unable to say. They certainly overlie the quartzite of that station, dipping in a southwesterly direction toward the valley. Section A, Plate XIV, will explain the relative position of the strata. It runs almost due northeast to southwest from station 36 to station 35. The trachyte (*f*) predominating on the western side of Coochetopa Creek comes to a close there, and along the bed of the creek a coarse-grained granite (*d*) crops out. Resting immediately upon it, we find a quartzitic white sandstone, (*e*,) covered by light shales and shaly limestones; above these, another white sandstone; and then yellow shales with isolated sandstone strata. These latter are the shales referred to in the previous section, and it is they that are mainly covered by trachyte, (*g*.) A few miles north of station 35 they are covered by drift, and do not appear again until near the base of station 36. Whether the sandstone there is conformable or not with the Cretaceous strata, or whatever its stratigraphical conditions may be, could not be made out on account of the utter lack of any exposure of structural conditions. The next section (B) is taken through station 35 to station 88, having a course of a few degrees east of north. Here the strata can be more readily followed, and it can be made out with certainty that the second sandstone stratum, (*e*,) probably even the first, bends upward again to the north, and, reclining upon the granite, forms a shallow synclinal valley. The drift-material deposited by Tomichi Creek is quite considerable, and hinders somewhat in recognizing structure; but the yellow and brownish sandstone capping the granitic bluffs in the western portion of Tomichi Valley is probably Lower Cretaceous. In the eastern part, the dip is off from the trachorheitic mountains to the westward; while from the western end, the dip is southeastward. Wherever the characteristic yellow and gray shales occurred, considerable quantities of fossils were observed, but, strange to say, never anything besides *Ostrea* and *Inoceramus.* Over westward, toward station 41, the shales have disappeared almost entirely on the northern side of the valley, and nothing but the lower sandstones remain. It seems probable to me that the Cretaceous rocks extend, at least for some distance to the south and southeast, under the covering trachorheites, judging from the general orographic features of the country, that seem to be more those of a sedimentary one than of a volcanic. The Cretaceous that we find along Tomichi must have come in from the northwest in the form of a bay, and was probably driven back by the volcanic activity that was developed soon after south of it. About ninety square miles are covered by this formation here; and if it extends under the trachorheites as far as I think it probable, it will amount to about one hundred and fifty square miles more. Between stations 26 and 27 a small fresh-water deposit was found, undoubtedly belonging to the Tertiary period, and probably the Miocene. A section on page , illustrating the position of the eruptive volcanic rocks, will show its position. Resting apparently upon granite, it dips off gently to the westward, containing, in its strata of white argillaceous limestones and shales, numerous remains of plants and smal shells of *Limnæa*. The volcanic material coming from station 27 eastward covered the greater portion of the iittle bay, so that not much of it is exposed at present. This occurrence may be some small, merely local, fresh-water deposit, or it may be the continuation of a more extensive series of strata, which cannot be determined unless the country is either very well known, so that additional exposures might afford some reliable data, or otherwise artificial means of testing would be employed. Of the two, the former seems more probable, as some of the neighboring streams cut in quite deeply, down to the granite, so that any sedimentary rocks occurring there would have been exposed. This little outcrop is the only one of Tertiary beds that was found throughout the entire section, but it seems probable, judging from the orographic features of the country, that west of our district we may find more extensive formations belonging to that age. It may seem strange that along the center and consequently western terminus of San Luis Valley there is neither Cretaceous nor Tertiary, as the waters of that period could not have had any very great obstacles to overcome in reaching those points.

The larger portion of section *c* is covered by volcanic rocks belonging to the trachorheite group, which form a heavy mass of mountains, sometimes rising to a very considerable elevation, covering at the same time over fourteen hundred square miles.

In this main mass of trachorheites we find every variety belonging to the group represented. As a rule, it may be said that the highest and most prominent points are composed of andesites and trachytes, the latter rarely, however; that the plateaus and terraces are andesitic, sometimes trachytic tuffs; the low, bluff-like hills along the base of the higher mountains are of a rhyolitic character; and a number of little hillocks are formed by an ashy material, probably not much older, if not as young, as the rhyolites. Discrimination from the lithological character alone becomes very difficult wherever such an immense number of varieties occur. On every hill, on every station, several varieties of the predominating rock can be found, varying within twenty yards of each other to such an extent that it is by no means an easy task to draw the lines of distinction correctly. A mass of high andesitic mountains occurs about five to six miles south of Mount Ouray, upon one of which station 24 is located at an elevation of 13,400 feet, and throughout that portion of the volcanic country a number of peaks nearly as high occur, forming an almost regular horseshoe, studded with numerous smaller hills inside. When seen in the field, the impression produced by it was that of one huge crater-edge, containing within its limits a number of smaller eruptive cones. Along the crest of that crater, the andesites are very compact, hard, almost jaspery in appearance, changing somewhat as they descend into the lower portions; and on the eastern edge those mountains are bordered by compact, red rhyolites that have flowed down into the valley to an elevation not much over 7,500 feet. Andesitic tuffs make up a very considerable portion of the country there, but, contrary to their usual character, frequently show a compact texture. The andesite on station 23 has a very fine-grained, homogeneous paste of maroon color, with numerous crystals of oligoclase, few of orthoclase, and some of chlorite embedded in it. So great, however, is the variation that a short distance from the top the paste turns buff, the oligoclase has disappeared, sanidite occurring instead, and fine needles of hornblende replace the chlorite. Whereby these changes are produced that are only local, and sometimes limited to a very small portion of the rocks only, I cannot say, but strongly suspect that differences in the process of cooling, regarding both the method of, and time consumed in, cooling, may have produced these effects. All over the mountain, however, that rises considerably above timber-line, the rocks weather in thin slabs, from one inch in thickness to several feet, giving a submetallic sound when struck with the hammer. Some of the mountains between Ouray's Peak and station 23 have a slight color, from light red to yellowish, owing, probably, not to a change of material but to a difference in the weathering. On station 24 the character of the andesite is very similar to that of station 23, showing the same compact texture, and the same minerals, with the exception of orthoclase and chlorite, which latter is replaced by crystals of mica. Sanidite is contained in numerous crystals. Magnetite occurs in considerable quantity. As before, the same changes of color occur, due this time more to weathering, as the composition of the rocks undergoes no change. Taking the general aspect of the rock, it resembles trachyte to some extent; but its geological features and mineral constituents make it out as andesite. Leaving this interesting point and proceeding westward, we find the character of the country changing somewhat, the high, massive mountains disappear along Saguache Creek, and instead we find low table-hills, with steep sides and level tops. Frequently the sides of these tables have a stratified appearance, and the last upper stratum presents a steep, rugged face. A very characteristic feature of the mountains can be observed all along Saguache Creek, and also across the continental divide, that is, the terrace-formation on their sides. Evidently the tuff that forms these hills has at one time flowed along in such a manner as to form a stratum; another flow has succeeded it, perhaps after a lapse of considerable time; and the conditions at present are such that the hill-side will not weather off so as to form an unbroken slope, but every one of these larger flows is designated by a sharp terrace of barren rock, which is well illustrated by the annexed cut. Frequently three, four, and even more terraces are found, one above the other, parallel to each other, presenting light colors mostly, varying from white to yellow, reddish, and light brown.

Throughout the southwestern portion of the section, the occurrence of the trachorheites is uniform and very similar to those just described. Station 32 is located on the edge of a trachytic ridge, where the rock is red, slightly vesicular, certainly enough so to give it the characteristic roughness, changing at times into black, then becoming more compact. Crystals of sanidite and brown mica are dispersed all through the rock, and hyalite is found coating the sides of any small fissures that may occur. Hyalite is found very frequently in these volcanic rocks, as is also jasper, the latter varying in color from white to yellow, red, brown, green, and black. This trachyte contains but a trace of magnetite, while an andesite found near by contains a considerable quantity. Station 33 to the southwest of 32 is located upon a high, prominent point composed of andesite. The lithological character of this rock is so constant that, although a great many miles apart, no specific differences are found, and in this instance again we have a rock

Fig. 11.

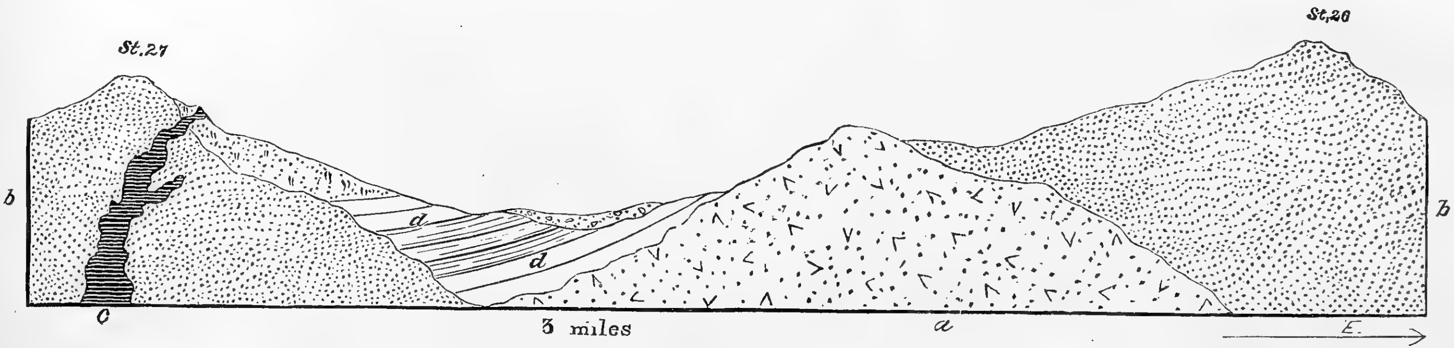
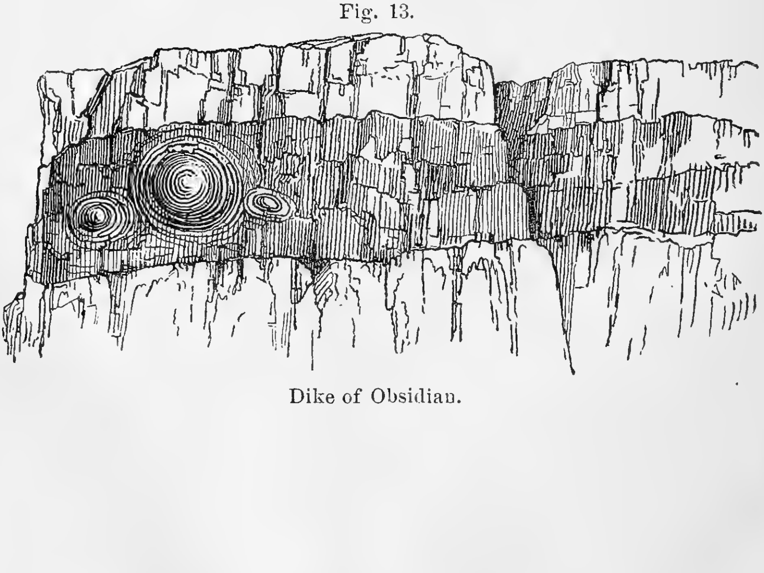


Fig. 12.

Strata of volcanic rocks near Sagnache.

Fig. 13.



Dike of Obsidian.

that could scarcely be distinguished from the andesite of station 56, more than eighty miles distant. Variations occur within certain limits, and are repeated at almost every place of occurrence in a greater or less degree, but the specific character remains true to itself. In the southern portion of section *c* andesite seems to form the highest peaks, well marked by their sharp, bold outlines, and their dark color, unusual in a country of trachytes and tuffs, while these latter compose the lower ridges and high plateaus. Station 34, west of Coochetopa Creek, is located on a sanidite trachyte; a brownish paste includes numerous crystals of sanidite, and also some of hornblende, black and bronze-colored mica. From that station north and eastward the tuffs, rhyolites, and trachytic ashes become more numerous again than they were in the more southerly portions, thereby changing somewhat the orographic features of the country, although it cannot be denied that this change may be partially produced by underlying sedimentary beds. The tuffs have overflown the Cretaceous beds east of the Coochetopa, and were probably cooled under water, whereby their character is changed to a considerable extent, as they present all possible varieties and differences in composition and texture. Mostly, however, they are of light color vesicular, containing crystals of sanidite, mica, and, if rhyolitic, free quartz.

At stations 26 and 27 we find a very interesting locality, showing a comparatively large variety of volcanic rocks, and at the same time the only deposit of sedimentary material that was observed in this great lava-region. Station 26 is located on a phonolitic andesite of a dark bluish-gray color, slightly vesicular at places, containing small needles of hornblende and small crystals of black mica and sanidite in a compact, microcrystalline paste. On the west side of the summit, the andesite shows columnar structure, each column being separated at a right angle to its longitudinal axis into numerous thin plates. Between stations 26 and 27 a low granitic hill makes its appearance, showing the andesitic cover for some distance. This granite is thoroughly altered by the effects of heat, which does not seem to have been quite sufficient, however, to bake it. Upon this granite, (*a*,) the Tertiary beds (*d*) are deposited, of which mention has been made above, covered on their western side by the rhyolitic ash lying upon the eastern slope of station 27. From white to yellowish pink and greenish, this ash presents itself as an agglomeration of feldspathic ingredients, mixed with small crystals of sanidite and mica, grains of quartz, fragments of andesite, and of obsidian also occur, altogether giving it the appearance of redeposited material. It is quite possible that it was deposited there at a time when Tertiary waters were still in that little basin, and that they owe a portion or all of the quartz-sand they contain to the fact of having taken it up from the lake-deposit. Not very far from the summit of the hill, the tuff becomes more compact, the fragments it contains are larger, its color a dark brown, forming a prominent bluff on that slope of the hill. About 25 feet from the upper edge of that bluff, a horizontal dike or vein of obsidian (*c*) occurs, 15 feet thick, and extending across horizontally for nearly 100 feet, until it is lost under the fallen *débris*. At the point where our sketch is taken, the obsidian shows spheroidal concretions, the largest one nearly 10 feet in diameter, the center of it forming a solid, round ball, with the obsidian nearest to it separating from the rest in concentrically spheroid scales. The obsidian contains small crystals of sanidite—therefore belongs to the porphyritic variety—and envelopes numerous small fragments of the tuff. A curious fact is that the tuff above the obsidian-dike is baked so thoroughly that it has become jaspery in texture, while that below remains unchanged. Quartz is contained in the shape of small fragments, which have been turned to semi-opal in the altered tuff. The cleavage of the latter has become conchoidal; it is hard, resembling jasper or massive porcelain more than anything else, and the change can be traced as far as the obsidian. Ascending to the summit of the hill, however, we again find andesite, identical with that of station 26. From the point where it covers the Tertiary beds the ash extends downward to Saguache Creek, and there follows along the base of the bluffs for a short distance.

On station 26 the andesite shows a phenomenon that is rarely equaled, and by which I was led to term it phonolithic andesite in contradistinction to other rocks of that group. When striking the large bowlders, even those of many cubic feet in size, they give a clear ringing sound, closely resembling that from a bell. The Ringing Hills at Pottstown, Pa., are similar.

In the southern portion of section *c* several times caves were found in the tuffs, a feature that seems to be characteristic to them. Crowning with a steeply-edged stratum some sloping hill, the caves had their entrance at the base of the rocky precipice, and extended inward sometimes for considerable distances. In several instances the shape of the entrance was so well cut that the idea of its having been done by human hands suggested itself.

Not unfrequently columnar structure was seen in different species of the trachorheites, as well in the andesite as in the tuffs, due most likely to particular circumstances by which the cooling may have been accompanied.

Besides this immense area of volcanic rocks, we have two more in section *c*, excepting those small remnants of overflows occurring in Tomichi Valley. Extending a little north, and about six miles west of station 45, is another accumulation of these rocks. It seems to be mainly trachyte, with probably some propylite, having a light-green paste, white to yellowish oligoclase, and a greenish hornblende. On the north side of the Gunnison another rock occurs that belongs to this group, covering the Carboniferous of station 38, composed of a light-grayish, almost white, microcrystalline paste, containing crystals of oligoclase and needles of hornblende, besides a very small quantity of magnetite. It is a trachyte, quite closely allied to propylite, and extends over but a small area to the southeast and east of the station. Station 42 is located on a trachyte of similar constitution, covering the Carboniferous rocks, which extends north and northeast into Dr. Peale's district, where he has found it, and gives a more definite description of it.

Dikes occur in considerable numbers throughout the granitic country, having a course of about north to south, and are composed of the same mineral constituents that characterize them in the other sections; epidote and hornblende mostly replacing mica, while at other times mica predominates.

Drift covers a considerable area along the western side of the Arkansas. A belt of about five miles in width runs along it, keeping parallel in its course and narrowing out toward the south. This drift is composed, so far as I have been able to learn from examinations at certain comparatively isolated points, of material that was brought down by the river mainly; secondarily, by the different creeks striking the river from the west. Although glacial action seems to have had considerable effect in transporting drift-material higher up on the Arkansas, I have not recognized any such means of conveyance in that portion of our district. Taking into account the shifting of streams parallel to their own general course, it becomes evident that the material deposited immediately along the base of the range parallel to the river must have been deposited by it, and not by any other means, provided lithological identification of the drift-rocks admits of no contradiction. This latter does not seem to be the case, however, and the accumulation of the greater portion of the redeposited material I ascribe to the action of the Arkansas. A number of creeks running out from deeply-cut ravines in the mountains have cut in an almost straight line through the drift; a circumstance which is readily explained by the fact that its resistance was so small as to necessitate no considerable deviation from a straight line. As they have cut in deeply, however, forms strongly resembling moraines have not infrequently resulted, which might mislead. Opposite station 4, the cañon of the Arkansas narrows and the drift-deposit disappears. Along Tomichi Creek a considerable quantity of drift has accumulated, covering about thirty to forty square miles, the material for which was brought from the neighboring granitic and quartzitic hills. Northwest of station 43 some drift has accumulated in the valley of the Upper Gunnison, part of which is due to the action of glaciers. In a long, narrow line, running from southeast to northwest, morainal deposits sweep down from the base of the high mountains to the valley. Characteristic narrow but level valleys, bordered on either side by lateral moraines, with a number of small glacial lakes, are found at the points of emanation. Changing their course slightly, these two moraines extend down into the valley, leaving at every favorable locality small lakes or swampy places, and they terminate on the sides in moraines, descending from 1,000 feet in height to 200. Reaching the valley, the ice melted and formed a large lake, at the place of which a swampy, low country now is found, inhabited by hundreds of beavers. In these moraines gold-washing has been carried on formerly, and is still carried on in some of the neighboring gulches. This is the only instance throughout our entire district where I could really recognize the action of glaciers.

Mineral deposits are found in only two localities of section *c*; the one on Mount Princeton, where a series of parallel veins are contained in the granite, running between the strata, which are peculiarly well-defined there. They are about 12,000 feet above the sea, but several of them have been worked to a small extent. Usually the strike is from northeast to southwest, and the dip about 135° to the north, with slight variations of either. The ores contained in these lodes are mainly galenite, sphalerite, and small quantities of fahlerz, resulting, when decomposed, in the formation of azurite and malachite. Argentite was found in a few specimens. According to report, assays that have been made are favorable. In the valley of the Upper Gunnison, *i. e.*, north and east of the entrance of the cañon, the drift contains gold, which has been worked at intervals for some years. In Union gulch, adjoining the valley, there were several miners at work at the time of our visit, apparently well pleased with their results. Single nuggets of several dollars in value are frequently washed out. Probably the drift-material of that region may contain paying quantities of the precious metal, which some day will most likely be turned to account by the enterprising western miner.

Resumé of section c.—In this section we have the greatest variety of granites met with thus far. Besides the red, middle to coarse-grained rock, that I think may safely be regarded as the oldest, a repetition of the type found in the two proceeding sections, we have another one, composing the Sahwatch range, containing as its most prominent peak Mount Princeton: near that we have the protogine, possibly owing its peculiar constitution to the close proximity with volcanic rocks; and lastly, the eruptive granite of station 38. Throughout, as well in lithological and mineralogical character as in the structure of mountains, the three main varieties can readily be distinguished. In other countries granites have been found, that are said to reach back only to very late geological ages; here we have one the protrusion of which I think falls into a Post-Carboniferous period. The evidence afforded by the Sangre de Christo range of section *b* is corroborated by the observations made here. Less noticeable than in the two preceding sections is a gradual or sudden rise of the main granitic mass, which, if it has occurred, must have been but slight, and not of long duration or great power.

An accumulation of hornblendic rocks is a curious and interesting feature, and the similarity they bear to alpine and other euphotides, combined with the fact of their usually reaching very high altitudes, may point to an analogy of formation and relation to surrounding rocks.

Astonishing is the mass of volcanic material that had accumulated and found its points of outflow in this section, at the same time showing no very massive deposits at any one point, as might have been expected. Upon the origin of this and the other volcanic effluvia, we will speak in the "Conclusion."

CONCLUSION.

In concluding the report of the geognostic and geological features of the district assigned to me for 1873, it may be of value to give, in general outlines, the distribution of geological formations throughout it, and to speak briefly of the correlation existing between them.

In taking a bird's-eye view over the mountains of this district, it becomes strikingly evident at a glance that two main systems of mountain-ranges traverse the country: the one, geognostically granitic, in a direction a little west of north and east of south; the other, volcanic, crossing it at almost right angles, having a course of about 15° south of west and north of east.

Granite seems to be the oldest rock found there; but there are four distinct varieties of it, three of which are considerably younger than the first, the red to pink variety, mostly coarse-grained, abounding, with local accumulations of the one or other constituent mineral. The second type, the age of which will probably be correctly defined as Post-Devonian, is that which occurs in the northeast portion of section *c*, forming the high sharp peaks that are so characteristic to the range west of the North Arkansas. While oligoclase is of exceedingly rare occurrence in the oldest granite, it is found to be the mineral second in quantity only to orthoclase in this instance, imparting an entirely different character both as regards appearance and weathering. Of probably the same age we find the porphyritic protogine of station 45, owing its constitution most likely to some different circumstances experienced while cooling. Eruptive granite is the fourth variety, occurring in the Sangre de Christo range and on station 38, of Post-Carboniferous age, resembling in its lithological character more closely that of Mount Princeton. Although the term "eruptive granite" is frequently used by European writers, this has not been done to any considerable extent by Americans; and I would state that I do not consider it eruptive in the same sense that basalt is eruptive, but merely wish to imply by that term that the granite, by some vertically-acting force the origin and effect of which cannot be discussed here, has been forced upward, may have not only assisted in locally disturbing strata with which it was at one time in no immediate contact, but has actually, by virtue of this force, been brought into contact with such strata. Footing upon the observation of facts that to me cannot be otherwise explained, I see no discrepancy with any well-founded hypothesis that may be universally accepted to regard the immediate action of the granitic masses as implying the agent of a vertical force to which it must owe its elevation. Examinations were made with a view to determine the presence of magnetic iron in the specimens of granite collected in this district, and it was found that not one specimen was without it. As a rule, the light-colored granites, of a more recent date than the red ones, contained more than the latter, a fact that can readily be explained by assuming that their younger existence upon the surface could not admit of so extended an influence of atmospheric agencies upon their constitution, while the older granite may probably owe its decrease in the percentage of magnetic iron, and, on the other hand, its red color, to the action of these agents. By increasing its percentage of oxygen, the iron compound contained would change in such a manner as to impart to the rock that color which it now possesses. It remains to be stated that there are two exceptions to the rule above given, where in both instances magnetite was contained as a mineral impregnation in the red granite, in the one instance even in crystals of three-fourths of an inch in diameter.

Of the Silurian formation we have some of the oldest strata, as indicated by the comparatively unsatisfactory paleontological remains, and from these upward the Devonian rocks also seem to be represented, although no strict identification was possible. The Carboniferous is well developed, showing great uniformity in the groups of strata. Considering the imperfect evidence derived from the fossil remains below the Arkansas sandstone, there might be some doubt regarding its age, and the question could arise whether it would not be more correct to assign it a position parallel to the "Old Red" of the Devonian; but, for reasons based upon stratigraphical evidence and the total absence of fossils that might decide, this has not been done. A wide gap now follows, comparing the formations of this district with those analogous from other parts of the world, until the Mesozoic period is reached. The position of this series seems to be as well established as possible with the very meager amount of fossils that has been found. In some of his earlier expeditions, Dr. Hayden has found *Pentacrinites* in some strata that are recognized as having their position above the so-called "red beds," which would settle the question, leaving ample space, however, for any subdividing of the group. Well-defined and of admirable uniformity in character are the Cretaceous strata, to which the five adopted divisions apply without discrepancy. The gradual receding of the formations belonging to this group from the mountain-edge, the still greater development of this feature during the Post-Cretaceous epoch, speak for the gradual rise of the land west of them during a period of time that must be located in the close of the Cretaceous. Apparently a knotty question arises when the age of the "Lignitic" beds is considered; but undoubtedly future investigations, not merely of the paleontological remains, but of the geognostic relations they bear to over- and underlying formations, will tend to clear up any lingering doubts. Those found in our district seem (speaking with all the reserve that a mere superficial examination demands) to be of an age which can paleontologically be referred neither to the Cretaceous nor to the Tertiary, analogous perhaps in character to the Wealden formation of Europe, that is placed between the Jurassic and Cretaceous. Views of the present day regarding "formation" and "age" are merely conventional, and it is more than probable that by the time a little more of the remaining four-fifths of the land on the surface of the earth are explored geognostically and geologically, they will be compelled to undergo considerable modification.

Tertiary, Diluvial, and Alluvial deposits are found under such conditions as would be favorable to their formation. In consequence of the rise of the main body of land, the marine Tertiary was forced to retreat farther toward those portions that were still submerged, and no strata were found that could be referred to this epoch unless of a local fresh-water character. Drift, belonging both to Diluvial and Alluvial ages, is abundant. Alluvial deposits, as everywhere, owe their character to the rock to which they owe their existence, and the old principle of "same cause, same effect" is clearly discernible.

Glacial phenomena, that seem to be more abundant farther north, were recognized in but one locality, and there they were not of any considerable extent.

By far more varied, and of deep interest, are the volcanic eruptive rocks, so widely distributed throughout the district. Richthofen's excellent classification, comprehensive and yet concise, finds a new support in the twenty-three hundred square miles of trachorheitic material contained in our district. Throughout, the given character of andesite, trachyte, and rhyolite could be relied upon as soon as the position of andesitic tuffs was properly recognized; and although the different conditions undoubtedly influencing the cooling of the masses at different points produced almost innumerable varieties, even within limited areas, his appreciation of identity and correlation was not impaired. A question of great importance arises during the contemplation of the immense quantities of this material; it is the one touching their origin. Without entering upon the various hypotheses that have been advanced upon this point, with a semblance of more or less probability, I will make a few suggestions that have occurred to me as the necessary consequence of the observation of facts.

As stated above, it was impossible to find even a single one of the specimens of granite free from magnetic iron, although more was found in the younger ones than in those preceding them in age. The same examinations carried on with a considerable number of trachorheites from different localities give the invariable result that andesite contains a large (comparatively speaking) percentage of this mineral; trachyte less; rhyolite still less; the tuffs of these species giving results in accordance with those shown by the rock to which they belong. The rising percentage of silica as they are higher—younger in the scale—until rhyolite contains free silica; their approximate uniformity in chemical composition throughout the world, which points to an origin from similarly constituted material; and their almost unexceptional occurrence in granitic countries, besides the great similarity of percentage which their constituents show, upon analysis, with the constituents of granite, seem to lead to the conclusion that they may owe their origin to a remelting of granite. More careful and specific examinations are required, however, to prove this hypothesis. With a view to so doing, I have undertaken investigations into the questions involved herein, and shall therefore do no more than suggest the idea until results obtained justify a more complete and comprehensive assertion.

A few words may also be said regarding the distribution of the geological formations over the entire district.

Granite forms all the higher portions of the eastern edge of the Front range; but on the northern side of the Arkansas it is covered largely by trachorheites, and, to some extent, by sedimentary formations. Continuing its course westward, it forms the main mass of mountains in the north, whereas the entire southwestern portion is volcanic. The sedimentary beds of Silurian and Carboniferous age traverse the central portion of the districts in a narrow band in a southeasterly direction, the former edging the latter in the northern portion, disappearing in the south. Again, they reach into the northwest corner of the district coming from the north, and covering about one hundred and fifty square miles. Mesozoic and Tertiary beds are found only along the eastern edge of the Front range, with the exception of one or two isolated patches of small extent. The Cretaceous occurs all along that same edge, extending into the mountains in a few bays of ten to twelve miles in length, and is found in the western portion of the district, a continuation of the formation farther north.

Volcanic rocks cover the granite partially in the eastern and northern half of the district, forming the high plateaus, while the granite appears in the eroded cañons. A few isolated patches are scattered throughout the granites, one of them extending in a very narrow line parallel to the Sangre de Christo range. The largest portion is that forming the southwestern corner of the district, which probably extends considerably beyond it both west and south.

Drift covers San Luis Valley, the upper valley of the Arkansas, and Wet Mountain Valley, besides small portions on the Tomichi, at Union Park, and on Taylor River Valley.

The mineral resources of this district are confined to gold, silver, iron, coal, and marble, of which mention has been made in speaking of the several sections in which they occur.

APPENDIX.

MINERALOGICAL NOTES AND A CATALOGUE OF THE MINERALS OF COLORADO TERRITORY.

MINERALOGICAL NOTES.

One of the most interesting regions in Colorado, from a mineralogical point of view, is undoubtedly the vicinity of Gold Hill, of which Mr. Marvine treats in his report, as it is located within his district.

There a number of dikes of porphyry have found their way out through the granite, and, contact between the two, a number of lodes have been found, several of which have attained considerable celebrity. The Red Cloud and Cold Spring are located on the two sides of a porphyry-dike 50 feet in thickness, striking about northeast to southwest, and from them principally the rare and valuable tellurids, sought for by mineralogists, have chiefly been obtained. Prof. F. L. Schirmer, of Denver, had the kindness to supply me with a number of specimens from the Red Cloud mine, which I have examined, and herewith give a report upon. Before speaking more particularly of the tellurids, a few words may be said explanatory of the circumstances under which they are associated with other minerals at the mines of that locality.

Composing the dike between the Red Cloud and Cold Spring, we find a porphyry of dark-grayish to purplish color, containing numerous small crystals of two varieties of feldspar in its cryptocrystalline, compact paste. While forming the hanging-wall of the Red Cloud, it is the foot-wall of the vein opposite. Fragments of this porphyry, mixed with particles and streaks of quartz and feldspar, together with small flakes of talc, make up the gangue-rock of the Red Cloud, collecting in small cavities, crystallizing in cubes combined with the pentagonal dodecahedron. Pyrite occurs throughout the vein, also forming at times narrow streaks, but invariably with a strong tendency to crystallize. At some points the porphyry too is thoroughly impregnated with this mineral. Galenite occurs sparingly in cubical crystals; also sphalerite in narrow seams. Quartz-crystals, coated by ferric oxide, are found in the small cavities occurring with them, both of more recent origin than the sulphurets. Compounds of silver, copper, selenium, &c., with sulphur, seem to be wanting entirely; instead, however, we have the unusually rich occurrence of tellurets, of which we shall speak presently.

To the west of the Red Cloud is the Cold Spring, the ores of which show no variation, however, while the same granite and the same porphyry form its walls.

East of the Red Cloud, striking almost due east and west, is the Winona, located between two walls of gneiss. In this lode the gangue-rock is mainly quartzitic, containing small portions of decomposing feldspar and of talc. Chalcopyrite and pyrite form the main ore, occurring in streaks and thin threads partly, partly disseminated in crystals of cubical and dodecahedral form throughout the gangue.

Some distance to the southwest of the Red Cloud we find the Central, Seven-Thirty, and Americus, located contact to a long dike of porphyry and the surrounding granite. In a light-gray microcrystalline paste we find embedded numerous small crystals of black mica, crystals of a probably triclinic feldspar, and small, irregular particles of white quartz.

Of all the veins located on this dike, the main one is chalcopyrite and pyrite, with the usual accessories; sphalerite and galenite occurring rarely. In none of the specimens that reached me could I find any tellurets, although their analogous mode of occurrence might lead to some expectation of their presence.

In various parts of the world, compounds of tellurium with other metals have been found, so that the first attempt at recognizing analogous minerals from the Gold Hill region was to identify them with those already described. It seems to me that the tellurets of the region under consideration show a greater variety of composition than those of other localities. For entering into combination with other elements, the facilities must have been great; we have one compound, that of tellurium and iron, which, although not occurring pure, enters into the formula of the mineral. During the coming field-season, I expect to obtain a satisfactory supply of material, in order to give a complete synopsis of the mineral-occurrences of the Gold Hill locality.

Two minerals were found, occurring both at the Red Cloud and Cold Spring lodes, that could not strictly be parallelized with any known species, and I have reserved the right of distinguishing them by a separate name, if subsequent examinations of more abundant and purer material will warrant it.

No. 1.

Isometric, imperfect crystals observed. Cleavage cubical, good. Mostly found in thin threads, or in small, irregular, foliated masses.

Hardness, 2 to 2.5. Specific gravity, 8.5253. Luster metallic, splendent. Color bright silver-gray to steel-gray; pale bright-yellow when exposed to atmospheric influences a short time. Streak metallic, gray to silvery. Opaque; brittle; partly malleable and sectile.

On account of the small quantities that could be spared for analysis, the tellurium was not determined but calculated; the result of careful qualitative examinations having revealed no trace of any other elements than those found and given below.

By analysis the following constituents were obtained:

Pb,	Fe,	Ag,	Au,	Te by diff.,	
53.19	5.05	0.31	trace	41.45	=100.00

Calculating the simple tellurets for each one of these constituents, we find there are required for—

53.19 Pb,	5.05 Fe,	0.31 Ag,
32.90	11.55	0.19 = 44.64 tellurium.

It is probable that slight replacements may account for the smaller quantity of tellurium found.

The percentage of constituents found leads to the formula—

$$3\,PbTe + FeTe$$

a very minute portion of lead having been replaced by silver. During the examination, great pains were taken to procure the mineral as pure as possible, and only such fragments that showed a distinct cleavage on all sides were subjected to the tests. Pyrite almost invariably is found associated with this mineral, and the idea suggested itself that the iron might be accounted for in that way. Several trials were made, therefore, without giving any sulphur however. It may be stated here that all the examinations were made of pieces obtained from one specimen.

This mineral has in its physical characters some resemblance to the *Altaite*, which, however, contains no iron and about 60 per cent. of lead.

In the open tube, the assay gives off white fumes of tellurous acid, condensing into colorless drops upon being heated to a high degree.

Before the blow-pipe on charcoal, with the oxygen-flame, the coal is coated with a white layer some distance from the assay, highly volatile, and near it a grayish-silvery coating is formed, consisting of the volatilized and recondensed mineral. After treating the assay on charcoal a little while, it becomes slightly magnetic, melts readily, and volatilizes at a comparatively low temperature.

When gently warmed with concentrated sulphuric acid, not heated to boiling, the tellurium contained in this mineral imparts to the acid a cherry-red color, more or less intense. Nitric acid affects it; nitro-muriatic dissolves it. The solution obtained is yellow, owing its color to the presence of iron.

This species occurs both at the Red Cloud and Cold Spring mines. If subsequent investigations, with a more ample supply of good material, confirm the result of the above examinations, I shall propose to distinguish this mineral from other tellurets of lead by the name of *Henryite*, dedicated to Prof. Joseph Henry, director of the Smithsonian Institution.

No. 2.

Probably orthorhombic, (no crystals were found from which the crystalline form could be deduced beyond a doubt;) occurring mostly in thin threads and foliated masses. Cleavage perfect; hardness, 1 to 1.5; luster metallic, splendent; streak submetallic, dark-gray to black; color between bright lead-gray and steel-blue; opaque; partly malleable and sectile; flexible when broken into thin scales.

In consequence of being obliged to work with very small quantities, it was impossible to make more than a partial quantitative examination, which, however, combined with the qualitative, appears to distinguish this mineral from any known species:

Au,	Ag,	
18.82	28.60	per cent.

while the qualitative analysis revealed yet tellurium, iron, and lead; of the latter merely a trace, however. An approximate determination of the iron leads me to infer that the formula will be—

$$3\,Ag\,Te + (Au\,Fe)\,Te$$

In this mineral, the percental ratio of Au to Ag is 2:3, while in the mineral nearest related to it, in the Petzite, it is 5:8; and while Petzite contains on an average 25 per cent. of gold and 40 of silver, these figures are not so high in our mineral.

In the open tube it gives off tellurous acid, acting like No. 1. Before the blow-pipe in the oxygen-flame, it coats the charcoal white, giving in the reduction flame an impure globule of gold and silver. After being heated a short time, the assay becomes highly magnetic, indicating the presence of a considerable quantity of iron. Nitro-muriatic acid decomposes the mineral.

Subject to the same conditions as No. 1, I shall, if the results are subsequently verified, propose for this mineral the name of *Schirmerite*, dedicated to Prof. J. F. L. Schirmer, of Denver, who kindly supplied me with specimens from his rich store.

NATIVE TELLURIUM.

Hexagonal; occurring massive and in small crystals; lateral cleavage, perfect; form, columnar masses in the accompanying white quartz.

Hardness, 2 to 2.5; specific gravity, 5.802, which is lower than that given for tellurium, 6.1 to 6.3; but may be explained by the fact that the metal and quartz could be separated but imperfectly. Structure, lamellar; color, tin-white to light steel-gray; luster, splendent; streak, submetallic, light-gray to gray.

In the open tube it gives off white fumes of tellurous acid and a strong selenium odor. Before the blow-pipe, on charcoal, melts readily, coating the latter white in the oxygen-flame; black or very dark-gray in the red flame. Treating for some time with the red flame on charcoal and moistening the black coating with concentrated sulphuric acid, the coating will turn a bright carmine upon warming gently. Held into a steady oxygen-flame it colors it blue, with the edges tinged bright green. Bismuth produces a slight yellowish tinge on charcoal near the assay. In the closed tube the characteristic red deposit occasioned by selenium is found.

As stated above, this tellurium is intimately associated with quartz, which composes 52 per cent. of the entire mass. An analysis, in which the constituents other than tellurium were determined approximately, gave the following result:

Te,	Se, Fe, Bi,	Au,	Ag.
90.85,	approximate,	trace,	trace.

Having obtained more material, a full analysis will be given. It is not so pure as the tellurium from Transylvania, which yielded from 92 to 97 per cent. of the metal.

CATALOGUE OF THE MINERALS OF COLORADO TERRITORY.

The following is a list of the minerals found in the Territory of Colorado, given as completely as possible up to date. In compiling it, the observations of Professor Schirmer, from Denver, Mr. J. A. Smith, territorial geologist, Mr. von Schulz, E. M., Mr. Peters, E. M., Mr. Frazer, E. M., Dr. A. C. Peale, Mr. Marvin, and myself have been used. The single initial after the enumeration of each locality or series of localities gives the name of one of the above-mentioned gentlemen by whom the mineral was collected or observed at that locality. Mr. Smith's Catalogue of the Principal Minerals of Colorado afforded much valuable information. The comparatively meager representation of mineral species in a country so richly endowed with mining-lands as Colorado is perceptible at a glance. Very little definite and applicable knowledge has thus far been gained relative to the distribution of minerals and ores throughout the world, and every catalogue, however small, if only accurate, adds its share to the further development of that knowledge.

ACTINOLITE.—In radiated form, of light-green color, on station 2, E. On Buffalo and Sopris Peaks, P. Bergen's ranch and North Boulder Creek, S.

AGATE.—Cloudy, of white and gray color in the trachytic formations of station 27, in various forms at the Los Pinos agency, E. In South Park, in the Arkansas Valley, and on the Frying Pan in varieties, P. Throughout Middle Park, M.

ALABANDITE.—At Quartzville, Peters.

ALABASTER.—Mount Vernon, S.

ALLOPHANITE.—Frankline mine, in Gilson Gulch; Fowler and Wells's tunnel, Sugar Loaf district, S.

ALUMINITE.—Mount Vernon, S.

ALUM.—Mount Vernon, S.

AMAZON STONE, (*Adularia.*)—Elk Creek, S.

AMETHYST.—At Nevada and other neighboring localities, S. On Rock Creek, P.

AMIANTHITE.—North Boulder Creek, E.

AMPHIBOLE.—Buffalo Peak, P. Montgomery, Peters.

ANGLESITE.—Freeland mine on Trail Creek, S. In crystals at the Horseshoe lead-mine, in South Park, Peters.

ANHYDRITE.—On Elk Creek, F. Crystallized at the salt-works in South Park, Peters.

ANTHOPHYLLITE.—North Boulder Creek, S.

APATITE.—At Fairplay, Peters.

APOPHYLLITE.—Station 22, E.

ARAGONITE.—Occurring in the form usually termed *flos ferri*, very beautifully in Marshal's tunnel, Georgetown, E. Golden, S.

ARGENTITE.—Colorado Central Mine, Terrible, and other mines at Georgetown; in the No Name, Caribou, and others at Caribou; in some mines near Nevada; in the Senator lode of the Hardscrabble mining-district; it occurs mostly in small quantities, imbedded either in quartz or in the predominating ore; when decomposed, native silver is the result, E. At the Silver Star, Moore, and other mines near Fairplay, Peters.

ARSENOPHYRITE.—Priest Mine, Fairplay, Peters.

ASBESTUS.—Occurs in small quantities, partly radiated, near Caribou, E.

AVENTURINE FELDSPAR.—On Elk Creek, S.

AZURITE.—In the No Name, together with malachite, the result of decomposition of fahlerz, Caribou; in the Rosita mines in Hardscrabble, E. On Trail Creek, S. On Crater Mountain, in the mines around Fairplay, and in the mines of Elk Mountain district, P.

BISMUTHITE.—In the Las Animas mine, pseudo-morphous after—

BISMUTITE.—From the Las Animas mine, Sch.

BARITE.—In yellow tabular crystals, clear in the Tenth Legion mine of Empire, in the Terrible mine near station 17, and on station 46; near Canyon City transparent crystals occur in the arenaceous formations of that locality, E. In Gilson Gulch, Georgetown, S. Crystals occur in the limestones around Fairplay, P.

BASANITE.—East of the salt-works in South Park, P.

BERYL.—On Bear Creek, Tiffanny's ranch, S.

BIOTITE.—On Buffalo Peak and station 64, P.

BITUMINOUS COAL.—At several localities along the Border range, at Pueblo and Canyon, E. On Trout Creek Pass, P.

BRUCITE.—On James Creek, F.

CALCITE.—In small crystals, scalenohedra, at the Monte Christo Central; on station 35, camp 32, E. At Mount Vernon, Bergen's ranch,

S. Rhombohedral crystals on Cheyenne Mountain; in the limestones of South Park; scalenohedra in Elk Mountain district; fibrous in Trout Creek Park; on Frying-Pan Creek, P.

CALEDONITE.—Freeland mine, Trail Creek, S.

CAOLINITE.—Camp 42, E.

CARNALLITE.—Salt-works, South Park, Peters.

CARNELIAN.—Middle and South Parks, M. Los Pinos agency, E.

CERARGYRITE.—Gilpin County lode, Black Hawk, S. Small, compact quantities in the Wade Hampton mine, Peters.

CERRUSSITE.—J. P. Whitney mine, in very small crystals; Central; No Name, Caribou; Caribou mine; Silver Hills mines and Rosita mines in the Hardscrabble district, E. Freeland mine, Trail Creek, S. In the Horseshoe mine it occurs earthy, and is found throughout the mines of Elk Mountain district, P.

CHALCEDONY.—On station 27; at the Los Pinos agency, E. Middle and South Parks, M. and P. Buffalo Park; Fair Play; Frying Pan; Trout Creek, &c., P.

CHALCANTHITE.—On Clear Creek below Black Hawk, in a deposit, and on several dumps near Central, E.

CHALCOCITE.—Bergen district, near Idaho City, F. Liberty lode, Bear Creek, S.

CHALCOPYRITE.—Auriferous in the Bobtail, Winnebago, Dallas, Gunnell, Running, Kansas, California, and other mines at and near Central; mostly occurring compact, and frequently very intimately intermixed with pyrite. It occurs in every paying gold-mine in Gilpin County, and the miners seem to think a great part of the "pay" dependent upon its presence. It also occurs in the Terrible, Pelican, Cold Stream, and other mines of Georgetown, as well as in those of Caribou and Hardscrabble, E. In the gold and silver mines of Fair Play and the Elk Mountain District, P.

CHLORITE.—On station 45, E. On Trail Creek, S. On Sopris Peak, P.

CHLOROPHANITE.—Bergen district, S.

CHROMITE.—Massive; Silver Hills and Fair Play, Peters.

CHRYSOCOLLA.—Champion lode, Trail Creek, S.

CHRYSOPRASE.—Rare, in Middle Park, S.

COAL.—*Vide* BITUMINOUS COAL.

COPPER.—Native; arborescent in the Gregory lode, Central, E.

COPPERASITE.—On the dumps of the Wood Lode and Nevada, E.

CUPRITE.—In crystals, from Sacramento Gulch and from the Sweet Home mine, Peters.

DOLOMITE.—From the Four-Mile Creek, P.

EMBOLITE.—Peru district, Snake River, F.

EPIDOTE.—In crystals together with garnet on Gunnell Hill, Central; in crystals, small, on stations 17, 43, 46, 50, and 77. A large number of the hornblende-dikes traversing the country contain epidote, either massive or in small crystals, E. On the summit of Mount Bros, Lake Creek Cañon, Grand Mountain, Elk Mountain Ridge, and all through the foot-hills, P. On Trail Creek, S.

FAHLERZ.—Terrible, Colorado Central, Pelican, and other mines of Georgetown; No name, Caribou, and others at Caribou; station 46, E. For particulars see chapter 1.

FELDSPAR.—Occurs in the gangue-rock of a large number of mines near Central and Georgetown; crystals showing the Carlsbad twin-system are found in Gregory Hill, Central, in the porphyry, at station 46, at Rosita, E. Twins are also found in the porphyries of Gold Hill, M., on Elk Creek; and at Idaho, S. Compare ORTHOCLASE.

FIRE-CLAY.—Golden, Ralston, Boulder, &c., S.

FLOAT-STONE.—Mammoth lode, Central, S.

FLOS FERRI.—*Vide* ARAGONITE.

FLUORITE.—Terrible mine, Georgetown, in light-green cubes; in small crystals and massive, of violet color, on Mount McClellan and Gray's Peak, E. On Bear Creek, S.; massive, pink and violet in the Sweet Home mine, Peters.

GALENITE.—In narrow seams, fine-grained, Winnebago; feathery in the Dallas mine; coarse-grained in the J. P. Whitney, Running, Monte Christo, Forks, and other mines of Gilpin County. In the Colorado Central, Equator, Star, Pelican, Terrible, and others it occurs in large quantities. The Cold Stream shows beautiful crystals, combination of cube and octahedron, with rarely the rhombic dodecahedron. The International, at an elevation of about 12,800 feet, has a heavy vein of galenite. The No Name, Caribou, Fourth of July, and other mines in Boulder County contain the mineral. The Silver Hill mines (fine-grained) and the Rosita mines in Hardscrabble district. On station 46, E. Hamilton, the mines around Fairplay show crystals; the mines of Elk Mountain district, the head of Iowa and of Empire Gulch contain galenite. In small scattering quantities it is found almost throughout the country, P.

GARNETS.—Crystallized in rhombic dodecahedra and sometimes ikositetrahedra; found together with epidote in the dike on Gunnell Hill. Closely resemble the garnets from Auerbach, in Germany. In mica-schist at camp 14 and at station 22, E. On Trail Creek, Bergen, &c., S. Montgomery, Peters.

GOLD.—Native gold in very small and indistinct crystals in the Bobtail, Gunnell, Quartz Hill, near Central, E. Tarryall Creek, Placer Diggings, near Fairplay, in imperfect crystals and laminæ; in Washington and California Gulches, in the Placers of Union Park, and numerous other localities, P. Occurring as the result of decomposition of the tellurids at Gold Hills, M. Lately discovered native in large quantities, though very minutely distributed, in the quartz-ledges of the San Juan mining-district.

GOSLARITE.—On the dumps of the Wood lode, Leavenworth Gulch, near Central, E.

GRAPHITE.—Trinidad mine, Las Animas County, Sch.

GREENOCKITE.—On sphalerite of the Dallas mine, Black Hawk, E.

GYPSUM.—Is distributed very widely throughout the Cretaceous formation of Colorado. Good crystals are rare. Selenite is the usual form of its occurrence, frequently being found in twins.

HALITE.—Salt-works of South Park, along some parts of the Platte River in springs, P. Found as salt-licks in various parts of the Territory.

HEMATITE.—Specular, on Procer Hill, Central, E. Head of Bear Creek; fibrous and specular in Philipps mine, Silver Hills; in the mines of Elk Mountain district; micaceous on station 65; on Sopris Peak, P.

HENRYITE, *n. sp.*—Red Cloud mine, Gold Hill, Sch. and M. Cold Spring mine, M.

HITCHCOCKITE.—On copper minerals of the Dallas mine, Black Hawk, E.

HORNBLENDE.—Occurs in numerous localities in the dikes, so that it would be useless to enumerate them. Good crystals none were found. Radiated on station 43, E.

HYALITE.—On stations 33 and 34 in trachyte, E. At the Hot Sulphur Springs of Middle Park, S.

IDOCRASE.—*Vide* VESUVIANITE.

IRON.—Native, in the Colorado meteorite found in 1866, S.

JAMESONITE.—Sweet Home mine, Peters. San Juan, Sch.

JASPER.—Green and red, station 33; yellow, red, brown, gray, Los Pinos Agency, E. Throughout Middle and South Parks, M. and P.

LABRADORITE.—Near Golden in the dolerites, E. Near Fairplay in the trap-rock, P.

LEAD.—Native, in Hall Gulch, Summit County, Sch. At Breckenridge, S. An announcement of native lead must always be received with the necessary caution. The specimen owned by Professor Schirmer I have seen, but, although it had a very "natural" appearance, was unable to decide.

LEPIDOLITE.—Station 17, in a form resembling the Saxon zimuraldite, E.

LEUCITE.—Table Mountain, Golden City, S.

LEUCOPYRITE.—Spanish Bar, S.

LICORITE.—North Clear Creek, S.

LIMONITE.—Near station 17, E.; in the Tertiary sandstones west of Plum Creek, near Colorado City, P.; in several localities of South Park, Peters.

MAGNESITE.—In small quantities in the running lode at Black Hawk, E.

MAGNETITE.—In loose nodules on Gunnell and Procer Hills, at Central; in small octahedric crystals in the gneissic rock on station 1; on station 54, E. Occurring in the granites of various localities, Silver Hills, White House, Capitol, in the doleritic rocks generally, P. At Idaho and Caribou, S.

MALACHITE.—Is found as the result of decomposition of fahlerz and other minerals at the Dallas, Leavenworth, and other mines near Central; at the No Name, Caribou, Seven-Thirty, Fourth of July, and others, at Caribou; at some of the Georgetown mines; at the Hard-scrabble mines, on station 46, and other localities, E.; at Crater Mountain, in the mines of Fairplay and Elk Mountain district, P.

MARCASITE.—Philipps mine, Fairplay, Peters.

MELACONITE.—Occurring at the Gunnell, Briggs, Leavitt, Leavenworth, and other mines, near Central, E.; at the Unknown mine in Montgomery, Peters.

MELANTERITE.—On the dumps of the Wood, Dallas, and Kansas mines, and others, near Central, E.; in the Sweet Home mine, Peters.

MESITINITE.—Black Prince lode, Lump Gulch, S.

METEORIC IRON.—*Vide* IRON.

MINIUM.—Freeland mine, Trail Creek, S.

MISPICKEL.—Together with pyrite in the Bobtail and other mines, E.

MOLYBDENITE.—Leavitt mine, at Central, S.; occurring in thread-like veins in Silver Hills, near Fairplay, Peters.

MUSCOVITE.—In good crystals on station 2, and in the coarse-grained granite near Cañon City; throughout the granite, and partly in the schist-rocks, E.

OBSIDIAN.—Porphyritic, in a dike, at station 27, E.; Buffalo Peak, Arkansas Valley, and Union Park, P.

ONYX.—Middle Park, M.

OPAL.—Milky and precious at Idaho City, E.

ORTHOCLASE.—In crystals in the porphyries on Gregory Hill, partly altered into sanidite. It occurs sometimes in very large pieces throughout the coarse-grained granites of Colorado, E.; in the porphyry-dike at Gold Hills, crystals of large size, M.

PEGMATITE.—At several localities in the vicinity of Georgetown, on station 2, E. Bear Creek and Gold Hills, in Boulder County, S.

PETROLEUM.—From the oil-wells in Oil Creek Cañon, to the east of Canyon City, E.

PETZITE.—In the gold-mines of Gold Hill, occurring in narrow seams and veins, M.

PHLOGOPITE.—On station 46, E.

PITCHBLENDE.—Occurs in large quantities; massive in the Wood lode in Leavenworth Gulch, near Central, E.

POLYBASITE.—In tabular crystals at the Terrible mine, near Georgetown, E.

PRASE.—Middle Park, M.

PREHNITE—Fair Play, in some of the mines, Peters.

PROUSTITE.—Occurring in the Brown lode, intermixed with galenite, F.

PSEUDOMALACHITE.—Little Platt River, south of Fair Play, P.

PSILOMELANE.—Seaton mine, Idaho, occurs in small quantities, E.

PYRARGYRITE.—In the Colorado Central, Terrible, International, Cold Stream mines, at Georgetown, associated with galenite, fahlerz, and sphalerite, E. In the Brown lode with galenite, F.

PYRITE.—One of the most widely-distributed minerals in the Territory. As a rule, it is auriferous, occurring crystallized in pentagonal dodecahedra in the Bobtail, Bates, Briggs mine; in cubes combined with the pentagonal dodecahedron at the Winnebago, Mack, Dallas, Kansas, Grand Army, Gunnell, and other mines, all near Central City. In immense bodies it is found in the Mammoth, Briggs, and Leavitt lodes. It is found crystallized in the Terrible, Pelican, New Boston, Cold Stream, and other mines near Georgetown; at the Tenth Legion mine in Empire; in cubes at stations 45 and 46, E. Found also in Silver Hills, crystallized in the mines of Buckskin. Cubes of four to five inches edge in the Philipps mine; in the Elk Mountain district, on Eagle River; in octahedra on station 65, P. In the mines near Idaho, crystallized and massive, M.

PYROLUSITE.—Massive at Buckskin and in Silver Hills, Peters.

PYROMORPHITE.—Freeland lode, Trail Creek, S.

PYROXENE.—Near Fair Play, Peters.

QUARTZ, CRYSTALS.—Gunnell lode, Briggs mine, Quartz Hill and other localities near Central. In the Rosita mines, in some of the Georgetown mines, at station 46, E. On East River, in the mines of Elk Mountain district, Iowa Gulch, Sopris Peak, P.

QUARTZ, SMOKY.—On the Colorado divide; large crystals on the Upper Platte, and on Pike's Peak, P.

QUARTZ, ROSY.—On station 70, E.; camp 39, P.; Bear Creek, S.

RHODOCHROSITE.—Sweet Home mine, Park County, Sch., in very beautiful specimens, and in the Diadem mine, Buckskin, Peters.

RUTILE.—On Ute Pass, occurring in quartz, Peters.

SARDONYX.—In Middle Park, M.

SCHIRMERITE, *N. sp.*—Red Cloud and Cold Spring mine; Gold Hill, Sch. and M.

SCHREIBERSITE.—In the Colorado meteorite, S.

SELENITE.—At various localities in the shales, station 35, E.

SEMIOPAL.—At Los Pinos agency, E.

SIDERITE.—Crystallized in South Park, Peters.

SILVER.—Native, as wire-silver at the Terrible, Georgetown, at the International on Mount McClennan; as wire-silver in the No Name and Caribou mines at Caribou, E. In small nuggets and thin scales near Fairplay, in Washington Gulch, Homestake lode, P.

SINTER.—Siliceous, South Park, S.

SMITHSONITE.—Jones's mine on sphalerite, near Central, E. Running lode, Black Hawk, F.

SODA.—Carbonate, from the Hot Springs of Idaho, E.

SPHALERITE.—Occurs in almost every mine; only few exceptions take place. In the lead-silver mines it is more abundant than in the gold-mines. It is found in the Winnebago, dark brown, Dallas, Gunnell, J. P. Whitney, Kansas, Wood, California, Running, Bobtail, Briggs, (small quantities in these two,) Monte Christo, and numerous other mines in the vicinity of Central. The mines of Georgetown invariably contain it. The Caribou mines show at times large quantities of the mineral. Station 46, E. Sphalerite containing cadmium is found in several mines near Fairplay, Peters.

SPINEL.—Crystal mine, Virginia Cañon, S.

STEPHANITE.—Colorado Central, Georgetown, E. Moose mine near Fairplay, and others, Peters.

STIBNITE.—Terrible mine near Georgetown, E.

SULPHUR.—In a small crystal on galenite from the Clifton mine near Central, von Schulz; found in Middle Park, S.

SYLVANITE.—In the Red Cloud mine of Gold Hill, occurring in foliated masses and thread-like veins, M.

TALC.—In fine scales among the gangue-rock of the Bobtail and Kansas near Central. In light-pink scales in the Silver Hills and Barton mines, Hardscrabble district, E. On Sopris Peak, P.

TELLURIUM, NATIVE.—At the Red Cloud mine of Gold Hill, in crystalline masses, belonging to the hexagonal system. Found in a specimen obtained from Professor Schirmer.

TENNANTITE.—Crystals in Buckskin Gulch, Peters. Geneva district, Park County, Sch.

TETRAHEDRITE.—Crystals in Buckskin Gulch, Peters.

TOURMALINE.—In the quartz of Gunnell Hill, Central, of Running Hill, Black Hawk, E. On Guy Hill and at Nevada, S. Station 64, P. Crystals with both terminations at Montgomery, Peters.

TUFFA.—Calcareous, Currant Creek, E. Roaring Fork and Frying Pan, P.

TURQUOISE.—Southern Colorado, doubtful, S.

URANINITE.—On the dumps of the Wood lode in Leavenworth Gulch, E.

VESUVIANITE.—In large crystals of simple combination on Mount Italia, station 64, P.

WILLEMITE.—Jones's mine, Central, E.

WOLLASTONITE.—Near Fairplay in the limestones, Peters.

ZINCITE.—Jones's mine, Central, S.

ZINKENITE.—Sweet Home mine, small crystals, Peters.

ZIRCON.—Bear River, Middle Park, S.

PART II.

SPECIAL REPORTS ON PALEONTOLOGY.

THE LIGNITIC FORMATION AND ITS FOSSIL FLORA.

BY LEO LESQUEREUX.

COLUMBUS, OHIO, *July* 14, 1874.

DEAR SIR: I send you herewith my report on the botanical paleontology of the Tertiary formations of the Rocky Mountains.

The results of the explorations of 1873 in regard to my special researches are exposed in the description of the new species of fossil plants, and in the discussion of the data furnished by these plants on the age of the Lignitic formations.

As there has been of late some discussion on this last subject, and as the opinions of the explorers do not yet agree, I have reviewed in the first part of my report the facts and arguments bearing evidence on the age of the Lignitic; in the second part, I have marked, by tables, &c., the distribution of the Tertiary flora in relation to the periods which they seem to represent; in the third part, the description of the new species, or of those which were not yet known from American specimens, is given; and the fourth has a review on the climate during the North American Tertiary epoch, as indicated by the character of the groups of its fossil flora.

Besides what is due to the co-operation of the members of your corps in the collection of specimens of fossil plants, the survey is greatly indebted to Captain Berthoud, and to Mr. A. Lakes, of Golden, for the discovery of new species and the communication of splendid specimens.

Very respectfully, yours,

L. LESQUEREUX.

Dr. F. V. HAYDEN,
United States Geologist, Washington.

INTRODUCTION.

I shall begin my report of this year by a more detailed review of the essential facts and data which, furnished essentially by vegetable paleontology, have forced my conclusions on the age and the geological distribution of the Lignitic formations of the West.

There is always some uncertainty in the reference of fossil species to peculiar geological stations, when the paleontologist is called to describe them and judge of their geological relations without having himself examined the localities wherefrom the materials have been derived; this on account of a casual mixing up of specimens, and also because the more characteristic species, which are sometimes of rare occurrence, escape the eye of those who, unacquainted with fossils, collect specimens at random, and wherever they find them, for the examination of a specialist. For this reason I have to base my classification on the localities which I have visited myself, and on those which, either from stratigraphical evidence or by a close analogy in the characters of their fossil remains, are ascertained as synchronous.

1st. I refer to Eocene (Lower American Eocene,) all the coal-strata of the Raton Mountains; those of the Cañon City coal-basin; those of Colorado Springs, where a coal-bed, the Gehrung's, is opened and worked; those of the whole basin of Central and North Colorado, extending from Platte River or from the Pinery divide to south of Cheyenne, including Golden, Marshall, Bowlder Valley, Sand Creek, &c., and, in Wyoming, the Black Butte, the Hallville, and the Rock Spring coal. By analogy of geological characters, compounds, and succession of strata, as indicated by Hayden, Leconte, and others, and also by the presence of species of fossil plants, which I consider as leading plants of the group, I refer to the same Eocene formation the Lignitic beds of New Mexico as far south, at least, as the Placière anthracite coal; in Wyoming, those of Bear River; and in Utah, those of Coalville, as described by Professor Meek in the former report of Dr. Hayden, (1872, p. 435.) From its fossil plants, the coal of Nanaimo, Vancouver Island, is referable to this section.

2d. I consider as American Upper Eocene (or Lower Miocene, the coal-strata of Evanston, and from identity of the characters of the flora, as seen from the specimens communicated to me, those of six miles above Spring Cañon, near Fort Ellis; of the locality marked near Yellowstone Lake, among basaltic rock; of Troublesome Creek, Mount Brosse, and Elk Creek, Colorado. The specimens from Bellingham Bay, Washington Territory, refer this locality to the same horizon.

3d. To the Middle Miocene I refer the coal-basin of Carbon, and from the identity of vegetable remains the Washakie group, Medicine Bow, Point of Rocks, and Rock Creek.

4th. To the Upper Miocene belongs the Green River group of Wyoming; the coal of Elko Station, Nevada; the leaf-bearing strata of South Park, near Florisant and Castello Ranch; of Middle Park, and of Barrell's Spring.

The localities where only a few specimens of undeterminate relation have been obtained, and which are not named in this connection, are of little importance. They may become positively identified with one of these stages of the Tertiary, and for this reason, in order that the means of comparison may be more easily recognized, I propose to modify the plan of my former reports in the following manner: The specimens examined from the exploration of past year (1873) will be described in separate sections or groups, to which are referable the localities wherefrom they are derived; and instead of placing in a single synoptical table all the species known from our American Tertiary measures, it will be more appropriate to prepare a table for each of the Tertiary stages, as recognized above; reserving a general table for a later time, when our Tertiary divisions are more positively recognized. It is to this last end especially, and as stated above, that these different tables may be useful. The materials which we have now on hand are abundant enough to point out a marked difference in the vegetation of the different horizon of the Tertiary, though the general characters of the separate groups which they represent are not yet well determined enough to give positive evidence in regard to the exactness of these divisions. As our Tertiary measures are of wide extent, and are likely to become more and more carefully studied, these different tables will afford points of comparison for local floras, and therefore for identification of local formations, just as, in the former reports, the general tables furnished for the comparison of the geological epochs, the Cretaceous and Tertiary, an evidence which is needed no more; for, indeed, I believe that from the descriptions, details, and expositions of the characters of each of these separate groups of the Tertiary, its age and its disconnection from the Cretaceous will be established positively enough to prevent any further discussion on the matter.

§ 1.—AGE OF THE NORTH AMERICAN LIGNITIC.

Besides the evidence furnished on the age of this formation by the characters of the vegetable remains, I have, in my former annual report to Dr. Hayden, drawn some collateral conclusions, which I wish to briefly review now, in order to separately consider, in regard to them, any new evidence afforded by the researches of 1873.

These conclusions were taken, 1st, from the fact of the immediate superposition of the strata bearing plants to well-characterized strata of the upper series of the Cretaceous, the Fort Pierre and the Fox Hill beds of Hayden's section, in the Report for 1871, (p. 87.) This immediate superposition of the heavy fucoidal sandstones and of the Lignitic over Upper Cretaceous rocks, is seen in full evidence, as remarked in the report, in the Raton Mountains of New Mexico, around Trinidad; all along the ridge of sandstone from Trinidad to the Spanish Peak; at the Cañon City coal-basin under the Lignitic formation, as marked in the section of Mr. Nelson Clark, superintendent of the coal-mines; at Colorado Springs, in following the bed of Monument Creek, from the depot to Gehrung's coal; at Golden, Marshall, &c. On this subject my observations agree with those formerly recorded by Dr. Hayden, Dr. Leconte, and others; the succession of the strata has been recognized by all the geologists.

2d. I have not denied, and do not deny now, the presence of animal Cretaceous remains in the strata of the Lignitic, though persisting to consider the formation as Tertiary notwithstanding; for I regarded and still regard the presence of some scattered fragments of Cretaceous shells as of little moment in comparison with the well-marked characters of the flora, characters which have been fully established by a large number of specimens obtained from all the localities referred to the Lignitic. I remarked, however, on the scarcity, if not the total absence, of Cretaceous animal remains in the whole extent of the Colorado basin, from the Raton Mountains to Cheyenne.

Since then, new evidence has been supplied to this subject, first by a letter of Prof. E. T. Cox, who, in company with Dr. R. Owen, found specimens of *Scaphites* and *Inocerami* in strata supposed to belong to the Cretaceous Lignitic, as quoted by Dr. Leconte in his Notes on the Geology of the Union Pacific Railway, (p. 19.) Professor Cox says, concerning these specimens, which are still in his cabinet—

I copy from my memorandum-book the section and notes made at Spanish Peak, a range of the Rocky Mountains, from a stage-station on Purgatory Creek.

Cretaceous.

Hard band	20 feet.
Thin and thick bedded sandstone, Schistose sandstone and shale, Solid bedded sandstone.	200 feet.
Thin coal	——
Solid grit, with pebbles	70 feet.
Talus at base	400 feet.

The talus rested upon the table-land, which is 240 feet above the bed of the creek; total height, from bed of creek to top of section, 930 feet. The ridge extended back from face of hill, and appeared to be about 100 to 150 feet higher.—(Note on section from memorandum-book:) Found in the wash at foot of talus in the above section, *Scaphites nodosa,* and a species of *Inoceramus.*

The section is similar to those given in Hayden's Report for 1872, (p. 319), of the Lignitic and its underlying heavy sandstone, on the Purgatory Creek, near Trinidad, which is underlaid by a talus of Cretaceous black shale, No. 4. It compares especially well to my own, in the same report (p. 320), of the range opposite Trinidad, where the underlying black and Cretaceous shales and covered space to the bed of the creek measure 300 feet. From this place, and along the stage-road to Spanish Peak, the distribution of the strata is the same, the heavy Lignitic sandstone towering over the talus of the black shale, like a wall, as reported, (*loc. cit.*, p. 321,) and overlaid by the beds of lignites, or the productive Lignitic. That, therefore, the Cretaceous fossils found at the base of the talus of black shale No. 4 do not prove that the Lignitic above is of Cretaceous age is evident enough. The section of Professor Cox, on the contrary, confirms the deductions taken in relation to the superposition of the Tertiary Lignitic to the Cretaceous in that part of the country.

The authority of Captain Berthoud, of Golden, has been often quoted on the same subject, and is generally considered as of great weight in geological matters of Colorado, a region which this gentleman has for many years surveyed for the construction of railroads and carefully examined with the eye of a practical geologist. He has been reported as supporting the assertion that Cretaceous mollusks had been found above the beds of the Lignitic formations. In regard to my inquiries on this subject, he had, like Professor Cox, the kindness to give his detailed opinion in a letter, whose statements are worth preserving. He says,

1st. That if Professor Stevenson observed *Inocerami, Ammonites, Scaphites, Baculites, Nuculæ,* &c., in superposition to Lignitic strata of Colorado, it is clear to me that it is only a case of local inversion; *i. e.*, that, as shown in our basin of Golden, the Lignitic sandstone has been so tilted up that, with the coal-seams near by, it was thrown over the perpendicular, and thus Cretaceous strata would appear in superposition.

2d. That between this Lignitic and the Cretaceous beds holding *Inoceramus,* &c., on Bear Creek, there is fully one mile on an east or west line, so that the Cretaceous beds and the Lignitic coal-shale, fire-clay, and sandstone are not conformable in dip, and clearly show the superposition of the Lignitic beds. This is undoubted, as the Cretaceous limestone *debris*, under green and yellow clay-beds, disappear under the coal-beds at our old camp on Bear Creek that you visited with me.

At Golden I cannot see that the Cretaceous beds are conformable to the sandstone and coal; so far I wrote to A. R. Marvine. Now, I will add to this for you some other remarks. It has always seemed to me a stumbling-block when ten years ago, or more, and until 1868–'69, I supposed and believed that our coal was Cretaceous, to find everywhere, when examined by me, that there was no conformability between the Lignitic Measures and the outcrop west; and that at Ralston, Bear Creek, Table Mountain, the stratification was also unconformable to all from the coal westward. But when I find that as we proceed east, the superimposed Tertiary beds are getting more and more horizontal, and that in the clays and sandstones above the coal, we see a well-developed resemblance in fossil plants up to the basalt overflow, I gave up the idea of the Cretaceous origin of this Lignitic, and the possibility that a salt-water deposit could belong to the same geological horizon, as indicated by the Tertiary fresh-water deposits, particularly as the conformability of this coal and this Cretaceous limestone can nowhere be shown. As to Dr. Leconte's report of what I found east of Pike's Peak, it is in the main true. I found coal when on a scout. I judged it was nine feet thick. It seemed almost horizontal, but I would not say it was horizontal, as it was badly cut up by the drainage of the small gully we found it in. In bluffs north or northwest I found several *Baculites* that seemed to come from a clay-bed in the bluffs; but whether this coal was superimposed to this baculite clay, or the clay was over the coal, I could not say positively either way. Southwest of this locality, twenty-five miles, on the Arkansas, the *Baculite* clay-beds are below the *Inoceramus* limestone, and no coal whatever above.

3d. The coal-bed opened near Platte Cañon I have not yet seen. I know that fine *Baculites* and *Scaphites* have been obtained there, said to be near the coal, but have no evidence of it; will visit and report to you, as soon as I can, just what I find there. But I think it is a case of local inversion, as the coal, to within three and one-half miles of South Platte River, is tilted up the same as at Bear Creek, Golden, Ralston, &c. Eleven miles north of Golden, on Coal Creek, these Lignitic beds are regularly inclined east, and no Cretaceous beds west of them can I find. At Murphy's coal-mine no Cretaceous fossils are found east of the coal. In Golden, cutting a deep well in the green Tertiary clay about 1,000 feet east of the coal has exposed a stratum of deep-green clay, with a large deposit (leaf-bed) with leaves changed into glossy coal. They seem to belong to *Salix*, *Platanus*, *Rhamnus*, &c.; a gramen, also a small fragment of an elytra, or wing-case of an insect. The fossil beds near Bowlder County are accompanied with clay full of casts of leaves, of sedges and grasses, mollusks, fossil turtles, and one or two bones that Professor Marsh thinks are *Dinosaurus*.

This is sufficient to show that, except the specimen of *Inoceramus* found by Dr. Leconte at the Raton over-Lignitic beds, no Cretaceous fossil mollusks have been found till now in the whole Lignitic basin from the Raton Mountains to Cheyenne.

3d. To answer the objections that at Black Butte, Coalville, Bear River, and other localities in Wyoming, the Lignitic beds and sandstone bearing plants had been recognized underlying strata with fossil remains of Cretaceous animals, I had to examine if, from its nature and its fossil plants, the Lignitic formation should be of necessity recognized as a whole, or if it could be separated into different members, the one representing the Upper Cretaceous, the other the Lower Tertiary. For this, of course, the essential documents to be considered in the view of my special researches are the fossil plants. From the large number of Fucoids in the sandstone, and from the identity of some of the species of these marine plants found by Professor Meek, even in connection with the lower strata of the Lignitic as far down as the arenaceous beds of Bear Creek and Coalville, with Cretaceous animal remains; from the prodigious preponderance of palms, leaves and fruits, recognized also in the same circumstance, &c., I forcibly admitted the unity of the Lignitic formation in its whole, and therefore limited the discussion to this point: the Cretaceous or the Tertiary age of the formation. The detailed examination of the fossil plants of the Lignitic and of their distribution affords more evidence on this question.

4th. To strengthen my position in regard to the conclusions afforded by vegetable remains, I compared the Lignitic formations to those of the Carboniferous epoch, remarking that, having positively a preponderance of land-plants or a land-character, they should be considered as a land-formation; that in every formation, especially in every land-formation like that of the Carboniferous, the fossil animal types are more or less in discordance with the vegetable forms in regard to the data furnished by them on the age of the formation. As in the Carboniferous we find Devonian mollusks far above the millstone-grit, and also Permian shells far below the Permian, and as the Carboniferous is now generally recognized as a homogeneous single formation, I argued that, the same disaccord being remarked in our Lignitic measures, we had to explain it in the same way, and should not, on that account, force an abnormal division of a formation whose flora is positively analogous or synchronous in its characters in the whole thickness. A discrepancy of the same kind is recognized in the Cretaceous formations of Europe, even between the groups of animal fossils which characterize them. The president of the Society of Natural History of Geneva, my honored friend, Rev. Duby, says, in his discourse of 1861, in regard to the geological observations recorded during the year,

That the society had been favored by Professor Pictet with numerous communications relative to paleontology, of which the most important is a notice of the succession of the cephalopod mollusks during the Chalk period in the region of the Swiss Alps and Jura. Mr. Pictet derives, from a detailed study of the fossils contained in the Cretaceous strata and their comparison with contemporaneous repositories, an argument in favor of the idea propounded by Mr. Barande, that two successive faunas must necessarily have existed together for some time, and he concludes by showing that paleontological faunas, distinguished through by marked characters, are not ordinarily susceptible of any rigorous limitation.

Messrs. Claparède and Favre took occasion to remark on this, how much the conclusions of Mr. Pictet must in future complicate the task of geologists who undertake to determine the age of the formations. On the same subject Count Saporta, one of the highest European authorities in vegetable paleontology, remarks,* in speaking of the presence of *Ammonites*, *Baculites*, *Inoceramus*, &c., in the American strata, which, by their fossil plants are characterized as Eocene, that these mollusks have persisted for a longer time in the Cretaceous of America than in Europe; a fact which is easily admitted, as, in France, the chambered cephalopods had left the Cretaceous seas of the south long before they disappeared from the north. The same remark is repeated in Jukes and Geikie's Manual of Geology, (p. 664.)

In parts of the north of France there occur curious banks of white pisolitic limestone, resting apparently in hollows of the chalk, &c., but sometimes on the same level as the lower beds of the Tertiary rocks above it. Some of the fossils are true Cretaceous, while none, I believe, are Tertiary forms.

We have apparently something like this in our geological Upper Cretaceous formation, if, as it seems proved, we do not find any kind of Cretaceous mollusks in the Lignitic basin of Golden, when their presence is still ascertained in the Lignitic of Bear River and Coalville. The English geologists remark on facts of this kind, (*loc. cit.*, p. 665:)

That the existence of local groups of rocks that will not exactly fit into the general series, either from their containing fossils different from those found in any other group, or from their uniting parts of two sets of fossils which are elsewhere distinct, although sometimes perplexing, seems neither unnatural nor different from what might be expected. It merely shows us that our geological series is a series of fragments, not one of absolutely continuous succession.

In his travels with the Hassler, Professor Agassiz has observed a case which may serve to explain anomalies between the records furnished by animal and vegetable remains in regard to the age of the strata.†

The geology of the coast of Possession Bay is interesting to the highest degree. All along the coasts, north of the Straits of Magellan, the Tertiary formations, same as along the coasts of Eastern Patagonia, are perfectly distinct, even seen from a distance, by their horizontal strata, also remarked on the coast of Fuego. In Possession Bay we landed to more carefully recognize the character of the country, &c. One mile inland from the cliffs I found, at 150 feet above the sea-level, a pond of salt water, which, to my great surprise, had an abundance of marine shells, identical with those of the sea along the coast. They were in a perfect state of preservation; many were living,

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* In letters.

† Letter of Professor Agassiz to Professor Peirce, in Boston Advertiser. I have to retranslate this from the French *Revue scientifique*, No. 46, May, 1873.

and I could collect a large number of specimens, with living animals, for preserving in alcohol. The most numerous were *Fuci, Buccini, Fissurellæ, Patellæ, Volutæ*, &c., all in the same numeric relation which was remarked in the sea under the cliffs. The presence of this salt pond, with its living inhabitants, proves a very recent upheaval of the coast. The exact time could not be precisely fixed without a more extensive geological examination. The fact is the most complete confirmation of Darwin's assertion, published more than thirty years ago, that there has been a recent upheaval of the coasts.

Admitting the fact as it is exposed by Professor Agassiz, and supposing that, after an epoch of time, there should be a contrary, slow movement or depression of the same land, and that from the start this depression should be accompanied by the introduction of fresh-water lakes, of swamps, &c., the growth of extensive bogs, and the formation of peat-beds by plants; that over it a succession of shales and sandstone should be formed by more rapid depression and the invasion of muddy or sandy water, &c., the result of this heaping-up of new materials would represent, of course, a more recent formation, characterized by its remains of fossil plants, this, under or below the level of a more ancient one, characterized by its fossil invertebrate animals, &c.

5th. In recording the opinions of geologists, who, by their researches, have furnished materials (animal fossils) as evidence of the Cretaceous age of the Lignitic, I quoted Professor Meek's passage of a letter, where his opinion is exposed rather in favor than in contradiction of mine. Of course, I was not then informed of his conclusions published later. We have now, in the report of Dr. Hayden for 1872, (pp. 431–462,) the result of the researches of this careful observer, tending to prove that the Lignite deposits of Coalville have been positively recognized underlying strata characterized as Cretaceous by their remains of mollusks. As no fossil plants have been discovered in connection with these coal-beds, except the omnipresent fucoid, *Halimenites major*, no argument can be put forward from the comparison of vegetable fossil remains. It is, however, remarkable that the constitution of the Lignite of Coalville, the thickness, the distribution of the beds, is about the same as that of Evanston; so similar, indeed, that the more experienced miners and superintendents of the mines at Evanston and other places consider these Lignitic beds as the same. The difference of fixed carbon in the lignite of the two localities is only 1 per cent.; that in the proportion of water, only 2; in volatile matter, only 3. And if we admit that the chemical compound of the coal and the lignite, like that of the peat, depends especially from the original constituents, the plants, we have in this fact of identity of chemical compounds more than a probability of a homogeneity of original or vegetable components. In this case the discussion is recalled to this point, as remarked above: the whole Lignitic being a homogeneous formation, we have to decide if it is Cretaceous or Tertiary.

The locality where the discussion on the relation of fossil remains may be made with the most advantage is that of the Bitter Creek series, where there is an abundance of vegetable remains represented, at Black Butte especially, and of animal fossils, saurians, shells, &c., also found in profusion in the strata of this series from Black Buttes to Rock Springs. In the whole series, neither Professor Meek nor his assistant have found any shells truly characteristic of Cretaceous age; and Professor Meek says himself, (p. 458,) "that although partly committed to the opinion that this formation belongs to the Cretaceous, and still viewing it as most probably such, he does not wish to disguise or conceal the fact that the evidence favoring this conclusion, to be derived from the mollusks alone, as now known, is by no means strong and convincing." As from the flora of Black Butte we do not have any identical or intimately related species to the Cretaceous plants, as all the types are Tertiary, even a large number Miocene, the conclusion is forcibly in favor of the Tertiary age of the Lignitic. Nearly one-half of the species of fossil plants found at Black Butte are identical with or closely related to Eocene and Miocene species of Europe. On this subject even the invertebrate animals seem to point out to the same conclusions; for Professor Meek remarks, (*loc. cit.*, p. 460,) "that he found directly associated with the reptilian remains of Black Butte (that saurian imbedded in Tertiary leaves) a shell which he cannot distinguish from *Viviparus trochiformis*, originally described from the Lignitic formations at Fort Clark, on the Upper Mississippi, a formation that has always been regarded as Tertiary by all who have studied its fossils, both animal and vegetable." The whole discussion on the subject, continued by Professor Meek, and reviewed clearly on the following pages, (pp. 461–462,) establish the same fact, that paleontological evidence from remains of invertebrate animals is rather in favor of the Tertiary than of the Cretaceous age of the group.

The conclusion of Professor Cope amounts to this: that from the Dakota group to the top of roof of the Black Butte main coal he met with an uninterrupted series of animal Cretaceous remains, mollusks in the lower beds and vertebrates in the higher, proving that the beds are Cretaceous(!). Comparing this with the flora of the Lignitic, he concludes that a Tertiary flora was contemporaneous with a Cretaceous fauna, establishing an uninterrupted succession of life across what is generally regarded as one of the greatest breaks in geological time.

This conclusion does not appear to exactly conform to facts, at least on the point of view of vegetable paleontology, for on this account, and contrary to what is remarked by Professor Cope in following his researches on the bones of extinct species of animals, we have from the Dakota group to the lowest strata of the Lignitic, or to the same bed at Black Butte, where the bones of that dinosaurian were found, an evident and total break in the succession of vegetable type, quite as marked as it can be in passing from the Jurassic to the Cretaceous. This anomaly may be explained in considerinig this fact: that the flora is in direct collateral relation with atmospheric circumstances which do not influence, at least not in the same way and with the same activity, the marine world and the land vegetation. Morever the lower Eocene of Europe has a series of clay beds bearing remains of land plants. They are intermediate, it seems, between the upper Cretaceous and the Lignitic formations, and thus indicate long periods of time sufficient to account for great modifications in the flora.

6th. Leaving aside these considerations, which bear indirectly on the subject, I have to come back to the question of the precedence which in a case like this should be accorded to fossil plants, for the determination of the age of the formation; for I cannot leave without contradiction a critical remark made against the report of last year, which, among others, says:*

Mr. Lesquereux has met the statements of Professors Meek, Cope, and Marsh, that Cretaceous mollusks had been found in and overlying the Colorado lignite deposits, by pointing to his 250 species of fossil plants, claiming that they far outweigh the testimony of the animal remains. In fact, however, these fossil plants have little bearing on the question.

The absence of fossil mollusks in the Colorado basin has been proved; but even admitting the contrary, and taking as an analogous case the coal of Black Butte, over which the skeleton of a dinosaurian, *Agathauma sylvestris*,† has been found imbedded into leaves of Eocene plants, shall we for the reason of the presence of these Cretaceous remains, still more

* Dr. Newberry, in Journal of American Arts and Sciences, vol. vii, April, 1874, p. 403.
† Cope, Second Bulletin of the United States Geological Survey.

important as characteristic than mollusk, admit the formation as Cretaceous, and consider the plants as without bearing on the question? I have last year spent some days at Black Butte and in the surrounding country, and may here record the observations which, related to this question, may not find their place elsewhere.

The Saurian bed, as it is now called, is at the top of the ridge facing the depot, at a short distance, half a mile east from it. The *débris* taken out in digging the bones of the animal are still mixed with a quantity of fragments of these bones, and some of the specimens are remarkably interesting, bearing as they do, fragments of bones on one side and fossil leaves on the other. The bed is a kind of arenaceous clay, mixed with ashes, and hardened to the consistence of brick by the combustion of the underlying beds of coal. It overlies, east of the station, three alternate ridges of whitish weathered sandstone of the thickness, taken altogether, of 96 feet, being 10 feet 8 inches above the upper ledge, which is a compact, white, hard sandstone, 10 feet thick, and is exposed and can be followed easily to the south for about a quarter of a mile, where the main coal-bed of Black Butte is worked. At this place the section in descending order is:

12. Fire-clay and shaly sandstone, 9 feet.
11. Yellow sandstone, 6 feet.
10. Shale and coal-brash, 1 foot.
9. Shaly sandstone and plants, 12 feet.
8. Coal, 3 to 5 feet.
7. Fire-clay, 2 to 7 feet.
6. Main coal, 5 to 7 feet.
5. Fire-clay, 5 feet.
4. Clay, capped with slaty sandstone, 5 feet 4 inches.
3. Coal, 3 feet.
2. Shale and clay, with oysters, 7 to 10 feet.
1. White sandstone, 10 feet 8 inches.

This sandstone, being the same as the upper sandstone under the Saurian bed, the former section shows the exact horizon where the bones have been found as within or above the lower 3-foot bed of coal No. 3, separated by 10 feet of fire-clay from the main Black Butte coal. It is very probable that both coal-beds disjointed, at the locality of the Saurian, by a mere clay parting, were destroyed by fire under the stratum of clay. Anyhow, I did not find in connection with the bones any species of plants differing specifically from those found in the sandstone No. 9 above the upper coal. The specimens represent *Sabal*, *Viburnum dichotomum*, *Ficus planicostata*, *Myrica Torreyi*, *Aleurites eocenica*, *Paliurus zizyphoides*, some stems, *Caulinites*, and fragments of leaves of a *Platanus*, whose middle part only is preserved, and which may be referable to *P. Haydenii*, the only kind of plant which was not recognized in the shale of the main coal. The case is clear: from all the fossil plants described from Black Butte none is referable to a Cretaceous species; they are all Tertiary, and force the admission made by Professor Cope in his review (*loc. cit.*, p. 16) that here a Tertiary flora is contemporaneous with a Cretaceous fauna. Now, this flora is typical for the compounds of the coal-strata, and, of course, the coal-strata are Tertiary. What shall be the name of this formation; is it Cretaceous on account of the saurian bones, or is it Tertiary on account of the fossil plants in which the skeleton is entombed, and which are found of the same relation all over the Lignitic formations, and at some places, as at Golden, the Raton, &c., from its base to the upper strata, and which two have entered into the composition of its essential strata, the Lignite? No geologist, I think, will hesitate a moment in pronouncing it, from its land-character, a Tertiary formation, therefore giving the precedence to the fossil flora over the fossil fauna for the determination of the age of this formation. It is, then, evident that the fossil plants have some weight and must decide.

7th. This brings me to the essential question which has to be examined in considering the relation of the age of the fossil plants of the Lower Lignite of the Rocky Mountains.

Though the flora is evidently related to that of the Tertiary of Europe by a large number of its species, it is, however, difficult to point out with uncontestable evidence to what stage of this Tertiary the relation is the more intimate. To come to an understanding on this subject, we have to compare the American fossil species with those known as yet from the publications of European authors, and at once are met with a scarcity of materials, especially from the Lower Tertiary strata or the Eocene, to which, considering the position of the Lignitic, its flora should be especially related. The Tertiary of Europe seems to have been, as expressed by Dr. Ettinghausen in his Contributions to the Radoboj Flora, "a kind of universal vegetable repository, representing types of all the regions of the world; a seminarium, which hereafter dispersed its offsprings over the whole surface of the earth." This conclusion is not my own. I should only say that the European Tertiary formations have been the recipient of species representing an heterogeneous vegetation, type of multiple and local changes. But this matter is out of the subject; we have only to record the fact that, so mixed in their *facies* are the floras of the Tertiary basins of the Old World that as yet no reliable delimitation has been established for the stages which they represent.*

In considering the characters of our Lower Lignitic flora, a critic has asserted that its genera are all, as well as the species, without relation to Eocene vegetable types of Europe, quoting as a proof of his assertion the flora of Mount Bolca, and that of Shepey in England. This last flora is merely known by fruits whose forms or species have been described and figured by Bowerbank, and which are heaped in prodigious quantity in the so-called London clay of England. This Eocene flora, however, cannot be taken for America any more than it has been for Europe as a point of comparison, for it has no leaves, and its fruits, of various and uncertain affinity, have as yet not been found elsewhere in the Tertiary of Europe, except a few *Nepadites*, merely mentioned (not described yet) from the Eocene of Mount Bolca. These Shepey fruits, as Heer remarks, are not characteristic of the formation, even say nothing in regard to the climate of the locality where they are found, as, from appearance, they have been floated down some river for a great distance, and are analogous to present deposits of this kind at the mouth of the Ganges. The Eocene flora of the Isle of Wight, at Alumbay, is represented by numerous leaves of *Aralia*, *Daphnogene*, *Ficus*, *Zizyhus*, *Cæsalpinia*, &c., which, according to Heer, have such a marked tropical and subtropical character that the fruits of Shepey may have been derived from the plants of this locality. These Alumbay leaves, to quote the same authority, are similar to species of Mount Bolca; three species are identified as the same, and three others are closely related. But also a number of them are Miocene; as, *Quercus lonchitis; Laurus primigenia; Myrica* (*Diandra*) *acutiloba; Cassia phaseolites;* or four species,

* Since writing this, the third and last volume of W. P. Schimper, *Palontologie végétale*, has appeared. The author, considering the vegetable groups of the Tertiary, divides the formation in the five following stages: *Paleocene*, intermediate to the Cretaceous and Tertiary; *Eocene, Oligocene, Miocene,* and *Pliocene.* The relation of our Lignitic vegetation seems to be with the Oligocene.

and four other species, *Laurus Forbesii*, *Daphnogene anglica*, *Quercus Burmensis*, and *Juglans Laharpii*, are related to Miocene species in the same degree. From this, it seems, the conclusion should be in favor of a more intimate relation of the flora of Alumbay, which is positively recognized of Eocene age, with that of the European Miocene than with that of Mount Bolca; for it has only six species identical or in relation with the Mount Bolca flora, while it has eight, bearing the same degree of relation to the Miocene. Some of the species of the North American Lignitic are identical with or closely related to those named by Heer. *Quercus furcinervis* is probably identical with *Q. Burmensis;* for, in many of the numerous American specimens of this species, the absence of an upper branch of the lateral veins, which, according to Heer, is the essential character which separates these two species, is positively remarked. *Daphnogene anglica*, is as positively identified as it can be from the short description given by Heer, it being different from *D. melastomacea* by the symmetrical form of the leaves and the branching of the lateral nerves. Heer says that the middle nerve is also branching. In our specimens it is simple; in Unger's species neither the lateral nor the middle vein branches. Though these species re-appear in some forms of the Miocene of Europe, they should be considered, I think, rather as Eocene than as Miocene types.

The Mount Bolca flora is represented by a large number of specimens of leaves and fruits disseminated in the numerous museums of Italy. Until now few of the species which they represent have been satisfactorily described. The little which is known of this flora is from the table of families furnished to Professor Heer by Professor Massalongo, and published with remarks in Fl. Tert. Helv., (vol. iii, p. 275.) This table has 53 groups of plants, among which the more numerously represented are: *Algæ*, 48 species; *Podocapeæ*, 5; *Palms*, 7; *Proteaceæ*, 5; *Ericaceæ*, 10; *Sterculiæ*, 10; *Buttneriaceæ*, 14; *Myrtaceæ*, 8, &c.; and among the species the most abundant, *Eucalyptus Italica*, Mass.; *Eugenia laurifolia*, Mass.; *Guayacites Heerii*, Mass.; *Zanthoxylum ambiguum*, U.; *Ficus Bolcensis*, Mass., which Heer says is similar to *F. multinervis* of the Miocene; *Santalum memecyloides*, Mass.; *Aralia primigena*, de la H.; in all ten species not described but briefly remarked upon by Heer. From the characters of the Mount Bolca flora as indicated in this exposition of Heer, it does not appear, indeed, that our Lower Lignitic flora has any marked relation to it; but the scantiness of materials, together with the uncertainty of the characters of a number of species named by Massalongo, renders a comparison impossible. Heer himself, in his exposition, remarks on this insufficiency of reliable characters. He, for example, counts only four species of Mount Bolca as represented in the Miocene of Europe, and a few more as closely related to Miocene species. He mentions among those ascending to the Molass of Switzerland, *Banksia longifolia* and *Dryandra Veronensis*, two species which have close relation with species of our Upper Miocene, the Green River group, rather than with species of the Lower Lignitic. Since Heer's short review of the Mount Bolca flora was published, in 1859, paleontology has not received any more precise information in regard to its characters. Schimper, in his Vegetable Paleontology, 1873, mentions only from this locality, besides 21 species of marine plants or fucoids, *Cyperites Bolcensis*, Mass., considered or described formerly by the same author as a *Flabellaria; Halochloris cymodoceoides*, Ung., also found at Soltzka; *Potamogeton tritonis*, U., and *P. nayadum*, U.; *Typha spadæ*, Mass., a species which Schimper supposes to be made from the leaves of some *Cyperaceæ;* five forms of *Castallinæ*, fruits comparable to the *Nepadites* of the London clay, representing probably a single species; *Latanites parvulus*, Mass., a palm; *Lomatia Bolcensis*, U.; *L. latior*, Heer, of which a small broken part is figured in the Baltic Flora, and to which one of the most abundant species of Black Butte *Myrica Torreyi*, Lesqx., so much resembles by its peculiar nervation and by the form of the leaves that better specimens only of the European plants can decide between positive identity or a very close relation; *Myrica Meneghini*, U., of a type represented with us in the Upper Tertiary of South Park; and *Daphnogene Veronensis*, Mass., which Schimper compares to *Cinnamomum Scheuchzeri*. This is all that is positively known of the flora of Mount Bolca. It is impossible to consider it as a kind of typical flora of the Eocene of Europe, and to assert that if we cannot point out any of our Lignitic species as identical with this flora, it is for that reason deprived of the character of the Eocene vegetation.

France has in the deposits of the old Travertins of Sezane a number of species whose types seem to be intermediate between the Cretaceous species and those of the Upper Eocene. This flora is known by the admirable work of Count Saporta,* who describes in it a *Sassafras* comparable to *S. Mudgii*, and leaves of *Magnolia*, related to *M. alternans* and *M. capellini*, three species described from the Dakota group. A number of forms of this Lower Eocene flora are also related to the Tertiary species of Europe, especially to those of the Mount Promina flora; and with our Lignitic flora it has closely allied two of the more characteristic and more abundant species of Black Butte, *Sterculia variabilis*, Sap., distinguishable only from *Ficus planicostata* by the unequal lateral base of the European leaves, and the beautiful *Viburnum giganteum*, related, by its size and nervation, to *V. marginatum*. Besides this, it has *Asplenium subcretaceum*, Sap., intimately related to the species which I have described as *Sphenopteris eocenica*, most abundant at Golden; *Cissus primæva* to *C. lobato-crenata*, also abundant at Black Butte and in the Colorado Lignitic basin, Mount Brosse, &c.; *Cornus platiphylla*, related to *C. impressa*. These all show affinity indeed to a flora so positively marked as Lower Eocene, that some of its types are still Cretaceous.

I have admitted, as indication of the Eocene age of our Lignitic flora, the great abundance of fucoidal remains, or of marine plants, in the underlying sandstone of the Lignitic, a character remarked in the sandstone of Mount Bolca, and also of the Flysh of Switzerland. One of the few species which I have as yet been able to describe, from the difficulty of obtaining specimens, *Halimenites minor*, is known from this last formation. Besides this, a comparatively large number of species of ferns, some of them identical with species of *Promina: Goniopteris polypodioides*, Ett., and *Sphenopteris eocenica*, or with that of Boernstadt: *Diplazium Muelleri;* then a great proportion of remains of palms, referable to as many species as have been described from Europe at least, some of them identical with species of Promina, Boernstadt, Häring, representing, like *Flabellaria latania*, *F. longirachis*, *F. Zinkeni*, some of the more ancient forms of palms recognized in the Ctenzoic times. The remarkable preponderance of palm remains has been mentioned from all the stations of the Lower Lignitic where fossil plants have been discovered: Vancouver, Fort Union, Black Butte, Golden, Sand Creek, Gehrung's, Cañon City, Raton Mountains, Placière, the Mississippi, &c. They have given to the vegetation of the epoch a subtropical character, marked still by a number of species of *Ficus* of the broad-leaved and palmately-three-nerved group, most of them new species, and none of the type of the lanceolate-pinnately-nerved leaves like *Ficus lanceolata*, *F. multinervis*, &c., which, with us

* Prodrome d'une flore fossile des Travertins anciens de Sezane, (1868.)

at least, represent types of the Upper Miocene only. Among species of the other genera of Eocene type, the Lignitic flora has still *Myrica Torreyi* of Black-Butte, possibly identical, as seen above, with a *Lomatia* of Mount Bolca; three species of *Platanus*: *P. Haydenii*, *P. Raynoldsi*, *P. rhomboides*, without any affinity with any of the Cretaceous or of the Miocene species known as yet; *Artocarpidium olmediæfolium*, U., described by the author from Sotzka; a fine new species of *Pisonia*, *P. racemosa*, allied to *P. eocenica*, Ett., of Häring, as well by the seed (or unopened buds) as by the leaves; *Daphnogene anglica* (?), which has been remarked upon as found at Alumbay; two species of *Nelumbium*, related to *N. Buchi*, Ett., of *Promina; Eucalyptus Häringiana*, of Häring; *Dombeyopsis grandifolia*, U., of Sotzka; a number of species of *Rhamnus* of a peculiar type, comparable, by the form of the leaves and the nervation, to tropical species of *Bridelia*. These can be considered as already giving to the flora of the Lignitic, in comparing it to that of Europe, an Eocene facies.

But we have in America a more reliable point of comparison, still forcing the conclusion that if even the Lignitic flora of the Rocky Mountains had no relation whatever to that of Europe, it should, notwithstanding, be considered as Eocene. I allude to the flora of the Mississippi, described from very good specimens obtained from such a lower stratum in the Tertiary that its reference to this formation rather than to the Cretaceous was for a long time uncertain. In the Geological Report of the State of Mississippi, Prof. Eug. V. Hilgard has given (p. 108) a section of the general distribution of the strata in the geological formations of the State, marking the place of the Lignitic of the Mississippi State and of the formations where his fossil plants were found as underlying the Vicksburgh and Clayborne beds, which form the upper stage of the American Eocene, the Lignitic representing the lower one: The correlation of the Mississippi fossil flora with that of Golden and of Black-Butte is evident enough. Of the Mississippi plants, the following have been recognized in the Western Lignitic: *Sabal Grayana*, Vancouver; *Populus monodon*, Raton Mountains; *P. mutabilis*, Black Butte, Raton Mountains, Vancouver; *Quercus chlorophylla*, Golden; *Quercus crassinervis*, Vancouver; *Ficus Schimperi*, intimately related to *F. platinervis*, as widely represented at Black Butte, Golden, &c., as the former is in the South; *Laurus pedata*, Raton Mountains; *Cinnamomum Mississippiense*, one of the most prevalent species of the Western Lignitic; *Magnolia Hilgardiana*, Raton Mountains; *M. Lesleyana*, Raton and Golden. This, without mentioning a number of closely-allied species and the identity of genera, gives to both the floras of the Mississippi and of the Western Lignitic formation a general character which can but be recognized as identical.

After all this, we remark in our Eocene flora some characters which may be called negative, namely, the absence of certain groups of plants represented either in the Cretaceous or in the upper groups of the Tertiary. No species has been discovered in the Lignitic which had been described from the Dakota group. This is the more remarkable that some peculiar types of this group, like *Liriodendron*, *Sassafras*, &c., re-appear above the Lignitic in the Evanston or second group, and in still greater numbers in more recent Tertiary divisions; and that even one of its rare species, *Cinnamomum Scheuchzeri*, is also absent until now, at least in the lower group, and present in the same second group and above. Heer remarks, in considering the fossil flora of Mount Bolca, the absence of representatives of a number of genera or families which take an important place in the Miocene, thus: *Salicineæ*, *Acerineæ*, *Cupuliferæ*, *Betulaceæ*, *Ulmaceæ*, *Abietineæ*, &c.

The absence of these types is as remarkable in the Lignitic flora as in the Eocene of Mount Bolca. While the upper group of our Tertiary abounds with conifers, *Abietineæ*, 11 species in 81, the Lower Lignitic has only two, one as yet of uncertain affinity, *Abietites dubius*, and two species of *Salisburia*, in nearly 200 species; of the *Salicineæ* it has only three species, two of which, *Salix tabellaris* and *S. densinervis*, both described from the Mississippi Eocene, are uncertain, the last, perhaps, an *Acacia*. It has also no species of *Acer*, none of *Betula*, *Alnus*, *Carpinus*, *Corylus*, &c.; no species of *Ulmus*, except one doubtful, with entire borders; for it is, indeed, the absence of leaves with dentate or serrate borders which is the more remarkable character of this group as well as of the Cretaceous; *Quercus furcinervis* and *Q. saffordi*, (perhaps a *Myrica*,) make with the *Viburnum maginatum* and its related species an exception, which is also remarked in the Cretaceous types *Q. primordialis* and some peculiar leaves with equal teeth turned outside and separated by obtuse sinuses, just of the same form as in this *Viburnum* of the Eocene. It is not to be denied, as seen in the comparative table, that a number of species of our Lower Lignitic are found in the two following groups of Evanston, Carbon, and even a few in the Green River group. But we have seen the same in the Eocene, even the Lower Eocene flora of Europe, and cannot from this reason admit that our Lower Lignitic flora is not Eocene, because some of its types have passed up to the other groups of the Tertiary.

§ 2.—DISTRIBUTION OF THE FOSSIL PLANTS IN THE DIFFERENT GROUPS OF THE TERTIARY.

The succession of the strata of the Lower Lignitic in relation to the distribution of the coal strata and to that of the fossil plants which characterize the formation is not positively known. The section at the Raton Mountains near Trinidad records an alternation of sandstone, shale, clay-beds, &c., 300 feet thick, with five beds of lignite, measuring altogether 11 feet 6 inches. Here the fossil plants are found in sandy shale at the base of No. 6 or in the upper part of No. 7 (Report for 1872, p. 319) in the middle of the section. At Cañon City, as indicated by Mr. Clark's section, (*loc. cit.*, p. 323,) the main coal 2 feet 2 inches is overlaid by shale, clay or thin coal, and a sandstone, over which, in No. 15, are found leaves of *Sabal* and of *Platanus Haydenii*, about 70 feet above the coal. At Gehrung's coal, near Colorado City, a shale bearing an abundance of *Sabal* leaves, *Ficus*, *Platanus Haydenii*, and *Rhamnus*, is also from 60 to 75 feet above the coal opened near by at the base of a compact sandstone. From Marshall a detailed section has been published by Dr. Hayden in his Report for 1869, (second edition, p. 129,) placing the strata bearing fossil plants at No. 22, about in the middle of the section, 200 feet higher than the lower main coal, and about 260 feet from the top. As far as I know, and from the explorations of others as well as from my own, no other strata bearing identifiable plants have been remarked in this section.

At Erie, the coal 8 to 9 feet is worked near the surface; its soft sandy shale is profusely mixed with remains of plants, which, to my regret, could not be examined sufficiently. They represent a few species of the Lower Lignitic of Golden, and also some remarkable vegetable fragments representing species not found elsewhere. As the underlying strata are not known, the position of this coal in the Lower Tertiary measures could not be ascertained. At Black Butte, the main coal, overlaid by soft shaly sandstone, with fossil plants in abundance, a stratum which, as remarked before, is the equivalent of the Saurian bed, is here apparently at the upper part of a section of 1,000 feet of measures of the productive lignitic.* In going west toward Point of Rocks, in a contrary direction to the dip of the strata, the Hallwell coal, a workable bed, and other Lignitic beds of unimportant thickness, are passed until reaching the abrupt terminus of the ridge near Saltwell. No remains of fossil plants were found in connection with any of these coal-strata. From Hallwell to Rock Springs, the dip of the measures is to the west until the upper strata of Lignitic are reached. Near this last place, a bed of coal 4 feet thick is passed, two miles before reaching the station, and here the main coal, 100 feet higher, is worked 6 to 9 feet thick. I was not able to discover any fossil plants in the whole thickness of the measures, and at Rock Springs the coal, which is evidently one of the highest of this group, has not any other plants but the fucoidal *Halimenites*. Its shale, however, is mixed with a profusion of shells. Considering this, it would appear that the upper beds of the Eocene Lignitic are, in Wyoming, the repositories of fossil plants. At Golden we have perhaps the best evidence concerning the distribution of the fossil plants in relation to Lignitic strata. The lowest strata of coal, in close proximity to the Cretaceous, and tilted up to the perpendicular, are interlaid by beds of white hard sandstone, which all, three of them at least in succession, have identifiable remains of fossil plants. The lowest sandstone has especially some species of Fucoids, among which the fine *Delesseria fulva*, together with a quantity of *Sabal*, *Rhamnus Goldianus*, *Platanus Haydenii*, *Quercus angustiloba*, *&c.* Under the basaltic deposits, which cover the Lignitic on the eastern side of the valley, half a mile distant from the Lignitic beds, the fossil strata bearing plants are horizontal; at some places composed of soft white clay, as east of Golden, on the slopes of North Table Mountains; at others, of shaly sandstone, as northeast of the School of Mines, on South Table Mountains. These deposits are all about at the same altitude of 300 feet above Clear Creek, 60 to 100 feet lower than the base of the lava-beds. They all contain not only the same types but mostly the same species of fossil plants as the sandstone, interlying the Lignitic beds in proximity to the Cretaceous. It therefore appears from this that the flora of the Lower Lignitic has the same characters in the whole thickness of the measures. There may be, of course, some difference in the species, or a predominance of some kinds at a higher or lower station, but the difference has not been yet remarked.

LIST OF THE SPECIES OF THE FIRST GROUP.

[Abbreviations for names of localities, &c.: R., Raton Mountains; P., Placière; G., Golden; M., Marshall's; S. Cr., Sand Creek; B. B., Black Butte; Y. St., Yellow Stone; Miss., Mississippi; V., Vancouver; Mo., Miocene; Gr., Group.]

Spheria lapidea, Lesqx.—R.
S. myricæ, Lesqx.—B. B.
Sclerotium rubellum, Lesqx.—G.
Opegrapha antiqua, Lesqx.—B. B.
Chondrites subsimplex, Lesqx.—R.
C. bulbosus, Lesqx.—R.
Delesseria fulva, Lesqx.—G.
D. incrassata, Lesqx.—R.
D. lingulata, Lesqx.—R.
Halymenites striatus, Lesqx.—G., R.
H. major, Lesqx.—G., R., B. B., (Gr. 2, 3.)

* Professor Meek estimates it to at least double this thickness, and considers the lower unproductive strata of this formation as Cretaceous. No evidence is afforded on this subject by vegetable remains.

H. minor, F. Os.—G.
Woodwardia latiloba, sp. nov.—G.
W. latiloba, var. minor.—B. B.
Pteris pennæformis, H.—G., Mo.
P. anceps, Lesqx.—G.
P. affinis, sp. nov.—G.
P. erosa, Lesqx.—R. G. (Gr. 4.)
P. subsimplex, sp. nov.—G.
P. Gardneri, sp. nov.—S. Cr.
Diplazium Muelleri, Heer.—G.
Aspidium goldianum, sp. nov.—G.
Goniopteris polypodioides, Ett.—S. Cr.
Sphenopteris eocenica, Ett.—G.
S. membranacea, sp. nov.—G.
S. nigricans, sp. nov.—B. B.
Hymenophyllum confusum, sp. nov.—G.
Gymnogramma Haydenii, Lesqx.—R., (Gr. 2.)
Lygodium compactum, Lesqx.—Miss.
Selaginella Berthoudi; sp. nov.—G.
Equisetum lævigatum, sp. nov.—S. Cr.
Sequoia Langsdorfi, A. B.,—B. B. V.—Mo., (Gr. 4.)
Abietites dubius, Lesqx.—R., G., (Gr. 2.)
Salisburia binervata, Lesqx.—Miss.
S. polymorpha, Lesqx.—V. (Gr. 2.)
Arundo Goepperti, A. Br.—R.—Mo.
Phragmites œningensis, A. Br.—R., G., M., B. B.—Mo., (Gr. 2, 3, 4.)
Carex Berthoudi, Lesqx.—G.
Smilax grandifolia, U.—G.—Mo., (Gr. 3.)
S. obtusangula, Heer.—B. B.
Sabal Grayana, Lesqx.—V., Miss.
S. Campbellii, Ny.—R., G., B. B., &c.
S. Goldiana, sp. nov.—G.
S. major, U.—G.
Flabellaria zinkeni, Heer.—G.
F. latania, St.—G.
F. eocenica, Lesqx.—B. B.
F. longirachis, U.—R., Y. St.
F. fructifera, sp. nov.—G.
Calamopsis Danai, Lesqx.—Miss.
Palmacites, species.—G.
Caulinites sparganioides, Lesqx.—B. B., (Gr. 2 and 3.)
C. fecunda, Lesqx.—M.
Eriocaulon porosum, sp. nov.—S. Cr.
Zingiberites undulatus, sp. nov.—G.
Rhizocaulon gracile, sp. nov.—B. B.
Populus attenuata, Goepp.—G., B. B.—Mo., (Gr. 3.)
P. monodon, Lesqx.—Miss., R.
P. mutabilis, A. Br.—B. B., Miss., R., V.—Mo., (Gr. 2 and 3 in var.)
P. balsamoides, Goepp.—P.—Mo., (Gr. 2.)
P. leucophylla, U.—B. B.—Mo., (Gr. 2.)
P. heliadum, U.— G.—Mo.
Salix integra, A. Br.—G., B. B.—Mo.
S. tabellaris, Lesqx.—Miss.
S. (?) densinervis, Lesqx.—Miss.
Myrica Torreyi, Lesqx.—B. B.
M. Torreyi, var. minor.—S. Cr.
Betula gracilis, sp. nov.—G.

Ulmus irregularis, Lesqx.—R., G.
Celtis brevifolia, Lesqx.—Miss.
Quercus angustiloba, A. Br.—G.
Q. Moorii, Lesqx.—Miss.
Q. platinervis, Lesqx.—V.
Q. Lyelii, Heer.—Miss.—Mo.
Q. retracta, Lesqx.—Miss.
Q. chlorophylla, U.—G., Miss.—Mo., (Gr. 2.)
Q. triangularis, Goepp.—G.—Mo.
Q. stramineus, Lesqx.—G.
Q. Wyomingiana, Lesqx.—B. B.
Q. furcinervis, Rossm.—Oregon, G.—Mo.
Q. Goldianus, sp. nov.—G.
Q. Saffordi, Lesqx.—Miss.
Q. crassinervis, U.—Tenn., V.
Q. multinervis, Lesqx.—V.
Q. Benzoin, Lesqx.—V.
Q. myrtifolia (?), W.—Miss.
Q. attenuata, Goepp.—S. Cr.
Q. Cleburni, sp. nov.—B. B.
Fagus feroniæ, U.—G.—Mo., (Gr. 4.)
Ficus Schimperi, Lesqx.—Miss.
F. cinnamomoides, Lesqx.—Miss.
F. tiliæfolia, Al. Br.—P., B. B., S. Cr., G., &c.—Mo., (Gr. 2 and 3.)
F. planicostata, Lesqx.—B. B.
F. planicostata, var. latifolia.—B. B., M.
F. planicostata, var. Goldiana—G., S. Cr.
F. Clintoni, Lesqx.—B. B.
F. asarifolia, Ett.—G.—Mo.
F. zizyphoides, sp. nov.—G.
F. spectabilis, Lesqx.—G.
F. auriculata, Lesqx.—G., (Gr. 2.)
F. truncata, sp. nov.—G.
F. corylifolia, Lesqx.—B. B.
F. ulmifolia, Lesqx.—R.
F. Haydenii, Lesqx.—B. B.
Platanus Raynoldsii, Ny.—B. B.
P. Haydenii, Ny.—G., R.
P. rhomboidea, sp. nov.—G.
P. Guillelmæ (?), Goepp.—B. B. (?), R.—Mo., (Gr. 3.)
Artocarpidium olmediæfolium, U.—G.—Mo.
Pisonia racemosa, sp. nov.—B. B.
Laurus pedata, Lesqx.—R., Miss.
L. colombi, Heer.—V.
Persea lancifolia, Lesqx.—Miss.
Benzoin antiquum, Heer.—B. B., G.—Mo.
Cinnamomum Mississippiense, Lesqx.—Miss., R., P., G., M., (Gr. 2 and 3.)
C. Rossmæssleri, Heer.—G.—Mo., (Gr. 2.)
C. Heerii, Lesqx.—V.
Elæagnus inæqualis, Lesqx.—Miss.
Banksia helvetica, Heer.—Miss.—Mo.
Andromeda Grayana, Heer.—R., V.—Mo., (Gr. 2.)
A. dubia, Lesqx.—Miss.
A. vacciniæfoliæ affinis.—Miss.
Diospyros stenosepala, Heer.—Y. St.—Mo.
D. brachysepala, Heer.—S. Cr., B. B.—Mo.
D. lancifolia, Lesqx.—V., (Gr. 2.)

D. anceps, Heer.—B. B.
Sapotocites americanus, Lesqx.—Miss.
Viburnum marginatum, Lesqx.—B. B.
V. Wymperi, Heer.—B. B.—Mo.
V. contortum, Lesqx.—B. B.
V. Lakesii, sp. nov.—G.
V. dichotomum, Lesqx.—B. B., R.
Cornus incompleta, Lesqx.—M.
C. Studeri, Heer.—G.—Mo., (Gr. 2.)
C. Holmesii, sp. nov., S. Cr.
C. orbifera, Heer.—G.—Mo.
Cissus lævigata, Lesqx.—G.
C. lobato-crenata, Lesqx.—B. B., (Gr. 2.)
Vitis tricuspidata, Heer.—B. B.—Mo.
Nelumbium tenuifolium, sp. nov.—S. Cr.
N. Lakesianum, sp. nov.—G.
Magnolia Hilgardiana, Lesqx.—R., Miss., (Gr. 2.)
M. laurifolia, Lesqx.—Miss.
M. Lesleyana, Lesqx.—G., Miss., R.
M. ovalis, Lesqx.—Miss.
M. cordifolia Lesqx.—Miss.
M. Inglefieldi, Heer.—B. B.—Mo., (Gr. 3.)
Terminalia radobojensis, U.—R.—Mo.
Asimina (?) leiocarpa, Lesqx.—Miss.
Eucalyptus Hæringiana (?) Ett.—B. B.—Mo.
McClintockia Lyallii (?) Heer.—B. B.—Mo.
Dombeiopsis trivialis, Lesqx.—G.
D. occidentalis, Lesqx.—G.
D. grandifolia (?), U.—G.—Mo.
D. obtusa, Lesqx.—R.
Acer (?) secreta, Lesqx.—R.
Sapindus undulatus, Lesqx.—Miss.
S. caudatus, Lesqx.—G., B. B.
Aleurites eocenica, Lesqx.—B. B.
Zizyphus distortus, sp. nov.—G.
Paliurus zizyphoides, Lesqx.—B. B., M.
Ceanothus fibrillosus, Lesqx.—G., B. B.
Berchemia parvifolia, Lesqx.—G., R.
Rhamnus marginatus, Lesqx.—Miss.
R. obovatus, Lesqx.—G., R., M., (Gr. 2.)
R. deletus, Heer.—R.—Mo.
R. Fischeri, Lesqx.—R.
R. salicifolius, Lesqx.—M., G., B. B.
R. rectinervis, Heer.—B. B., G., M.—Mo., (Gr. 2.)
R. Dechenii, Web.—B. B.—Mo.
R. acuminatifolius, W.—G.—Mo.
R. Goldianus, Lesqx.—G.
R. Goldianus, var. latior.—G.
R. Cleburni, Lesqx.—G., B. B.
R. discolor, Lesqx.—B. B.
R. inæqualis, sp. nov.—G.
R. alaternoides Heer.—G.—Mo.
R. Meriani, Heer.—B. B.—Mo.
Xanthoxylon dubium, Lesqx.—R.
Juglans appressa, Lesqx.—Miss., (Gr. 2.)
J. Saffordiana, Lesqx.—Miss.
J. rugosa, Lesqx.—M., G., B. B., (Gr. 2 and 3.)

J. Smithsoniana, Lesqx.—R., G.
J. Schimperi, Lesqx.—G., M., (Gr. 4.)
J. rhamnoides, Lesqx.—G., B. B., (Gr. 2.)
J. Baltica (?) Heer.—B. B.—Mo.
Cercis eocenica, Lesqx.—M.
Phyllites truncatus, Lesqx.—Miss.
P. Mahoniæformis, Heer.—V.
Carpolithes palmarum, Lesqx.—B. B., G., R., (Gr. 2.)
C. falcatus, Lesqx.—B. B.
C. spiralis, Lesqx.—P.
C. compositus, Lesqx.—P.
C. Mexicanus, Lesqx.—P.

REMARKS ON THE SPECIES OF THE FIRST GROUP.

In looking for the species which characterize essentially this group, and may be considered as leading species of the Lower Lignitic, we have first to eliminate those which, as omnipresent Tertiary species, are about equally distributed in at least three stages of the Tertiary measures. They are considered as typical for the whole epoch, but cannot be taken as characteristic of any of its subdivisions, no more in this country than in Europe, where they have the same general distribution. Among them we count: *Sequoia Langsdorfi*, *Phragmites Œningensis*, *Arundo Gœpperti*, *Platanus Guillelmæ*, *Ficus tiliæfolia*, *Cinnamomum Scheuchzeri*, *Rhamnus rectinervis*, *Juglans rugosa* and the closely allied *Juglans acuminata*. *Cinnamomun Scheuchzeri* has not been yet discovered in the Lower Lignitic, but has been recently found in the Cretaceous strata of the Dakota group. Of the species as yet known only from American specimens, the ones more generally recognized at different localities of the Eocene Lignitic, are: All the fucoidal or marine remains of plants, especially *Halimenites major;* and in the other classes: *Abietites dubius*, most of the species of *Sabal* and *Flabellaria*, especially *S. Campbellii*, *S. Grayana; Caulinites sparganioides*, *Populus monodon*, *Myrica Torreyi*, *Quercus crassinervis*, *Ficus planicostata* and its varieties, *Ficus auriculata*, *Platanus Haydenii*, *P. Raynoldsi*, *Laurus pedata*, *Cinnamomum Mississippiense*, *Viburnum marginatum*, *V. dichotomum*, *Cissus lobato-crenata*, *Magnolia Hilgardiana*, *M. Lesleyana*, *Sapindus caudatus*, *Paliurus zizyphoides*, *Ceanothus fibrillosus*, *Rhamnus obovatus*, *R. salicifolius*, *R. Goldianus*, *R. Cleburni*, *Juglans Smithsoniana*, and *J. Rhamnoides*. To this list, already numerous, we have to add the European species of the Lower Tertiary, recognized in the same circumstances as the former, *Flabellaria latania*, *F. longirachis*, *Quercus chlorophylla*, *Q. angustiloba*, and those which have been already compared to Eocene species of Europe, and found identical and closely allied to them. These, however, have a less extensive distribution than those mentioned above, not only considering the horizontal but also the vertical distribution. None of them has been seen at a higher stage of the American Tertiary, while of the others, *Halimenites major*, *Caulinites Sparganioides*, *Cinnamomum Mississippiense*, *Cissus lobato-crenata*, *Magnolia Hilgardiana*, *Rhamnus obovatus*, ascend up to the second group. Even the four first species named above have representatives in the third division of the Tertiary.

In considering the species of the whole list in regard to their vertical distribution, we find 25 species, or 13 per cent., represented in both groups 1 and 2; 11 species, or 6 per cent., ascend to group 3, and only 5, or 2½ per cent., to the upper division. Of these, *Pteris pennæformis*, *Fagus feroniæ*, and *Juglans Schimperi* have not as yet been found in the intermediate groups. I have placed in the table of the first group the species of fossil plants described from the Lower Mississippi Tertiary, in order to show their relation to species of the Western Lignitic, a relation which has been remarked already. For the same reason, the species of Vancouver, described from the specimens of Dr. Evans, are placed in the table, indicating, with the flora of the lower group, a relation as evident as that of the Mississippi flora by *Sequoia Langsdorfi*, one of the universal Tertiary species; *Salisburia polymorpha*, recognized at Spring Cañon or of the second group; *Sabal Grayana*, of Mississippi; *Populus mutabilis*, *Quercus crassinervis*, described from Mississippi specimens in the Geological Report of Tennessee;* *Quercus platinervis*,† whose nervation is similar to that of *Ficus planicostata*. *Laurus Colombi* is described by Heer in his flora of Vancouver, together with *Sequoia Langsdorfi*, *Andromeda Grayana*, and *Diospyros lancifolia*. These two last species, however, are from Buzzard Inlet, and are probably referable to an upper stage of the Eocene, as they ascend to the second group in our Western Lignitic measures. The little known, therefore, of the Vancouver flora refers it to this lower stage of the Tertiary.

LIST OF THE SPECIES OF THE SECOND GROUP.

[Names of localities and abreviations: E., Evanston; Sp. C., Spring Cañon, near Fort Ellis; Tr. Cr., Troublesome Creek; Mt. Br., Mount Brosse; E. Cr., Elk Creek; Y. S. L., southern borders of Yellowstone Lake; B. B., Bellingham Bay; Mo., Miocene; Gr. Group.]

Halymenites major, Lesqx.—E., (Gr. 1 and 3.)
Gymnogramma Haydenii, Lesqx.—Sp. C., (Gr. 1.)
Equisetum (!) limosum (?) Lesqx.—Y. S. L.
Abietites dubius, Lesqx.—Sp. C., (Gr. 1.)
Abies setigera, Lesqx.—Sp. C.
Salisburia polymorpha, Lesqx.—Sp. C., (Gr 1.)
Phragmites Œningensis, A. Br.—E.—Mo., (Gr. 1, 3, 4.)
P. Alaskana, Heer.—Sp. C.—Mo.
Cyperites angustior, A. Br.—E. Cr.—Mo.
Cyperus chavannesis, Heer—E.—Mo.
Caulinites Sparganioides, Lesqx.—Sp. C., (Gr. 1.)
Populus arctica, Heer.—E., Tr. Cr.—Mo., (Gr. 3.)
P. mutabilis, var. lancifolia, H.—Sp. C.—Mo., (Gr. 1 and 3.)
P. mutabilis, var. repando-crenata, H.—E., Sp. C.—Mo., (Gr. 1 and 3.)
P. balsamoides, Gp.—Y. S. L.—Mo., (Gr. 1.)
P. leucophylla, U.—Sp. C.—Mo., (Gr. 1.)
P. ovalis (?), Gp.—E.—Mo.
P. Zaddachi, Heer.—Sp. C.—Mo.
Salix Grœnlandica, Heer.—Sp. C.—Mo.
S. Evanstoniana, Lesqx.—E.
S. angusta, A. Br.—Sp. C.—Mo., (Gr. 4.)
S. Islandica, Lesqx.—B. B.
Myrica ambigua, Lesqx.—Sp. C.
Alnus Kefersteinii, Gp.—E., Sp. C.—Mo., (Gr. 3.)
Planera dubia, Lesqx.—B. B.
Betula caudata, Gp.—E.—Mo.
B. Stevensoni, Lesqx.—E., (Gr. 3.)
Quercus platania, Heer.—Sp. C.—Mo., (Gr. 3.)
Q. negundoides, Lesqx.—E.
Q. drymeja, U.—E.—Mo.

* Geology of Tennessee, by James M. Safford, (1869,) p. 427, Pl. K, Fig. 1.
† No specimens of this species are entire enough to show any part of the borders.

Q. Gaudini, Lesqx.—B. B.
Q. Ellisiana, Lesqx.—Sp. C.
Q. Pealei, Lesqx.—Sp. C.
Q. Godeti, Heer.—Sp. C.—Mo.
Q. Laharpi, Gd.—Sp. C.—Mo.
Q. chlorophylla, U.—Sp. C.—Mo., (Gr. 1.)
Q. Evansii, Lesqx.—B. B.
Corylus McQuarryi, Heer.—E., Sp. C.—Mo., (Gr. 3.)
Fagus Deucalionis, U.—E.—Mo., (Gr. 3.)
F. Antipofi, Heer.—E. Cr.—Mo., (Gr. 3.)
Ficus tiliæfolia, A. Br.—Sp. C., E.—Mo., (Gr. 1 and 3.)
Ficus Gaudini, Lesqx.—E.
F. auriculata, Lesqx.—Sp. C., (Gr. 1.)
Morus affinis, Lesqx.—E.
Platanus nobilis, Ny.—E. Cr., E.
P. dubia, sp. nov.—Tr. Cr., Mt. Br.
P. aceroides, U.—E., Sp. C.—Mo., (Gr. 3.)
Laurus primigenia, U.—Sp. C.
L. sessiliflora, sp. nov.—E.
Persea Brossiana, sp. nov.—Mt. Br.
Sassafras, species.—Sp. C.
Cinnamomum Mississippiense, Lesqx.—E., (Gr. 1 and 3.)
C. Scheuchzeri, Heer.—E., Sp. C.—Mo., (G. 4.)
C. crassipes, Lesqx.—B. B.
Cinnamomum Rossmæssleri, Heer.—Sp. C.—Mo., (Gr. 1.)
Andromeda Grayana, Heer.—E., Sp. C.—Mo., (Gr. 1.)
A. reticulata, Ett.—Sp. C.
Persoonia oviformis, Lesqx.—B. B.
Diospiros lancifolia, Lesqx.—E., B. B., (Gr. 1.)
Fraxinus denticulata, Heer.—Sp. C.—Mo.
Cornus impressa, sp. nov.—Mt. Br.
C. Studeri, Heer.—E.—Mo., (Gr. 1.)
Nyssa lanceolata, Lesqx.—Sp. C.
Cissus lobato-crenata, Lesqx.—Mt. Br., (Gr. 1.)
Vitis Olriki, Heer.—E.—Mo.
Liriodendron species.—Sp. C.
Magnolia Hilgardiana, Lesqx.—E., (Gr. 1.)
Acer trilobatum, A. Br.—E., Tr. Cr., B. B.—Mo., (Gr. 3.)
Rhamnus obovatus, Lesqx.—E., (Gr. 1.)
R. acuminatifolius, Web.—Sp. C.—Mo.
R. rectinervis, Heer.—E., Sp. C., (Gr. 1.)
Rhus deleta, Heer.—E.—Mo.
R. Evansii, Lesqx.—E.
R. bella (?), Heer.—Sp. C.—Mo.
Juglans denticulata, Heer.—Sp. C.—Mo., (Gr. 3 and 4.)
J. appressa, Lesqx.—E., (Gr. 1.)
J. rugosa, Lesqx.—Sp. C., E., E. Cr., &c., (Gr. 1 and 3.)
J. obtusifolia, Heer.—E.—Mo.
J. rhamnoides, Lesqx.—E., (Gr. 1.)
J. Woodiana, Heer.—Buzzard Inlet.
Carya antiquorum, Ny.—E.
Cassia concinna, Heer.—E.—Mo.
C. phaseolites U.—Sp. C.—Mo.
Calycites hexaphylla, Lesqx.—E.
Carpolithes arachioides, Lesqx.—E.
C. palmarum, Lesqx.—E., (Gr. 1.)
C. osseus, Lesqx.—E. Cr.

REMARKS ON THE SPECIES OF THE SECOND GROUP.

The flora of group No. 2 seems to be composed of species in part identical with or closely allied to those of group No. 1, or with those of group No. 3. The species of Spring Cañon have, besides those which are represented in the whole Tertiary, *Gymnogramma Haydenii*, *Abietites dubius*, *Salisburia polymorpha*, *Caulinites Sparganioides*, *Ficus auriculata*, or five species considered as Eocene, type of the first group. The same locality has, however, of species represented in the third group, and which are truly Miocene, *Salix angusta*, *Alnus Kefersteinii*, *Quercus platania*, *Corylus McQuarryi*, *Platanus aceroides*, and *Juglans denticulata*, or seven species. The flora of Evanston is mixed in the same way, for it has, in common with the first section, fruits of palms, (no leaves, however, have been found there as yet,) *Magnolia Hilgardiana*, *Rhamnus obovatus*, *Juglans appressa*, *J. rhamnoides*, or five species; and, with the third group, *Populus arctica*, *Betula Stevensoni*, *Fagus Deucalionis*, *Platanus aceroides*, *Acer trilobatum.* This intermixture of types might be explained in supposing that the specimens of Spring Cañon were obtained from different localities; but, as we have the same *facies* at Evanston, this supposition is groundless. Evanston has an enormous thickness of lignite deposits, separated in a number of beds of pure coal by clay partings, or thin intermediate layers of shale and sandstone. Four beds of lignite, measuring altogether 43 feet, are reported in a section of 99 feet*, the middle one, 32 feet thick, being cut by four clay partings. It seems, therefore, that there was at this locality, and perhaps also at Spring Cañon, a protracted formation of lignite beds, continuing, nearly without interruption, from the Lower to the Upper Eocene. I am inclined to consider this group No. 2 as Upper Eocene on account of the conglomerate beds by which it is overlaid. Its flora has, however, a marked character of its own by a number of species which as yet have not been seen out of it: *Salix Evanstoniana*, *Myrica ambigua*, *Quercus negundoides*, *Q. Ellisiana*, *Q. Pealei*, *Ficus Gaudini*, *Morus affinis*, *Platanus dubius*, *Laurus sessiliflorus*, *Calycites hexaphylla*, *Carpolithes arachioides*, &c. All the European species recognized in this group are Miocene. A number of its types, too, mostly found also in the third group, are northern types, arctic or Alaskanian: *Phragmites Alaskana*, *Populus arctica*, *P. Zaddachi*, *Salix Grœnlandica*, *Quercus platania*, *Corylus McQuarryi*, *Fagus antipfi*, *Fraxinus denticulata*, *Vitis olriki.* Taking all together, one-half of this flora is a compound of arctic or of European Miocene species.

LIST OF THE SPECIES OF THE THIRD GROUP.

[Abbreviations for names of localities: C., Carbon; W. G., Wahsatch or Washakie group; M. B., Medicine Bow; R. C., Rock Creek; P. of R; Point of Rocks; Mo., Miocene; Gr., Group.]

Sclerotium pustuliferum, Heer.—C. (?)
Halymenites major, Lesqx.—C., (Gr. 1 and 2.)
Taxodium, dubium, Heer.—C.—Mo., (Gr. 4.)
Sequoia Heerii, Lesqx.—C.
Equisetum Haydenii, Lesqx.—C., (Gr. 4.)
Phragmites Œningensis, A. Br.—M. B.—Mo., (Gr. 1, 2, 4.)
Cyperites, species.—P. of R.
Smilax grandifolia, U.—C.—Mo., (Gr. 1.)
Acorus brachystachys, Heer.—W. G., C.—Mo.
Caulinites Sparganioides, Lesqx.—C., (Gr. 1, 2.)

* Dr. A. C. Peale in Hayden's Report, 1871, pp. 194, 195.

Liquidambar gracilis, Lesqx.—W. G.
Populus arctica, Heer.—W. G., P. of R., M. B., C.—Mo., (Gr. 2.)
P. decipiens, Lesqx.—C.
P. attenuata, A. Br.—R. C., C.—Mo., (Gr. 1.)
P. æqualis, Lesqx.—R. C.
P. mutabilis, var. repando-crenata, A. Br.—C.—Mo., (Gr. 1 and 2.)
P. latior, var. transversa, A. Br.—W. G.—Mo.
P. latior, var. cordifolia, A. Br.—M. B.—Mo.
Alnus Kefersteinii, Gp.—C.—Mo., (Gr. 2.)
Betula Stevensoni, Lesqx.—C., (Gr. 2.)
Quercus platania, Heer.—C.—Mo., (Gr. 2.)
Q. Olafseni, Heer.—P. of R.—Mo.
Q. æmulans, Lesqx.—W. G.
Q. acrodon, Lesqx.—R. C., C.
Q. Haydenii, Lesqx.—R. C.
Corylus McQuarryi, Heer.—C.—Mo., (Gr. 2.)
C. grandifolia (?), Ny.—P. of R.
Fagus antipofi, Heer.—P. of R.—Mo., (Gr. 2.)
Fagus Deucalionis, U.—C.—Mo., (Gr. 2.)
Ficus tiliæfolia, A. Br.—W. G.—Mo., (Gr. 1 and 2.)
F. oblanceolata, Lesqx.—C. (?)
F. lanceolata, Heer.—C.—Mo., (Gr. 4.)
F. multinervis, Heer.—C.—Mo.
F. arenacea, Lesqx.—C.
F. Gaudini, Lesqx.—C.
Platanus aceroides, U.—C., R. C.—Mo., (Gr. 2.)
P. Guillelmæ, Gp.—C., P. of R.—Mo.
Coccoloba lævigata, Lesqx.—C.
Cinnamomum Mississippiense, Lesqx.—C., (Gr. 1 and 2.)
Cinnamomum species.—C.
Cornus rhamnifolia, Heer.—P. of R.—Mo.
C. acuminata, Ny.—W. G.—Mo.
Vitis Islandica (?), Heer.—P. of R.—Mo.
Magnolia Inglefieldi, Heer.—W. G.—Mo., (Gr. 1.)
Asimina miocenica, Lesqx.—C.
Dombeyopsis æquifolia, Gp.—P. of R.—Mo.
Acer trilobatum, var. productum, Heer.—C.—Mo., (Gr. 2.)
Paliurus Columbi, Heer.—W. G., C.—Mo.
Zizyphus Meekii, Lesqx.—C.
Z. hyperboreus, Heer.—C.—Mo.
Rhamnus intermedius, Lesqx.—W. G.
R. Goldianus, var. latior, Lesqx.—C., (Gr. 1.)
Juglans acuminata, A. Br.—W. G.—Mo., (Gr. 4.)
J. rugosa, Lesqx.—C., W. G., P. of R., (Gr. 1 and 2.)
J. denticulata, Heer.—C.—Mo., (Gr. 2 and 4.)
Carpolithes cocculoides, Heer.—C.—Mo., (Gr. 2.)

REMARKS ON THE SPECIES OF THE THIRD GROUP.

The general character of the flora of the third group is positively Miocene. Its types are not mixed with older ones, and indicate for the localities where the specimens were found a higher stage of the Lignitic, which, however, appears to succeed the second group without any marked disturbances. According to the observations of Messrs. Meek and Hayden, the Washakie group is conformably superposed to the Black Butte or Bitter Creek series, without changes of lithological characters, and there are still at Carbon and other localities a few remnants of the lower Lignitic flora: *Halymenites major*, *Smilax grandifolia*, *Caulinites Sparganioides*, *Ficus tiliæfolia*, especially *Cinnamomum Mississippiense*, and a variety of *Rhamnus Goldianus*. But of the 56 species of the group, 31 are identified with species of the European Miocene, or of the Arctic flora. Of these last it has 13 species, or 23 per cent., four of them already counted in the Evanston division: *Acorus brachystachys*, *Populus arctica*, *P. decipiens*, *Quercus platania*, *Q. Olafseni*, *Corylus McQuarryi*, *Fagus antipofi*, *Vitis Islandica*, *Magnolia Inglefieldi*, *Paliurus Colombi*, *Zizyphus hyperboreus*, *Juglans denticulata*, and *Carpolithes cocculoides*. The Miocene *facies* of the flora of this division is equally well marked in species of its own or American species, like *Equisetum Haydenii*, *Betula Stevensoni*, *Ficus Gaudini*, *Coccoloba lævigata*, *Asimina miocenica*, *Zizyphus Meekii*, &c., all species evidently of more recent types than those of the two lower groups. The relation of this division with No. 2 is, however, indicated by 17 identical species, more than one-fourth of the whole number, while it is allied to the upper group only by a few of the omnipresent species, *Taxodium dubium*, *Phragmites Œningensis*, *Juglans acuminata*, *J. denticulata*, and by only two species, *Equisetum Haydenii* and *Ficus lanceolata*, not recognized in the lower groups.

The plants of all the localities referred to this division are of the same type. But the specimens labeled Point of Rocks and Rock Creek have apparently been mixed, or indicate different localities than those which now bear these names. The Point of Rocks station is lower in the measures than Black Butte, and its flora should have the Eocene character, of course. But I could not find any remains of plants there or around in that barren country, though I spent two days in searching for them. The Rock Creek station is Cretaceous, and for miles around I found there nothing but representatives, in rocks and fossil animal remains, of the two upper groups of this formation, to fifteen miles farther west than Medicine Bow, where heavy sandstones of the Tertiary are covered by the lignite deposits of carbon.

LIST OF THE SPECIES OF THE FOURTH GROUP.

[Abbreviations for names of localities: B. Sp., Barrel's Spring; Hy. F., Henry Fork; Gr. R., Green River; S. P., South Park; M. P., Middle Park; El., Elko; M. Cr., Muddy Creek; Mo., Miocene; Gr., Group.]

Hemitelites Torelli(?), Heer.—Gr. R.
Pteris pennæformis, Heer.—Hy. F.—Mo., (Gr. 1.)
Blechnum Gœpperti, Ett.—Hy. F.
Aspidium Fischeri, Heer.—M. Cr.—Mo.
Lygodium neuropteroides, Lesqx.—B. Sp.
Ophioglossum Alleni, Lesqx.—S. P.
Salvinia cyclophylla, sp. nov.—M. P.
Lycopodium prominens, sp. nov.—El.
Equisetum Haydenii, Lesqx.—B. Sp., (Gr. 3.)
E. Wyomingense, sp. nov.—Gr. R.
Taxodium dubium, St.—El.—Mo., (Gr. 3.)
T. tijanorum, Heer.—B. Sp.—Mo.
Glyptostrobus Europeus, Heer.—S. P.—Mo.
Sequoia angustifolia, Lesqx.—El.
S. Langsdorfi, A. Br.—S. P.—Mo., (Gr. 1.)
S. Coutsiæ(?), Heer.—M. P.—Mo.
Thuya Garmani, Lesqx.—El.
Thuites callitrina, U.—S. P.—Mo.

Pinus polaris, Heer.—S. P., E.—Mo.
Pinus(!), species.—S. P.
Abies Nevadensis, Lesqx.—El.
Arundo Gœpperti, Mu.—Gr. R—Mo., (Gr. 1.)
Phragmites Œningensis, A. Br.—Hy. F., B. Sp., El.—Mo., (Gr. 1, 2, 3.)
Juncus, species.—Gr. R.
Poacites lævis, H.—B. Sp., El.—Mo.
Cyperus(!) Braunianus(?), Heer.—B. Sp.—Mo.
Cyperites Deucalionis, Heer.—B. Sp.—Mo.
Carex tertiaria, Heer.—Hy. F.—Mo.
Sparganium, species.—B. Sp.
Acorus(!), species.—S. P.
Populus Richardsoni, Heer.—El.—Mo.
Salix elongata, Web.—El.—Mo.
S. angusta, A. Br.—Gr. R.—Mo., (Gr. 2.)
S. media(?), A. Br.—El.—Mo.
Myrica nigricans, Lesqx.—Gr. R.
M. copiana, sp. nov.—S. P.
M. acuminata, U.—M. P.—Mo.
M. undulata, Heer.—El.
M. latiloba, Heer.—M. P.—Mo.
M. partita, sp. nov.—El.
Comptonia Bronguarti(?), Ett.—El.
Ulmus tenuinervis, sp. nov.—M. P.
Planera longifolia, Lesqx.—S. P.
Quercus semi-elliptica, Gp.—El.—Mo.
Q. lonchitis, U.—Gr. R.—Mo.
Q. Elkoana, sp. nov.—El.
Q. neriifolia, Heer.—S. P.—Mo.
Fagus feroniæ, U.—El.—Mo., (Gr. 1.)
Ficus lanceolata, Heer.—S. P., M. P., Gr. R.—Mo., (Gr. 3.)
Ficus Jynx, U.—El.—Mo.
F. Ungeri, Lesqx.—G. R.
F. populina, Heer.—G. R.—Mo.
Cinnamomum Scheuchzeri, Heer.—Gr. R.—Mo., (Gr. 2.)
Diospyros Copeana, sp. nov.—El.
Fraxinus prædicta, H.—M. P.—Mo.
Ampelopsis tertiaria, Lesqx.—Gr. R.
Weinmannia (?) rosæfolia, sp. nov.—M. P.
Eucalyptus americana, Lesqx.—Gr. R.
Acer, species.—B. Sp.
Sapindus angustifolius, sp. nov.—M. P.
S. coriaceus, sp. nov.—El.
Staphylea acuminata, sp. nov.—M. P.
Ilex affinis, Lesqx.—Gr. R.
I. stenophylla, U.—Gr. R., M. P.—Mo.
I. subdenticulata, sp. nov.—M. P.
I. undulata, sp. nov.—M. P.(?)
Ceanothus cinnamomoides, Lesqx.—Gr. R.
Paliurus Florisanti, sp. nov.—S. P.
Rhus drymeja, sp. nov.—M. P.
R. Haydenii, sp. nov.—M. P.
Juglans acuminata, Heer.—Gr. R.—Mo. (Gr. 3.)
J. Schimperi, Lesqx.—Gr. R., (Gr. 1.)
J. denticulata, Heer.—Gr. R.—Mo. (Gr. 2 and 3.)
J. thermalis, Lesqx.—M. P.

Pterocarya americana, sp. nov.—M. P.
Carya Heerii(?), Ett.—Gr. R.
Podogonium, fruit.—M. P.
Podogonium, leaf.—S. P.
Cæsalpinia(?) linearifolia, sp. nov.—S. P.
Acacia septentrionalis, sp. nov.—S. P.
Leguminosites, fruit and leaf.—El.
Carpolithes et semina.—M. P.

REMARKS ON THE SPECIES OF THE FOURTH GROUP.

The fourth group is remarkably distinct from the lower ones by its peculiar *facies*. It has for characters of its flora a proportionally large number of ferns, 6 species, a *Salvinia*, a *Lycopodium*, 2 species of *Equisetum*, 11 species of conifers, and 9 species of *Glumaceæ*, viz: 30 species of acrogenous monocotyledonous and gymnospermous plants, or 37 per cent. of the whole number of species as yet known as its representatives. Moreover, the balance of the species is limited to few genera: to *Salix*, 3 species; *Myrica* and *Comptonia*, 7; *Quercus*, 5; *Ilex*, 4; *Rhus*, 2; *Juglandeæ*, 6. At first sight, this group appears scarcely referable to a Miocene flora, so different is its *facies* from that of any of the former divisions. It has, however, 32 of its species identical with species of the European Miocene, or a proportion of 40 per cent.; while it is allied only to the lowest American group by 5 species, mostly of general distribution: *Pteris pennæformis*, *Phragmites Œningensis*, *Fagus feroniæ*, *Juglans Schimperi*. With the second group it has in common the same *Phragmites*, *Salix angusta*, *Cinnamomum Scheuchzeri* and *Juglans denticulata*; and with the third *Phragmites* still, *Equisetum Haydenii*, *Taxodium dubium*, *Ficus lanceolata*, *Juglans acuminata*, and *J. denticulata*. It has thus preserved a remnant of the flora of the other groups, which, considered altogether, is very little; for the three first divisions have 267 species, and in eliminating *Phragmites Œningensis*, represented in all the divisions of the Tertiary, we find only 11 species, or 5 per cent., of the flora of the Green River group represented in the others. If it had not so many typical representatives of the Miocene of Europe, and if at the same time it had some one of our living species, it might be considered as Pliocene. But of more recent types than those of the former groups, it has scarcely any; I can name only *Ulmus tenuinervis*, the fine *Staphylea acuminata*, and *Ampelopsis tertiaria*. The remains of plants at Green River are found in laminated shales with an abundance of skeletons of fishes. At Elko station, South and Middle Parks, the plant-bearing beds, composed of the same kind of thin, laminated, fragile, soft shale, have also preserved remains of fishes, insects, and feathers.

The peculiar compound of the thin laminated slates of the formation, and the similarity of animal fossil remains, prove, as well as the general character of the flora, that the localities named in the above table are referable to the same group. Very few species, however, have been observed at more than one locality; while, on the contrary, the species, most of them at least, are represented by a very large number of specimens. This fact, like the distribution of the species, indicates a vegetation of high land, covered with lakes, swamps, and deep forests of conifers, with a thick undergrowth of ferns and shrubs. With a vegetation of this kind, the number of species is limited, and these are generally circumscribed in local groups. A vegetation analogous to this, covered the northern half of Europe after the Drift period. In the Tertiary epoch it has its analogue with the Œningen or upper stage of the Miocene.

§ 3.—DESCRIPTION OF SPECIES.

I have described here only the forms which are considered as new species, with those, which though already known from Europe, had not yet been recognized from American specimens. A few also are remarked upon, which, represented by better specimens, have their characters and their relation more clearly defined.

The researches of the past year have added to the American Tertiary flora about one hundred species, of which sixty are new ones. The whole number represented in the tables of distribution amounts now to nearly three hundred and sixty.

I have followed for the description the same plan as in the two former annual reports of Dr. Hayden, briefly exposed the essential characters of the species, and quoted references for analogies whenever I could find any in the publications of European authors, in order to obviate the absence of figures, which, though, now already made, have to be reserved for a final report.

Except for the specimens found by myself, the names of the discoverers are carefully recorded, with the localities where the fossil remains have been found.

SPECIES OF THE FIRST GROUP.

WOODWARDIA LATILOBA, *sp. nov.*

Frond large, bipinnatifid; pinnæ opposite, decurrent upon the thick rachis, long, linear, slightly tapering to the point, equally lobed; lobes disjointed to three-fourths of their length, united by narrow obtuse sinuses, broadly lanceolate, obtuse, scythe-shaped upward, becoming more connivent toward the point of the pinnæ; upper pinnæ more and more obtusely and less deeply lobed, passing to mere equal undulations; nervation undistinct, except the middle nerve of the lobes, which is narrow but well marked, ascending to the point of the lobes; secondary veins parallel to the rachis and to the middle nerve, branching in ascending, forming by anastomoses of their divisions one or two rows of large areolæ, and joining the borders in parallel veinlets.

Large and splendid specimens have been obtained of this form by Mr. Arthur Lakes, of the School of Mines of Golden, to whom the survey owes many valuable discoveries. The numerous fragments represent the characters of the whole frond. Its consistence is thick, coriaceous; the surface is smooth, nearly polished; and the details of nervation are recognizable only upon fragments which show the lower surface of the pinnæ, or whose upper surface is destroyed by maceration. The fructifications have not been discovered yet.

Habitat.—Golden; South Table Mountain, *A. Lakes.*

WOODWARDIA LATILOBA, *var.* MINOR.

Only small fragments of this form have been obtained at Black Butte. They represent the upper part of a pinna of exactly the same form and with the same mode of division as the specimens of Golden. The lobes, however, are much smaller, less scythe-shaped; the basilar veins follow the rachis, as in the former species, going from the base of one middle nerve to that of the other above, forming thus a band on both sides of the rachis, passing also in long areas up and along the middle nerve of the lobes and from their anastomoses ascending to the borders and forking twice. In the normal form, the veins, though thicker, are less distinct, and form two rows of polygonal areolæ in passing up to the borders; in this variety (?), the veinlets are merely forked in going up.

This small form is closely allied to *Woodwardites arcticus*, Heer, differing, however, by the nervation. The fragments representing Heer's species are, like those of Black Butte, too small for an exact comparison. His described specimens are from Greenland and from Alaska.

Habitat.—Black Butte; Wyoming.

PTERIS PENNÆFORMIS, Heer.

Pinnæ long, linear-lanceolate, taper-pointed, entire to above the middle, undulate upward, serrate at or near the point, thickish; medial nerve thick, especially toward the base of the leaflets, where it is bi-grooved and three-striated; veins in an acute angle of divergence, close, thin, mostly simple, or forking once. The fragments of leaves or pinnæ, as described here, closely resemble the species of Heer, (Fl. Tert. Helvet., I, p. 38, Pl. xii, Fig. 1,) differing slightly by the borders, which, serrulate at or near the point, are undulate or distantly and obtusely dentate above the middle, and entire downward. Heer describes his species as serrulate near the point and entire downward. In comparing our specimen to the figure marked above, the denticulation appears merely more marked in the American form.

This species has been described already in Hayden's Report for 1871, (p. 283,) from specimens from Henry's Fork, too fragmentary for positive determination.

Habitat.—Golden, Col.

PTERIS AFFINIS, *sp. nov.*

Frond simply pinnate; pinnæ subcoriaceous or thickish, short, about 5 centimeters long, oblong-lanceolate, broader at the middle, rapidly tapering to a slightly obtuse point, gradually narrowed downward, and rounded to the point of attachment; borders undulate; nervation thin, but very distinct; veins open, curving from the middle nerve to the borders, slightly more deflexed downward in reaching the midrib, dichotomous, none simple, or scarcely any, forking once or twice, rarely three times.

Different from the former by its nervation, shorter obtuse pinnæ, undulately-crenate borders, and thinner substance of the leaves. From *P. anceps*, Lesqx., (Hayden's Report, 1872, p. 376,) it differs especially by more distant and more oblique veins.

Habitat.—Golden; rare like the former, but obtained in better specimens.

PTERIS EROSA, Lesqx.

Pinnæ broadly-lanceolate or ovate-lanceolate, taper-pointed or acuminate, serrate upward, with crenulate or lacerate borders below; medial nerve thick; veins oblique, straight, mostly simple, forking near or at the base, rarely above the middle, distant, parallel. It has been formerly described in Supplement to Hayden's Report, 1871, (p. 12.)

By its nervation and the form of its pinnæ this species is related to *P. longifolia*, *L.*, or to some of its varieties with serrate borders.

Habitat.—Raton Mountains, where the first incomplete fragments were discovered; Golden, where it was found in more perfect specimens.

PTERIS SUBSIMPLEX, *sp. nov.*

Pinnæ thick, coriaceous, simple, entire, linear-lanceolate, narrowed in curving to the base, (point broken,) large, varying in size, from 2 to 4 centimeters broad, and at least 10 to 12 centimeters long; middle nerve narrow, deeply marked; veins distinct, simple, or merely forking once near the base or above the middle, open, slightly curved downward in passing to the borders, which are slightly crenate by contraction to the point of the veins. This fine fern is comparable to some species of *Danæa.* It differs, however, from those which I have for comparison, by the direction of the veins, which do not turn upward in reaching the borders, but join them in the same curve and degree of divergence which they follow from their point of attachment to the middle nerve.

Habitat.—Golden. It is in the collection in many fragments, none showing the point of the leaflets.

PTERIS GARDNERI, *sp. nov.*

Frond large, simply pinnate; pinnæ large, linear, in right angle to the rachis, sessile, rounded to the base, with entire, deeply undulate borders; middle nerve broad, thin, grooved in the middle, flattened on the borders; veins nearly at right angle to the midrib, abruptly curved down at the base or decurring to it, forking once near the base, and once, also, generally above the middle; divisions or veinlets joined by cross-branches, forming here and there some irregular elongated polygonal areolæ. The pinnæ are larger than those of *P. pennæformis*, but apparently of about the same form. The species essentially differs by its strong, thick veins, more distant, joined by cross-branches, &c.

Habitat.—Roof of coal-mines, Sand Creek, Colorado, *A. Gardner.*

DIPLAZIUM MUELLERI (?), Heer.

Pinnæ narrowly-lanceolate, tapering to a long acumen; borders margined, inflated, distantly equally serrate; medial nerve broad, bi-grooved; veins at an acute angle of divergence, very close, dichotomous, some of the branches uniting by anastomosis; substance very thick, coriaceous. The substance of the leaflets seems composed of two layers; the upper one, either scaly or villous, is sometimes destroyed or erased as a pellicle of coaly matter. Through this crust the veins are somewhat obsolete; but when it is destroyed, the details of nervation are very clear. The anastomosis or cross-branches of the veinlets is somewhat like that of *Pteris Gardneri;* it is, however, not as frequent.

I consider this form as identical with *Diplazium Muelleri* as described in Heer, (Boernst. Fl., p. 8, Pl. i, Fig. 2.) There is, however, a difference in the borders of the pinnæ, which, in the European species, are doubly serrate, while they are equally and simply serrate in the American form; and in the cross-branches of the veinlets, which are not remarked in the description and figures of Heer. It is probable that the specimens from Boernstadt had the upper surface covered by the coating of scaly matter, and that, therefore, the minute details of nervation were not observable. Professor Heer finds the relation of his species to the living *Diplazium celtidifolium.* Ours is rather comparable to some species of *Acrostichum,* like *A. aureum,* which has also its veins here and there joined by cross-veinlets.

Habitat.—Golden; South Table Mountain.

ASPIDIUM GOLDIANUM, *sp. nov.*

Frond bi-tripinnatifid; primary pinnæ enlarged, broadly deltoid; secondary pinnæ linear, alternate, rapidly decreasing in length in ascending, joined to the rachis in an obtuse angle of divergence, alternately equally pinnately-lobed; lobes free for two-thirds or three-fourths of their length, oblong, obtusely or slightly acute, inclined outside; middle nerve distinct; veins 5 to 7, simple, slightly curved inward, parallel, obsolete, marking the borders as slightly serrulate by their impressions. The substance of the leaflets is subcoriaceous; the surface smooth; the borders really entire, but, as it is the case in species of this kind when they have a thick consistence, they are marked as apparently denticulate by the impression of the veins. Both primary and secondary rachis are narrow; the secondary pinnæ are sessile, not decurrent by the lowest lobe.

This species is closely allied to *A Serrulatum*, Heer, of the Boernstadt flora, differing by the more entire borders, more numerous tertiary veins, &c.

Habitat.—Golden; found only in fragments.

GONIOPTERIS POLYPODIOIDES, Ett.

Pinnæ linear, lanceolate-pointed, remotely denticulate; primary veins parallel and at equal distance; secondary veins at an obtuse angle of divergence, apparently alternate, simple, curved inward. By the form of the pinnæ and the distantly denticulate borders, the specimens represent the European species as figured and described by the author in Mount Promina flora. The veins are, however, scarcely discernible, as also the very small crenulations exposing the points of the secondary veins; the points of the middle veins, however, are marked by small, distinct teeth. The identity of this form with the European species is not quite certain. Its nervation is very undistinct.

Habitat.—Sand Creek, *W. H. Holmes.*

SPHENOPTERIS MEMBRANACEA, *sp. nov.*

Frond bi-tripinnate; primary pinnæ long, linear-lanceolate, rigid, erect, or at a narrow angle of divergence; tertiary pinna short, oblong-lanceolate, decurrent, deeply and equally 5–6-lobed; lobes oblong, acute, or slightly obtuse, distinct, to near the base, single-nerved.

This is perhaps a variety of *S. eocenica*, Ett., described in Hayden's Report for 1872, (p. 376,) a species very common at Golden. It has, however, a different *facies*, especially by its membranaceous shining substances, the rigid divisions, the much shorter ultimate pinnæ, the more distinct narrower pinnules, and the decurring base of the secondary pinnæ joined by a margin along the rachis, &c.

Habitat.—Golden, rare, *A. Lakes.*

SPHENOPTERIS NIGRICANS, *sp. nov.*

Frond polypinnate; secondary (?) pinnæ narrow, linear in outline, (as much as can be seen from the fragments;) tertiary pinnæ at a right angle of divergence from the narrow slightly-winged rachis, short, sessile, (the lowest pinnules covering the rachis by their borders, but not decurrent,) linear, abruptly narrowed to a small obtuse terminal lobe, pinnately deeply-lobed; pinnules in right angles to the rachis, free to near the base, oblong, obtuse, undulately pinnately-lobed on the borders; middle vein scarcely distinct, alternately pinnately-divided in 4 to 6 pairs of veinlets, curving downward, and forking once, except the upper pair, which is simple. The surface seems to be villous or squamose, covered as it is by a black pulverulent thin coating of coaly matter. The nervation of this species is pteroid, somewhat like that of *Pteris blechnoides*, Heer, (Fl. Tert. Helv., I, p. 40, Pl. xii, Fig. 8b;) the form of the leaflets refers it, however, to the genus *Sphenopteris.*

Habitat.—Black Butte.

HYMENOPHYLLUM CONFUSUM, *sp. nov.*

Frond polypinnate; tertiary (?) rachis grooved, thick, divisions in an open, nearly right angle of divergence to the main rachis, dichotomous; pinnules cuneiform, enlarged upward, dichotomously three, many times divided in linear, short obtuse lobes, entered each by a simple veinlet diverging from dichotomous branches of the primary veins. The divisions are decomposed many times, the last pinnule being only 3 millimeters long and 1½ millimeters broad; all are crowded and mixed upon another. The surface is minutely punctulate, as if it had been tomentose or ciliate. The specimens are fragmentary.

Habitat.—Golden.

SELAGINELLA BERTHOUDI, *sp. nov.*

Stem slender, spreading, prostrate(?), or creeping(?), dichotomous, divisions simple, or the longer ones the lowest, also dichotomous; leaves four-ranked, by two rows of alternate distichous linear-oblong, lingulate, pointed, longer leaflets, spreading on both sides of the stem and branches, and two rows of small oval or nearly round ones, closely appressed to the base of the longer leaves and covering it. The distichous leaflets are 3 to 4 millimeters long and 1 millimeter wide, the small ones less than 1 millimeter square. This fine species greatly resembles some species of our time, like *S. stolonifera*, *S. Martensii*, &c. Its characters are distinctly recognizable.

Habitat.—Golden. Discovered by *Capt. E. Berthoud*, to whom the survey owes the communication of this remarkable species.

EQUISETUM(?) LÆVIGATUM, *sp. nov.*

Stem thick; its surface irregularly wrinkled lengthwise, not costate, contracted at the articulations, of which only one is seen upon the specimen in the middle of the stem. The articulation bears the scars of four branches, marked by whorls of somewhat undistinct, close rays, enlarging from the center to the circumference. The characters are not sufficiently discernible; the scars of branches are scarcely distinct, and the stem, apparently crushed above or below the articulation, is nearly half as large on one side of it as on the other. It may represent a root of *Equisetum* marked around with the scars of rootlets.

Habitat.—Sand Creek, *W. C. Holmes.*

SEQUOIA LANGSDORFII, A. Br.

Is represented by small, somewhat obscure specimens. The leaves are slightly shorter. It is the only difference which may be remarked in comparing it to the numerous figures published of this species by European authors. It may represent the same species as Abietites dubius, Lsqx., from the Raton mountains. (Hayden's Report, 1872, p. 347.)

Habitat.—Black Butte, above main coal.

SMILAX(!) GRANDIFOLIA(?), Ung.

The lower half of the leaf only is preserved upon the specimen. Its base is rounded to the petiole, three-nerved from the base or irregularly five-nerved by the division, near its base, of one of the lateral veins, and on the other by a marginal veinlet coming out from the top of the petiole; middle nerve and lateral veins crossed by few thin branches or oblique nervilles. The nervation is similar to that of Unger's species in Sillog., (Pl. ii, Figs. 5–8;) the form of the leaf, however, differs, it being rounded to the petiole, not cordate.

Habitat.—East of Colorado Springs, *A. C. Peale.*

FLABELLARIA LONGIRACHIS, Ung.

Leaves very large, as seen from numerous fragments; rays attached in an acute angle of divergence to the very narrow rachis, obtusely carinate, marked in the length by obtuse equal striæ less than one millimeter apart; epidermis comparatively thick. As Unger remarks it, the rays are not duplicate or folded in their contact to the rachis. The species is represented by many specimens; it appears identical with that described by Unger.

Habitat.—Divide between Yellowstone Lake and Snake River, *Hayden*; Raton Mountains, Golden.

FLABELLARIA(?) FRUCTIFERA, *sp. nov.*

Two fragments representing the base of an apparently large palm-leaf, with very numerous rays, 60 to 80, acutely carinate, nerved; primary nerves a little more than 1 millimeter distant; secondary veins very thin, slightly discernible; top of the rachis or petiole flat or enlarged on the sides, reniform. Joined to it is a small raceme of cylindrical oblong obtuse fruits, tapering to a slender peduncle, narrowly striated in the length, slightly flattened by compression, 1 centemiter long, ½ centimeter wide in the middle. Four of these fruits are attached to a common pedicel, partly imbedded into the stone, alternately diverging from it by short peduncles.

Habitat.—Golden.

ERIOCAULON(?) POROSUM, *sp. nov.*

Leaves basilar, rosulate, spreading, entire, linear-lancolate, broader at the middle, gradually tapering upward to a slightly obtuse point, and downward to a very short petioled base; medial nerve broad, concave; lateral veins two, nearly parallel, with apparent ramifications toward the borders, forming round polygonal small areolæ. The leaves are thick, of a spongious texture apparently; the meshes along the borders are not distinct, and may be formed by contraction of the epidermis. I do not find any species to which this form may be comparable, except the leaves of some large rossulate *Eriocaulon*. The specimen is cut through by rootlets nearly as thick as the leaves are broad.

Habitat.—Sand Creek, *W. H. Holmes.*

ZINGIBERITES(?) UNDULATUS, *sp. nov.*

Fragments of large leaves, whose outlines are not preserved, equally undulate on the surface, marked with oblique, distinct, parallel primary veins, 2 millimeters distant, with 6 to 7 very thin intermediate veinlets. The surface is covered with a thick epidermis or the leaf is subcoriaceous. The surface-undulations are formed by deep furrows, which, however, are more or less distinct, and which do not cut the connection of the veins. There is no trace of rachis to which the fragments of an evidently large leaf may have been attached.

Habitat.—Golden.

RHIZOCAULON GRACILE, *sp. nov.*

Branches slender, straight, irregularly forking, bearing oblanceolate, scythe-shaped, very obtuse, small leaves, with the base descending or decurring along the stem, joined to it by a very short, thickish petiole, appearing like a swelling of the narrowed base of the leaves. The leaves are about 7 millimeters long, 2½ millimeters broad toward the point where they are broadly rounded; they curve downward from the point, of attachment, appearing placed upon the slender stem, or rachis, in a spiral order. They are of a thick consistence; their surface covered with a coating of coaly matter, obliterating nearly every trace of nervation An undefined medial nerve seems apparent on some leaves; but it may be a mere linear artificial depression. On other leaves, deprived of epidermis, some thin striæ running parallel and lengthwise are recognizable. By the disposition of the branches and of the leaves these vegetable fragments resemble those figured by Schimper as illustration of the genus *Rhizocaulon*, Sap., (in Paleont. Veget., Pl. lxxx, Fig. 8.).

Habitat.—Black Butte, burned shale above the main coal.

POPULUS MUTABILIS, Heer.

One leaf only, representing a small form, (like that of Heer, Flor. Tert. Helv., II, Pl. lxi, Figs. 9, 10.) The basilar veins are also attached to the middle nerve, a little above the borders and opposite, with three pairs of alternate secondary veins above them, all in an acute angle of divergence. The leaf, however, does not appear coriaceous.

Habitat.—Black Butte.

POPULUS HELIADUM, Ung.

Leaves broadly-ovate, round-truncate to the base, long-petioled; borders entire, merely undulate toward the point; lower secondary veins open, marginal, thin, the upper ones parallel, close, simple, or forking once, ascending in an acute angle of divergence close to the borders, where they curve. By its form, the direction of the lateral veins ascending straight to near the borders, &c., this leaf is similar to that described by Unger, (Fl. v. Sotzka, p. 37, Tab. xv, Fig. 7,) differing, however, by the secondary veins more numerous and at equal distance; a difference which may be merely casual.

Habitat.—Golden.

SALIX INTEGRA, A. Br.

Leaves entire, linear-lanceolate, taper-pointed or acuminate, narrowed or tapering to the petiole; lateral veins mostly opposite, in an acute angle of divergence, the lowest pair less open than the upper ones, at least in the leaves with a tapering base.

We have specimens of Golden and of Black Butte; in these last, the leaves are more rounded to the short petiole, and the secondary veins are all under the same angle of divergence. There is, however, no marked difference, and both forms agree in their characters with the leaves of this species as described by Herr, (Fl. Tert. Helv., II, p. 32, Pl. lxviii, figs. 20–22.) The nervation of the leaves of Golden is the same as Fig. 21, while the form of the leaves of Black Butte more closely resembles Fig. 22.

Habitat.—Golden and Black Butte.

MYRICA TORREYI, Lsqx., *var.* MINOR.

One leaf only has been found of this variety (?) Leaf shorter, shorter-pointed, less gradually decreasing downward to the petiole; borders denticulate, with close, smaller teeth. No other difference separates this leaf from the typical form described from Black Butte in Report for 1872, (p. 392.) It is probably a mere local variety.

Habitat.—Sand Creek, Colorado, *A. Gardner.*

BETULA GRACILIS (?), Ludw.

Species represented by only one ovate, obtusely-pointed leaf, unequal at the round subcordate base; borders crenulate; nervation camptodrome; veins curving close to the borders and following them, anastomosing downward with thick nervilles, in right angles to the secondary veins. The impression of the leaf upon the stone is deep, and, therefore, it represents apparently a coriaceous leaf, a character which is not mentioned in the description of the author. (Paleont., vol. viii, p. 99, Pl. xxxii, Fig. 4.) All the veins, like the nervilles, are coarsely marked.

Habitat.—Golden.

QUERCUS FURCINERVIS, Rossm.

Leaves subcoriaceous, lanceolate, more generally oblanceolate, rapidly narrowed to an acute point, tapering downward and rounding from near the base to a short petiole, distantly and regularly dentate from near or above the base; lateral veins parallel, at equal distance, (11 pairs in a leaf of 10½ centimeters long,) slightly curving in passing up to the borders, mostly simple, all craspedodrome, rarely forking near the point by an upper thin tertiary vein passing upward under the base of the teeth; nervilles distinct, in right angle to the veins, forming by cross branches large rectangular areas. The lower part of the leaves is generally entire, and the lowest veins camptodrome or undulating in ascending along the borders. When dentate near the base, the lower veins enter the teeth. Heer, in describing *Q. Burmensis*, de la H., (in Fl. Tert. Helv., III, p. 315, foot-note,) says that the form of leaves, dentation, and nervation of this species identify it to *Q. furcinervis*, from which, however, it differs by the absence of an upper branch on the point of the secondary veins. In the leaves of Oregon most of the secondary veins are simple, rarely one or two are seen with the upper small branch passing up under the teeth. These leaves, therefore, are referable as well to *Q. furcinervis* as to *Q. Burmensis.*

Habitat.—Oregon, under the lava-beds of the Cascade Mountains, *Prof. Jos. Le Conte;* clay-beds of Spanish Mountains, California, *Prof. Whitney.* Golden, in fragments.

QUERCUS GOLDIANUS, *sp. nov.*

Leaves oblong, rounded to an obtuse point, narrowed to the base (?) (destroyed,) with borders undulate or slightly rarely dentate with short obtuse teeth; nervation camptodrome and craspedodrome.

This species may be a mere deviation of the former, though the leaves, for their point, at least, are far different. The nervation is the same; the borders of the leaves undulate, entire, except near the middle, where they are distantly dentate, the teeth being then entered by the point of the secondary veins, which forks under the base of the teeth by a small border-branch. The nervation is, therefore, the same as in the former species, modified only according to the divisions of the borders of the leaves, which are either entire, with secondary veins camptodrome, or dentate, with the same veins craspedodrome. The nervilles are also of the same character, like the details of areolation. The form of the leaves, however, especially at the entire obtuse point, is far different, and in one of the leaves the borders seem to be perfectly entire or merely undulate. There is only in the collection two specimens, one representing the upper part of a leaf, the other a longer and larger leaf, with the point and the base destroyed.

Habitat.—Golden.

QUERCUS ATTENUATA (?), Göpp.

Leaf oval-oblong, narrowed downward to a slender petiole and upward to a short point; penninerve; lateral veins nearly opposite, at an acute angle of divergence, slightly curving in passing to the borders and with few branches, craspedodrome, their points and those of their divisions entering short distant teeth. Except that on this leaf the denticulation of the borders is simple and the teeth equal or of a same order, while, as represented by Göppert, in Fl. v. Schossnitz, (p. 17, Pl. viii, Figs. 4–5,) there are generally two or three small teeth between the larger ones, which only are entered by the veins, there is not any appreciable difference between the American and the European leaves. That this difference is not a specific one is seen by Fig. 5, (*loc. cit.*,) whose teeth are mostly equal and of the same order.

Habitat.—Sand Creek, Colorado, *A. R. Marwine.*

QUERCUS CLEBURNI *sp. nov.*

Leaf oblong, oval, obtusely-pointed, distinctly obtusely-dentate, tapering to the base and decurring to the short petiole, penninerve; medial nerve thick; secondary veins at a very open angle of divergence or nearly at right angle to the middle nerve, obsolete. This form is closely related to *Q. urophylla*, Ung. (Fl. v. Sotzka, p. 33, Pl. ix, Fig. 9,) differing by smaller, more regular teeth. The leaf is unequilateral, as in Fig. 9, (*loc. cit.*,) and on one side the divisions or denticulation of the borders are smaller and more regular than on the other.

Habitat.—Black Butte.

FICUS TILLÆFOLIA, Al. Br.

The species is common enough in the Colorado basin. Specimens from Sand Creek are covered with fragments of its large leaves of the same type and as well characterized as those figured by Heer, (Fl. Tert. Helv., III, Pl. cxlii, Fig. 25.) One of the fragments indicates a leaf of 18 centimeters long and 14 centimeters wide. Specimens from Golden represent also this species, but in smaller leaves.

Habitat.—The whole Lignitic basin, common.

FICUS PLANICOSTATA, Lsqx., *var.* GOLDIANA.

This form differs from the normal one, so abundant at Black Butte, by narrower, more gradually acuminate leaves, and by the primary veins thin and not flattened. This variety is closely related to the leaves described by Saporta in his Fl. Foss. de Sezanne, (p. 400, Pl. xii, Figs. 6–7) as *Sterculia variabilis.* Fig. 6 represents a leaf slightly unequilateral, a character not remarked in the leaves of Golden. The author says that *F. Micheloti* of Watelet is apparently the same species. The normal form of *F. planicostata* is different by its broad, flat primary nerves and its coarser areolation. Except this, the essential characters are the same.

Habitat.—Golden. The variety only is found at this place; the normal form most abundant at Black Butte has been discovered above a bituminous shale of Coal Creek, Colorado, by *W. H. Holmes.*

FICUS ZIZYPHOIDES, *sp. nov.*

A small oval, obtuse(?) (point destroyed,) entire, thick-nerved leaf, palmately 5-nerved; lower pair of veins marginal; second pair turned upward and branching; middle nerve thick, simple, with close, thick fibrillæ in right angle to the veins; petiole thick, apparently long. The lateral veins branch twice, the marginal ones many times, in short divisions, curving along the borders in festoons. The leaf is wrinkled across by the pressure of the nervilles; if representing a *Ficus* it belongs to the section of the *Populineæ.* The petiole is thick from the base of the leaf downward.

Habitat.—Golden.

FICUS TRUNCATA(?), *sp. nov.*

Leaves oblong-ovate, truncate-cordate at base, obtusely-pointed, entire, undulate, penninerve; secondary veins nearly parallel, distant, on an acute angle of divergence, the lower pairs only slightly more open and opposite, camptodrome. The substance of the leaves is subcoriaceous; they are short-petioled and some of them unequilateral; the lowest pair of secondary veins is from above the base of the leaves, and under them there are still one or two pairs of shorter, thin, marginal veinlets curving downward and following the borders. The species is, for the form of the leaves, comparable to *Quercus fagifolia*, Göpp., of which we have specimens from Golden. But the nervation and areolation are far different, and similar to that of *Ficus auriculata*, Lesqx., to which, also, the species is related by the general outline of the leaves. It may be a variety of it.

Habitat.—Golden.

PLATANUS RHOMBOIDEA, *sp. nov.*

Leaves coriaceous, rhomboidal in outline, largest in the middle, cuneate, and entire from the middle to the base, slightly lobed with short, acute lobes, broadly-lanceolate to the point and strongly dentate, the acute teeth being nearly as long as the lobes and all equal; nervation platanoid; areolation undistinct. This leaf might be considered as a young leaf or a form of *Platanus Haydenii*, Newby. It differs, however, greatly by its cuneate base, the sharp, broadly-lanceolate, long, equal teeth, and the thick, coriaceous leaves. The base is destroyed.

Habitat.—Golden; communicated by *A. Lakes.*

ARTOCARPIDIUM OLMEDIÆFOLIUM(?), Ung.

A single leaf, elliptical, acuminate, narrowed to the base, slightly unequilateral, penninerve; borders obtusely unequally dentate, entire near the base, which appears slightly decurring upon the petiole; secondary veins thin, parallel, more oblique on one side than on the other. Though this leaf is smaller than those figured by Unger, (in Fl. v. Sotzka, p. 36, Pl. xiv, Figs. 1–2,) and by Heer, (in Fl. Tert. Helv., II, p. 70, Pl. lxxxiv, Fig. 8,) I have scarcely any doubt about its identity with the European species. The surface of the leaf is crumpled; its substance appears rather thin. Except the difference in size, there is no character indicating any kind of difference.

Habitat.—Golden, *A. Lakes.*

PISONIA RACEMOSA, *sp. nov.*

Leaves small, entire, thickish, rather membranaceous, obovate, round-obtuse, gradually narrowed to a flexuous petiole, penninerve; lateral veins, four pairs, on an acute angle of divergence, parallel, curving quite near the borders; areolation obsolete; fruits or unopened buds(?) in branching corymbs or clusters of 6–8 pedicelled, either erect or horizontal or pending achenia(?), which are short, narrowly ovate, acute, with a truncate base; pedicels filiform. This species is closely allied to *P. eocenica*, Ett., (Fl. v. Här., p. 43, Pl. xi, Figs. 1–22,) differing especially by its much shorter achenia(?) in more divided racemes. D'Ettinghausen compares the fruits(?) of his species to the unfolded buds or the ovaries of some *Pisonia*. In the American specimens, these ovaries appear like ripe small seeds, their tegument being a thin shell, and the inner substance, transformed into coal, appearing as a small nutlet split in two.

Though these remains are referable to the same kind of vegetables as those published by D'Ettinghausen, their relation to the genus *Pisonia* is uncertain.

Habitat.—Black Butte, very rare.

CINNAMOMUM AFFINE, Lesqx.

From the comparison of a large number of specimens representing various forms of this species, (mentioned first in Am. Jour. Sc., vol. xlv, p. 206,) it proves to be, as I supposed, a mere variety of *C. Mississippiense*, Lesqx., described in Trans. Phil. Soc., vol. xiii, p. 418, Pl. xix, Fig. 2.

Habitat.—The species is common at Golden, and found in the whole thickness of the North American lignitic measures.

DAPHNOGENE ANGLICA(?), Heer.

This form has been described from fragmentary specimens as *Cinnamomum Rossmæssleri*, Heer, in Report for 1872, (p. 379.) From a more complete leaf, it appears referable to Heer's species as described in Flor. Helv., (vol. iii, p. 315.) He says that the leaves are ovate-lanceolate, long-acuminate, triplenerved, with the middle and lateral nerves branching, remarking still that it differs from *D. melastomacea*, Ung., by the equilateral base of the leaves and the lateral veins at a more acute angle of divergence. In comparing the American leaf with Unger's species, the same difference is marked as that indicated by Heer, and it appears, therefore, that these leaves of ours are, if not identical, at least very closely allied to the Eocene species of England.

Habitat.—Golden, *Capt. Berthoud.*

DIOSPYROS BRACHYSEPALA, Heer.

Leaves broadly oval or slightly obovate, obtuse, narrowed in a curve to the base, entire, rather membranaceous, but not thick; secondary veins alternate, curving to and along the borders, mostly simple or with few branches, deflected downward in reaching the middle nerve. Though this leaf is not in a perfect state of preservation, the details of areolation being obsolete, it agrees in its recognizable characters with Heer's description of the species in Fl. Tert. Helv., III, (p. 11, Pl., cii, Figs. 1–14,) resembling especially Fig. 6 for its form and Fig. 2 for the nervation or the distribution of the lateral veins. Leaves of the same kind have been described in Report for 1872, (p. 394,) from Black Butte.

Habitat.—Sand Creek, Colorado, *A. R. Marwine.*

VIBURNUM MARGINATUM, Lesqx.

This species is described from Black Butte, the only locality where it has been discovered till now, in Report for 1872, (p. 395.) By its size and the nervation of its leaves, it is related to *Viburnum giganteum*, Sap., (Fl. Foss. de Sezanne, p. 370, Pl. ix, Fig. 1,) distinct, however, by the more tapering point of this last species, and the form of its triangular sometimes double dentate teeth. The author remarks also the relation of his species to the American living *V. lantanoides*, and to *V. erosum*, Thb. of Japan, to which the species of Black Butte has still more affinity than the Eocene species of France.

VIBURNUM LAKESII, *sp. nov.*

Leaf coriaceous, round in outline, obtusely(?) trilobate (the upper part is broken,) with obtuse sinuses; serrate along the borders to near its base, borders and teeth thicker and membranaceous or cartilaginaceous; three-nerved from the base, lateral nerves thick, much divided, divisions branching also like the secondary veins, which are nearly at equal distance from the primary ones and parallel, few, opposite, all the branches going up to the points of the teeth. The species has a close relation to *V. marginatum*, so abundant at Black Butte. It has the same type of nervation, but is, however, very different by the thicker substance of the leaves, the thicker primary and secondary veins, the three-lobate form of the leaves, and the truly serrate (not dentate) borders. The base of the leaf also is abruptly turned downward or nearly truncate. The species is a very fine one, and it is regrettable that it is represented as yet by a single fragmentary specimen.

Habitat.—Golden; communicated by *A. Lakes.*

CORNUS STUDERI, Heer.

Leaves variable in size, entire, oval-lanceolate, taper-pointed or acuminate, rounded in narrowing to the petiole; lateral veins simple, parallel, curving in passing up to near the borders, along which they join each other in festoons; fibrillae distinct, in right angle to the veins, or sometimes diverging upward. This species is represented by numerous leaves of different size, the largest at least 14 centimeters long, with 12 to 14 pairs of veins, (the base is broken,) the small leaves only 6½ centimeters long with 9 to 10 pairs of lateral veins. The lowest veins are always closer than the upper ones; these near the top become nearly parallel to the midrib. The substance of the leaves is thickish and somewhat coriaceous.

Habitat.—Golden. It is also common at Evanston.

CORNUS HOLMESII, *sp. nov.*

The upper part of an ovate-lanceolate entire leaf, with secondary veins thin, very distant, alternate, much curved in passing up in an acute angle from the middle nerve toward the borders. The point of the leaf is broken. Though the specimen is fragmentary, it represents evidently a *Cornus* specifically distinct from the other fossil species by the great distance of the secondary veins. By this character only it is distantly related to *C. Buchi*, Heer.

Habitat.—Bituminous shale, Coal Creek, Colorado, *W. H. Holmes.*

CORNUS ORBIFERA, Heer.

Leaves round or broadly oval, entire; rounded upward to the point, and also downward to a short, curved petiole; medial nerve thick; secondary veins deep, though narrow, inflated at their point of union to the midrib, which they join in a broad angle of divergence, arched in ascending to the borders. The substance of the leaves is thickish, the surface rough, secondary veins all simple, effaced close to the borders, the lowest in right angle and marginal. The nervilles are close, oblique to the veins, simple or branching.

Habitat.—Golden.

NELUMBIUM TENUIFOLIUM, *sp. nov.*

Leaves exactly round, peltate from the middle, small, 8 to 9 centimeters in diameter, of a thin texture, with flat, undulate borders; primary nerves 13, equal and at equal distance, thin or narrow, nearly simple or sparingly branching, crossed at right angle by nervilles, which by ramification form large square areas. The leaf shows the upper side somewhat convex at the center. The species is represented by two leaves, one of which is in a good state of preservation.

The essential difference between this and the next consists in the thin substance of its leaves; the veins scarcely ramified, and their divisions not half as thick; the surface smooth, not roughened by the secondary and tertiary nervation, and one primary nerve the less. Differences of the same kind are, however, remarked sometimes between leaves of the same species of our time. In *N. luteum*, for example, the upper surface is generally smooth, and the nervation less distinct, while the lower one is coarse, with the veins apparently thicker; in the same species the tissue of the leaves is thicker and harder in the floating leaves than in those raised above water by longer pedicels. The difference of one nerve the less might also be considered as of no value for a specific distinction. However, in the numerous leaves of *N. luteum*, large and small, the primary nerves are always of the same number—21. Both these fossil forms have no trace of a middle nerve; at least this one has none; but the leaves representing the next described species has, between two of the veins, a split, which may represent the medial nerve or take its place.

Habitat.—Sand Creek, *A. Gardner.*

NELUMBIUM LAKESIANUM, *sp. nov.*

Leaves coarse, thickish, peltate, exactly round, with the petiole central; borders turned down; center concave, regular; all the veins, (14,) equal in thickness, equally diverging from the center to the circumference, deeply marked, branching near the borders, crossed by thick, flexuous nervilles at right angles and disjointed; surface rough. This species is represented by three specimens of the same form, two small leaves and a much larger one. They differ from *N. Buchi*, Ett., (Fl. Mt. Promina, p. 36, Pl. ii, Fig. 1,) by the central point of attachment of the petiole, the absence of a thick branching principal or middle nerve, &c.

A number of nuts or fruits, which I think referable to the same species, have been found at the same localities as the leaves. They are cylindrical-oblong, truncate at base, with a small central mamilla, or round scar, representing the point of attachment at the base of the alveolæ of the receptacle; covered by a thin, shelly integument, and obtusely pointed. The point is crushed in all the specimens. They are comparatively of large size; nearly 2 centimeters long, 8 millimeters in diameter. The forms of these fruits is somewhat like that of those of our *N. luteum;* they are proportionally longer, however, the shelly surface is thinly lined or striate in the length; the basilar scar marking the point of attachment is 1½ centimeters broad, slightly conical or convex pointed, with a rough surface.

Habitat.—Golden; discovered and communicated by *A. Lakes.*

MAGNOLIA LESLEYANA, Lesqx.

Represented by the upper part of a very large leaf, its widest part 9 centimeters broad, rounded in tapering to a point; lateral veins parallel, distant, at unequal distance, at the same angle of divergence, and curving to and along the borders, as in the leaf described from Mississippi in Proc. Phil. Soc., (vol. xiii, p. 421, Pl. xxi, Fig. 1.) The more distant of the secondary veins are separated by shorter, more open, tertiary veins, as marked upon the same figure. The tertiary nervation and areolation are distinct, and evidently refer this fragment to a *Magnolia.*

Habitat.—Golden.

DOMBEYOPSIS TRIVIALIS, Lesqx.

This species is described in Hayden's Report for 1872 (p. 380) from an imperfect specimen. We have now a nearly entire leaf, 3-palmately-nerved, round-square in outline, obtusely 3–5-lobed, the two lateral principal lobes short obtuse, the middle one broad, nearly round, base of the leaf deeply cordate or auricled, marked by two simple marginal veinlets coming out from the round point of attachment of the petiole, and descending toward the borders of the auricles. The three primary nerves are ramified, the lateral bearing two or three outside branches, the middle one a few alternate pairs. The nerves, at least the primary divisions, are craspedodrome; their largest branches also ascend to the point of the lateral shorter lobes. Besides the analogy of form of this species with *Ficus Dombeyopsis*, Heer, remarked in the first description, (*loc. cit.*,) its relation to *D. tridens*, Ludw., (Paleont., vol. viii, p. 127, Pl. xlix, Figs. 2, 3,) is noticeable.

Habitat.—Golden, in the white sandstone overlying the lowest coal-beds.

DOMBEYOPSIS GRANDIFOLIA(?) Ung.

A mere fragment, referable to this species described by Unger in Fl. v. Sotzka, (p. 45, Pl. xxvii, Fig. 1.) This fragment shows six principal veins from the flattened top of a thick striate petiole, with strong nervilles, dividing in the middle of the space between the veins, and forming large, square, or polygonal areolæ. The specimen is, however, too fragmentary to allow a satisfactory comparison.

Habitat.—Golden, South Table Mountain.

ZIZYPHUS DISTORTUS, *sp. nov.*

Leaves large, membranaceous, entire, at least near the base, where only the borders are distinctly preserved, round obtuse, enlarged on the sides, abruptly rounded and slightly cordate to the petiole, palmately 5-nerved from the base; middle nerve simple, not branching; lowest veins thin, merely marginal veinlets; middle pair of lateral nerves divided in 3 to 4 branches curving upward; nervilles close, numerous, at right angle to the middle nerve; petiole comparatively long, 2 centimeters. The nervation of this species is similar to that of *Z. plurinervis*, Heer, (Flor. Tert. Helvet., III, p. 76, Pl. cliv, Fig. 31,) as marked upon the right side of the leaf; the secondary veins are, however, less numerous, more distant, longer, and in a more acute angle of divergence; the middle nerve has no branches; and the nervilles are closer, numerous, parallel, and continuous from the middle nerve to the borders. The leaves are mostly unequilateral, or more enlarged on one side, and irregular in shape, either rounded or more narrowed to the base.

Habitat.—Golden.

CEANOTHUS FIBRILLOSUS, Lesqx.

Species described in Report for 1872, (p. 381,) from imperfect specimens. Others of the same kind have been obtained; one shows a deeply cordate base, broader than any of the same species, 7-nerved from the base; external veins merely marginal and simple, the lateral ones branching, especially in the upper part of the leaf; surface crossed by close, distinct nervilles, in right angle to the veins, continuous. This leaf is coriaceous, and does not show any trace of areolation; the nervilles are scarcely half a millimeter apart.

Habitat.—Golden, Black Butte, &c., rare.

RHAMNUS RECTINERVIS, Heer.

A fragmentary specimen found at Coal Creek, Colorado, by *A. R. Marvine*, is referable to this species. The leaf is, however, shorter and broader than those representing this species from Black Butte, the Raton Mountains, and Golden.

RHAMNUS GOLDIANUS, Lesqx.

This species, described in Report for 1872, (p. 382,) is very common at Golden, and its numerous leaves, as seen from the specimens, are extremely variable. The small form is oval, obtusely or abruptly pointed, rounded at base to a short petiole; lateral veins close, 3 millimeters distant, more or less ramified, especially in the middle or near the base of the leaves; nervilles nearly as thick as the veins, very close, and oblique to the veins. This form closely resembles *Berchemia multinervis*, Heer, differing merely by the narrower, more lanceolate form of the leaves, more rounded or cordate at the base, by the nervilles more oblique to the secondary veins, and by their divisions, the veins being all simple in *Berchemia.* To this species is, perhaps, referable the small leaf from Marshall, described as *B. parvifolia*, Lesqx., in Am. Jour. Sci. and Arts, (vol. xlv, p. 207.) I am unable to compare the specimens communicated to me by Dr. J. Leconte, and now out of my hands. Two figures of these leaves, which were carefully made, do not show any trace of ramification of the secondary veins.

Habitat.—Most abundant at Golden; the variety with large leaves has been found also at Black Butte.

RHAMNUS INEQUALIS, *sp. nov.*

Leaf ovate, lanceolate, apparently rounded to the petiole, (point and base of leaf destroyed;) medial vein turning to one side near the point; lower secondary veins at an angle of divergence of 25°, and at a greater distance from the second pair, which is more open and parallel to those following it in ascending, all simple; nervilles numerous, distinct at right angle to the veins. Intermediate to the lower pair of secondary veins, and the more distant second pair above, there is a thick tertiary vein passing out to the middle of the leaf, and there anastomosing on both sides with nervilles. By its unequal sides and its nervation this fragment is related to *R. Œningensis*, Heer, (Fl. Tert. Helv., III, p. 78, Pl. cxxiii, Fig. 31.)

Habitat.—Golden.

RHAMNUS ALATERNOIDES, Heer.

A very small leaf, 14 millimeters long, 7 millimeters broad, oval, pointed, narrowed to the base, distinctly nerved by 5 pairs of lateral veins, the lowest opposite, the others alternate, curving near and along the borders, which are irregularly and distantly serrate. This leaf has the same form and characters of nervation as those of the species described by Heer in Fl. Tert. Helv., (III, p. 78, Pl. cxxiv, Figs. 21–23,) being intermediate for the size between Figs. 21 and 22. The middle nerve is thick; the lateral veins distinct and at irregular distances.

Habitat.—Golden.

RHAMNUS MERIANI(?), Heer.

Leaf oblong, enlarging gradually from the rounded narrow base to above the middle, where it is abruptly acuminate and sharply and distantly dentate; borders entire downward to the base; nervation camptodrome; secondary veins parallel, in an acute angle of divergence, ascending nearly straight to the borders, where they curve and which they follow, entering the teeth by their divisions. From *R. Meriani*, Heer, as represented in Fl. Tert. Helv., (III, p. 82, Pl. cxxvi, Figs. 5–11,) this leaf differs by its oblanceolate or lingulate form, the veins more straight and on a more acute angle of divergence, and the borders entire from under the dentate acumen. There is, however, a marked difference in form and nervation in the numerous leaves of this species, as figured by Heer, (*loc. cit.;*) therefore the separation into a new species of this only leaf, whose characters are so closely related to those of the European form, is questionable.

Habitat.—Black Butte; in shale, above the main coal.

SPECIES OF THE SECOND GROUP.

POPULUS ARCTICA, Heer.

This species has been already mentioned from the Washakie group, Medicine Bow, Carbon, &c., (Reports for 1871 and 1872,) but not described. The present form appears to be the most common in the Lignitic measures. Leaves coriaceous, entire or undulately crenate, round or more enlarged on the sides and reniform, obtuse, or obtusely short-pointed, truncate at base; nervation 7-palmate from the top of the petiole; middle nerve crossed by strong nervilles at right angle, with two pairs of secondary veins in its upper part; inner pairs of basilar veins curving inward in passing up toward the point where they join the branches of the middle nerve; lateral basilar veins ramified outside, except the lowest pair, which is simple and marginal, all distinctly camptodrome. The two specimens from the locality indicated below have the same form of leaves as those in Heer's Fl. Arct. (Pl. v, Fig. 3,) one with the borders nearly entire, the others with crenulate borders. It appears generally distributed in the whole thickness of the Lignitic measures, except in the first group, where it has not yet been discovered.

Habitat.—Troublesome Creek, Colorado, *Mitchell.*

PLATANUS DUBIA, *sp. nov.*

This form, represented by a large number of specimens, corresponds evidently with the description of *P. nobilis*, Newby., in Extinct Floras of North America, (p. 67.) In this last species, however, the lateral and basilar nerves are described as straight and parallel, terminating, and their branches also, in the teeth of the margins. In the new species or variety, *per contra*, the leaves are perfectly entire, and the secondary veins and their divisions are all camptodrome, or curving near the borders, and following them in festoons. It is probable that this difference is merely casual. One of the specimens from Troublesome Creek shows the close secondary veins camptodrome along the borders of the inner side of the lobes, while on the outside a few of them teminate in small teeth, and are therefore craspedodrome. This remarkable species, which seems rather related to some southern forms of *Araliaceæ* than to *Platanus*, and which too is related by form and nervation to the *Sassafras* leaves of the Cretaceous, has apparently, like these, two distinct kinds of nervation and of border-leaves, resulting from the disposition of the secondary veins.

Habitat.—The specimens, all presenting the same characters, are from Mount Brosse, *Dr. Hayden*; Willow Creek, *Holmes*; Troublesome Creek, *Mitchel.* The distribution of this species appears to be limited to few localities, where its remains are generally in great abundance and exclusive of those of any other.

LAURUS SESSILIFLORA, *sp. nov.*

A fructified narrow branch, bearing, attached to it, at equal distance and sessile, four involucre or persistent calyces, nearly equally divided to near the point of attachment in four oblong lanceolate-obtuse sepals 4 to 5 millimeters long, diverging crosswise. The appearance of the remarkable fragment representing this vegetable is not easily conceivable from a mere description. It is somewhat like a small branch of a *Galium*, with whorls of four thick, short, half-open leaflets, the two opposite ones on each side of the pedicel being joined to below the middle, and rounded on the other side to the point of attachment like split involucral teguments. They are alternately placed upon each side of the pedicel and sessile. The same piece of shale bears some small oval-obtuse seeds or nutlets, obscurely striated in the length, which seem to have been detached from these involucres. The relation of these fragments is apparently with some kind of *Laurineæ*, like those described by Heer, (Fl. Tert. Helv., II, Pl. xc, Fig. 17,) and also with the fruit of *Benzoin antiquum*, (same plate, Fig. 8.) The relation is confirmed by the presence upon the same specimen of a fine well-preserved leaf of *Laurus*, which I refer to the same species as *L. sessiliflorus*. It is small, narrowly-elliptical, blunt-pointed, narrowed to the base; secondary veins alternate in an acute angle of divergence; the upper pairs at equal distance and parallel; the lower ones more distant and on a more acute angle of divergence, all camptodrome, following the borders in festoons, anastomosing by nervilles, which are numerous, in right angle to the middle nerve, forming large rectangular areas. This leaf also resembles that of *Benzoin antiquum*, Heer, (*loc. cit.*, Fig. 2,) differing especially by the secondary veins more regular and still more distant.

Habitat.—Evanston; shale, above the upper coal, *Wm. Cleburn.*

PERSEA BROSSIANA, *sp. nov.*

Leaves large, subcoriaceous, rigid, with entire, recurved borders, oblong-lanceolate, narrowed in a curve to a short acumen, and attenuated to a short petiole; nervation deeply marked; surface undulate or bossed between the secondary veins, which are parallel, on an acute angle of divergence; nervation and areolation of a *Laurus*. The form of the leaves is the same as that of *L. Canariensis*. The axils of a few of the secondary veins are marked by a small tubercle or inflation as in this last species, and also in the leaves of *Daphnogene Heerii*, Gaud., but less distinct.

Habitat.—Mount Brosse or Troublesome Creek, *Dr. Hayden.*

CINNAMOMUM ROSSMÄSSLERI, Heer.

Two leaves, subcoriaceous, entire, or long oval, pointed(?), (broken,) narrowed to a thick petiole; palmately 3-nerved; lateral veins thin, obsolete from above the base of the leaves, curving at a distance from the borders in following them upward.

The details of nervation are very undistinct, and the species not positively identified. The leaves resemble especially those represented under this name by Unger, in Fl. Radoboj, (Pl. 1, Figs. 10, 11;) the lateral veins, however, seem to approach nearer to the border in the American form.

Habitat.—Troublesome Creek, *W. H. Holmes.*

CISSUS LOBATO-CRENATA, Lesqx.

The specimens exactly represent the species as described from Black Butte, (Report for 1872, p. 396;) the large leaves, with obtuse teeth or undulate borders; the smaller leaves, more acutely lobed and dentate, representing apparently *Vitis tricuspidata* of Heer. In all the leaves the base is truncate, and one of the specimens shows them to be long-petioled.

Habitat.—Willow Creek and Mount Brosse.

CORNUS IMPRESSA, *sp. nov.*

Leaves thick, coriaceous, entire, deeply impressed into the stone, regularly elliptical, rounded to a very short, scarcely marked acumen, rounded also to the base, which is broken; secondary veins on an acute angle of divergence, slightly curving in ascending to the borders, regularly camptodrome, simple or rarely branching once near the point, and anastomosing in festoons along the borders with strong nervilles; these are in right angle to the middle nerve, mostly simple and continuous; the upper veins abruptly join by a curve the point of the middle nerve. This distinct species is related to *Cornus orbifera* by the form of the leaf, which is, however, more elongated, and by its strong nervilles, which are, however, more distant and less ramified; it also differs from it by the lateral veins curving at a distance from the borders, and less numerous.

Habitat.—Mount Brosse, Colorado, *Dr. Hayden.*

ACER TRILOBATUM, Al. Br.

Leaf broadly oval in outline, round-cordate at base, 3-obtusely short-lobed, and obtusely dentate on the borders, which are erased and undistinct; nervation 5 palmate, the lower pairs of basilar nerves being mere thin marginal veinlets; middle nerve branching from the middle; secondary veins in an acute angle of divergence; areolation similar to that of *A. trilobatum* as figured by Heer, (Flor. Tert. Helv., III, Pl. cxiii, Fig. 8.) From all the forms of this species, however, the leaf differs by the base rounded and more deeply cordate, and by shorter obtuse teeth and lobes. The middle lobe is broadly taper-pointed. The leaf is also comparable to *A. Sismondi* of Gaudin.

Habitat.—Troublesome Creek(?) The specimen is without label, but mixed with those of this locality.

THIRD GROUP.

None of the localities referable to the third group had been visited by any member of the explorations of Dr. Hayden in 1873, and no new materials have been added to the flora of this group since the publication of the Report for 1872.

SPECIES OF THE FOURTH GROUP.

SALVINIA CYCLOPHYLLA, *sp. nov.*

Leaf nearly round, slightly cordate or truncate, 21 millimeters long, 25 millimeters broad, therefore slightly reniform, very entire; lateral nerve on a broad angle of divergence, or nearly in right angle to the straight half-round middle nerve, scarcely thicker than their divisions or the nervilles, which, crossing the areas in various directions, form an irregularly quadrate or polygonal areolation. This species does not compare with any fossil one known as yet; it is related by its size to *S. Reussi*, Ett., (Bil. Fl., p. 18, Pl. 1, Fig. 21,) and by the areolation to *S. reticulata*, Heer., (Fl. Tert. Helv., III, p. 156, Pl. cxlv, Fig. 16.)

Habitat.—Middle Park, *Dr. Hayden.*

LYCOPODIUM PROMINENS, *sp. nov.*

Stem or branch slender, dichotomous; divisions short, erect, slightly open, distant, 2 centimeters long; leaves alternate or in spiral, cylindrical, inflated to the more or less acute point, apparently connate at the narrowed base, 4 to 5 millimeters long, half a millimeter broad, half open, some of them curved outside. With the sterile branch, the specimen has a somewhat obscure fragment, apparently a crushed fruiting ear, whose surface is rough or granulate. It is, however, too obscure for positive identification.

Habitat.—Elko, Nev., *Prof. Cope.*

EQUISETUM WYOMINGENSE, *sp. nov.*

Fragments of stems, equally distinctly striate, 2 centimeters broad, articulate, bearing at the articulations whorls of thickish long rootlets. These stems or rhizomas, evidently referable to *Equisetum*, are in profusion in the shale at the cut four miles west of Green River Station; but none of the specimens have any remains of a sheath or of leaves and branches. This form is comparable to *E. Braunii*, Heer., (Fl. Tert. Helv., III, p. 157, Pl. cxlv, Fig. 29.) On the American specimens, however, the rootlets are in fascicles, diverging star-like, much longer and thicker than in Heer's species; at least 1 millimeter broad and 5 to 6 centimeters long.

Habitat.—Green River.

TAXODIUM DUBIUM, Sternb.

The species is represented by a large number of fragments or branches with distichous, linear, short, obtuse leaves, narrowed and rounded to the point of attachment, sessile. This form is rather comparable to *T. dubium* as described and figured by Heer in Fl. Arctica, (Pl. ii, Figs. 24, 26,) than to the variety *T. distichum-miocenicum*, represented in Spitz. Fl., (Pl. iii,) whose leaves are slightly narrower proportionally to their length.

Habitat.—Elko Station, very abundant, *Prof. Cope.*

GLYPTOSTROBUS EUROPEUS, Al. Br.

Only two small branches are referable by their size and the form and disposition of the leaves to this species. Some of the leaves are lingulate, short, appressed, mixed with linear-lanceolate-pointed, open, and longer ones. The fragments are small, and do not bear any cones. The shales of the same locality are, however, marked by irregular, generally round-oval cavities, which appear to have been made by the impressions of cones of this species.

Habitat.—South Park, Castello Ranch, *Dr. Hayden*; near Florisant, *Prof. Cope.*

SEQUOIA ANGUSTIFOLIA, Lesqx.

A short diagnosis of this species is given in Report for 1872, (p. 372,) from specimens from Elko Station. It was sent this year in a large number of specimens, from the same locality especially, and all the specimens bear the same character. Leaves comparatively narrow and pointed, decurrent at base, half open or even nearly erect; seeds large, round-oval, truncate, at the slightly enlarged base, rounded at the top. It is comparable to *S. Nordenskiöldi*, Heer, of the Spitzbergen Flora, (Tab.

iv, Figs. 4–38,) differing by longer, narrower, more acute leaves, and by the larger seeds, quite round or obtuse, not pointed upward. The same character, the large size of the seeds, separates this species from *S. Langsdorfii*, which it resembles somewhat more by the form of the leaves; these, however, are still narrower than in any of the numerous forms of this species.

Habitat.—Elko, *Prof Cope.* Two specimens, with more open, shorter leaves, but equally narrow, come from Middle Park, *Dr. Hayden.*

SEQUOIA LANGSDORFII(?), Brgt.

Only a small fragment, identifiable with this species, as figured by Heer, (Arct. Fl., II, p. 464, Pl. xliv, Fig. 2.) It is not possible to ascertain identity from such a fragment. It, however, shows the two forms of leaves as in the quoted figure. There is also from the same locality a small branch with lateral simple branchlets, bearing short, linear, pointed leaves, similar to those of *S. Coutsiæ*, Heer, (*loc. cit.*, Pl. xli, Fig. 10^b,) except that all the leaves are erect, not curved inward. This may be still referable to *S. Langsdorfii*, though the leaves are shorter and more acutely pointed.

Habitat.—Elko Station, *Cope*; the var., Middle Park, *Cope* and *Hayden.*

PINUS POLARIS, Heer.

Leaves very long proportionally to their narrow size, 1 millimeter broad, 6 to 7 centimeters long, obtusely-pointed; medial nerve thick and broad; lateral veins thin but distinct, three or four on each side. As far as the leaves indicate it, these fragments represent, indeed, Heer's species, as described in Fl. Spitz., (p. 39, Pl. v, Figs. 18, and 15^b–15^d.) There are, however, no seeds indicating relation to the same species. The shales are covered with crushed fragments of conifers, scarcely discernible, and, therefore, mostly undeterminable. Among these are wings of coniferous seeds similar to those which the same author figures as *P. stenoptera*, (same plate, Figs. 21, 23.)

Habitat.—South Park, near Castello Ranch, *Dr. Hayden*, Florisant, *Prof. Cope.*

The shale of South Park, Middle Park, and Elko station have a quantity of crushed remains of conifers, leaves, cones, separate scales, and seeds, which may be described hereafter with figures, but whose description without illustration would be incomprehensible for the reader and useless to science.

ACORUS AFFINIS, sp. nov.(?)

Stem thick, evidently striate or nerved by parallel, distant, thick veins; bearing a broad, short, crushed ear, with seeds placed in parallel or spiral rows, and whose form is undistinct. The species is related to *A. brachystachys*, Heer, (Spitz., Fl., p. 51, Tab. viii, Fig. 7,) which has been described already from Creston and from Carbon, (Report for 1872, p. 385;) differing by its larger stem, with more distant and thicker striæ, and its broader ear, which is crushed and somewhat indistinct, though of the same form. The seeds, apparently trigonal in form, are flattened, and in rows, which rather seem parallel than in spiral. The form is still specifically uncertain.

Habitat.—Florissant, South Park, *Prof. Cope.*

POPULUS RICHARDSONI, Heer.

Leaves petioled, broadly ovate or nearly round, truncate at the base, deeply obtusely crenate, 5-nerved from the base; primary nerves flexuous, branching in right angle or at a broad angle of divergence; substance thin or not coriaceous. Of the six specimens representing leaves of this species, none is preserved in its whole. Though fragmentary, however, enough is left to recognize the essential characters and identify the species. The leaves are variable in size, from 4 to 8 centimeters in diameter, some narrower, more elongated, ovate truncate or slightly emarginate to the petiole. From *P. arctica*, it differs essentially by the thinner substance of the leaves, and by the deeply-crenate borders. Some of the obtuse teeth are longer and narrower than represented in the figures of this species, (Fl. Arct., p. 98, Tab. iv, vi.)

Habitat.—Elko, *Prof. Cope.*

SALIX MEDIA, Al. Br.

The species already described from Green River specimens, (in Supplement to Report for 1871) is represented still by two others, which, also, have not preserved any trace of nervation, and are identifiable only by the form of their leaves.

Habitat.—Elko, *Prof. Cope.*

MYRICA COPIANA, *sp. nov.*

Leaf lanceolate, taper-pointed, 10 to 11 centimeters long, 3 centimeters broad, doubly and deeply serrate, with alternate longer and shorter acute teeth, penninerve; nervation craspedodrome; secondary veins open or nearly in right angle to the middle nerve, passing up to the point of the larger teeth, with thinner, shorter tertiary veins between them, ascending to the point of the shorter teeth; all curving slightly upward in entering the teeth. This fine species, represented as yet by a single specimen, is distantly related to *Myrica Graeffii*, Heer, (Fl. Tert. Helv., III, p. 176, Pl. cl, Figs. 19, 20;) the leaf of the American species being, however, twice as large, the teeth turned outside, sharp, pointed, &c. The same specimen bears some alate seeds of a conifer, like those described by Heer in Spitz. Fl. as *Pinus abies*.

Habitat.—Near Florisant, South Park, *Prof. Cope.*

MYRICA ACUMINATA, Ung.

Leaves coriaceous, with smooth surface, linear-lanceolate-acuminate, dentate; nervation camptodrome, obsolete. These leaves, compared to Unger's species as figured in Fl. of Sotzka, (Pl. vi, Figs. 5–10,) appears, indeed, identical with it. But the author says of his species, (p. 30,) *serraturis equalibus, minimis, approximatis*, a character which is in disaccord with the figures (*loc. cit.*) and with that of our specimens. This character, however, is of little importance in regard to identification; for one of our specimens, representing a long, acuminate leaf, has equally serrate border on one side, while on the other the teeth are close and unequal. As far as it can be seen, the secondary veins appear close, straight to the point of the teeth, and on an acute angle of divergence from the middle nerve. From another locality a set of specimens represent the same species under the same form and nervation, but with much smaller, narrower, and shorter leaves than those figured by Unger, and also than the first ones described above.

Habitat.—Middle Park, *Dr. Hayden*, one mile west of Florissant, South Park, *Dr. Peale.*

MIRICA UNDULATA, Heer.

Leaf membranaceous or subcoriaceous, small, 3½ centimeters long, (the point and base are destroyed,) 1 centimeter broad, linear-oblong, with deeply-undulate borders; nervation camptodrome; lateral veins open, joined by curved fibrillæ nearly in right angle to the veins, forming by ramification a small polygonal areolation; the direction of the secondary veins intermixed with shorter tertiary ones, their mode of curving to and along the borders, and the areolation, are of the same kind as in the leaves of *Myraca* (*Diandra*) *undulata*, Heer, (Fl. Tert. Helv., III, p. 188, Pl. cliii, Figs. 22, 23.) The American leaf is in its size and its tapering base exactly similar to Fig. 23; its undulations are only more definite. I consider it as identical.

Habitat.—Elko, *Prof. Cope.*

MYRICA LATILOBA, Heer, *var.* ACUTILOBA.

Leaves membranaceous, linear-lanceolate or oblong-lanceolate, pinnately deeply divided in large, pointed, triangular lobes, narrowed to a short petiole; secondary veins distinct, craspedodrome, open, ascending to the point of the lobes; tertiary veins under the same degree of divergence, curving along the borders, and anastomosing with pinnate branches of the secondary ones. This species is represented by one fragment only, showing the lower part of a leaf, bearing three lobes on one side and only one on the other. In Heer's species, (Fl. Tert. Helv., III, p. 176, Pl. cl, Figs. 12–15,) the leaflets are more obtuse or less pointed than in the American leaf, which also differs by a somewhat longer petiole. This form is apparently a mere variety.

Habitat.—Middle Park, Colorado, *Dr. Hayden.*

MYRICA PARTITA, *sp. nov.*

Leaf subcoriaceous, linear, narrow, one centimeter broad, alternately equally lobate; lobes distinct to the base, turned upward, broadly lanceolate, narrowed to a short point, denticulate along the lower side and near the point of the upper border; secondary vein ascending to the point of the acumen; tertiary veins parallel, shorter, passing up to the lower teeth in anastomosing by nervilles in right angle to the secondary vein; areolation round-polygonal, small. Like the former, the species is represented by a fragment only. It is distantly related to the following.

Habitat.—Elko, Nevada, *Prof. Cope.*

MYRICA (COMPTONIA) BRONGNARTI(?), Ett.

Leaf coriaceous, linear, narrow, half a centimeter broad, alternately pinnately obtusely dentate; nervation obsolete, pinnate, camptodrome; secondary veins simple. It is not possible to positively recognize the nervation of this leaf, which, by undulation of its surface corresponding with the teeth, has the *facies* of a small branch of conifer. It resembles some of the leaves published in Ett. (Häring Flor.) as *Diandra Brongnarti*, especially that of Pl. xix, Fig. 20; the lobes, however, being less deeply parted, or like mere obtuse teeth, though the appearance is that of a lobate leaf.

Habitat.—Elko, *Prof. Cope.*

ULMUS TENUINERVIS, *sp. nov.*

Leaves thin, very unequal at the base, deeply cordate on one side, tapering on the other to the middle nerve, half a centimeter higher up;

oblong or ovate, lanceolate, taper-pointed, unequally serrate; lateral veins thin, flexuous, or curved to the borders, craspedodrome, simple or branching. The species is closely allied to *U. Bronnii*, Heer, which Massalongo considers identical to his *U. affinis*. Ours differs by thinner, more distant, lateral veins, by its shorter petiole, and the more acute teeth of the borders. None of our living American species is comparable to it.

Habitat.—Middle Park, *Dr. Hayden.*

PLANERA LONGIFOLLA, Lesqx.

This species has been briefly described in Report for 1872, (p. 371.) The collection has received a large number of specimens from Middle Park, representing it in its various forms. The leaves are generally ovate-lanceolate or merely lanceolate, more or less acutely, and all equally simply dentate; lateral veins simple, strong, going straight up to the point of the teeth, under various degrees of divergence; petiole 5 millimeters long, thickened to the base. The leaves vary in length and width, being generally smaller and narrower than those of *P. Ungeri.* Captain Berthoud, however, has sent me sketches of leaves of a *Planera*, one of which is 2½ centimeters long and 2 centimeters broad, therefore broadly oval, with sharp teeth, exactly like the leaf published by Heer, (Arct. Flor. II, Pl. xlv, Fig. 5[a]) as *P. Ungeri.* This leaf is so different in *facies* from all those which I have seen and used for the description of the American species that I cannot consider it as representing the same. I have, therefore, to admit that two species are represented in the Upper Tertiary measures of the Rocky Mountains, at least till I have seen the specimens or recognized intermediate forms.

Habitat.—Elko and South Park. The last specimens were sent by *Dr. Hayden.*

QUERCUS ELKOANA, *sp. nov.*

Leaves subcoriaceous, flat, ovate, taper-pointed or acuminate, 8 to 10 centimeters long, rounded and narrowed to the base, (broken,) doubly serrate, with teeth alternately long, irregular, sharp-pointed, and one or two small ones at their base; nervation pinnate; lateral veins simple, parallel, craspedodrome, (straight or scarcely curving in passing up to the borders; fibrillæ thin; areolation same as that of *Fagus feroniæ*, which this leaf resembles, and to which it could be referable but for the large size of the regular and regularly-pointed teeth. The substance of the leaves is thicker than in this last species.

Habitat.—Elko, *Prof. Cope.*

QUERCUS NERIIFOLIA, Heer.

Only a fragment of an oblong-lanceolate, entire leaf, with distinct nervation; secondary veins at right angle to the middle nerve, branching and effaced near the borders, with intermediate shorter tertiary veins, more or less oblique to the secondary ones. The form of the leaf is like that of Fl. Tert. Helv., (II, Pl. lxxiv, Fig. 4,) and the nervation similar to that of Fig. 5.

Habitat.—Near Florissant, west of Pike's Peak, *Dr. A. C. Peale.* This locality may be referable to another group.

FAGUS FERONIÆ, Ung.

This species is represented by a dozen specimens, representing the leaves in their various forms, as figured and described by Ett. Bil. Flor.,

(p. 50, Pl. xv, Figs. 12–20.) These leaves are variable in size, from 5 to 8 centimeters long and proportionally broad, oval in outline, taper-pointed, narrowed downward and wedge-form to a long petiole, doubly, irregularly, unequally serrate; nervation craspedodrome; secondary veins on an acute angle of divergence, simple, straight; fibrillæ thin, in right angle to the veins; areolation composed of very small, irregularly square and polygonous meshes. The American form agrees by all its characters with the leaves of the Bilin Flora. It differs, however, from Unger's figures (Chloris Prot., Pl. xxviii,) by the teeth of the borders more numerous and generally more accute, and by the longer petiole.

Habitat.—Elko, *Prof. Cope.*

FICUS LANCEOLATA, Heer.

Leaves thickish, lanceolate, gradually tapering to a thick petiole, penninerve; secondary veins open, parallel from the base, camptodrome; nervilles close, in right angle to the secondary veins; areolation in small polygonal meshes. This species is represented by specimens of two localities. All agree with the characters represented by the author (Flor. Tert. Helv., II, p. 62, Pl. lxxxi, Figs. 2–5,) the leaves being only somewhat smaller.

Habitat.—Florisant, South Park, *Cope*; Willow Creek, Middle Park, *Holmes*; Cut-off, west of Green River Station, with fish remains.

FICUS JYNX, Ung.

Leaves coriaceous, linear-lanceolate, tapering to the petiole, penninerve; secondary veins open, close, numerous, thickish, straight to the borders, along which they abruptly curve. This leaf is comparable to some forms of *F. multinervis*, Heer, but still more to the leaf of Bil. Fl. (Pl. xx, Fig. 7,) referred by Ettinghausen to *F. Jynx*, Ung. The petiole is narrower than in *F. multinervis.*

Habitat.—Elko, *Prof. Cope.*

DIOSPYROS COPEANA, *sp. nov.*

Leaf of medium size, 7 centimeters long and half as wide, broadly obovate, entire, gradually narrowed downward to a short petiole, rounded upward to an obtuse point; nervation penninerve, camptodrome; lateral veins thin, distinct, the lowest in a slightly more acute angle of divergence, curving in passing to the borders, which they follow in anastomosing in double festoons, and separated by shorter tertiary veins. The nervation and the form and *facies* of the leaf are of a *Diospyros;* some of the leaves of our living *D. Virginiana* have about the same form, though generally broader, and rounded at the base.

Habitat.—Elko, *Prof. Cope.*

FRAXINUS PRÆDICTA, Heer.

A small leaf, broad in the middle, gradually narrowed to its base, (petiole broken,) and upward in the same degree in a long obtuse acumen; borders slightly and distantly dentate; nervation camptodrome; secondary veins curving upon each other in following the borders, with border-branches or veinlets passing up to the points of the very short and small teeth marked only from the middle downward; borders nearly entire upward. There is only one leaf representing this species; but it so much resembles those of Fl. Tert. Helvet., (III, p. 22, Pl. civ, Figs. 13, &c.,) that it is scarcely possible to doubt the identity of these forms. In the specimen described here, the nervation is perfectly distinct.

Habitat.—Middle Park, *Dr. Hayden.*

WEINMANNIA, ROSÆFOLIA, *sp. nov.*

A compound, imparipinnate leaf, with 3 to 5 pairs of narrowly elliptical leaflets, obtusely pointed, rounded to the sessile base, the terminal leaflet only short-petioled, obtusely serrate toward the point, entire from the middle downward; medial nerve thick, half-round; lateral veins and areolation obsolete; rachis half-round, narrowly margined. The dentation of the leaves is not distinct; some leaflets, separated from the rachis upon the same piece of shale, are smaller and have entire borders. I refer this leaf to the genus *Weinmannia* on account of the likeness of these remains with living species of this genus figured in Fl. v. Häring by Ettinghausen, (Pl. xxiii, Figs. B, C.) In these American forms, the rachis is not alate; it is so, however, in *W. Glabra*, DC., whose leaflets, though much smaller, have the same form. In the leaves of this genus, the secondary nervation is also mostly obsolete or scarcely distinct; the surface being generally covered with villous hairs. In the fossil species, the base of the leaflets seems to bear a thick tuft of hairs. The specimens are very fine.

Habitat.—West of Florisant, *Dr. A. C. Peale.*

SAPINDUS ANGUSTIFOLIUS, *sp. nov.*

Leaves compound, imparipinnate; rachis thick, flat, but not winged; leaflets linear-lanceolate, entire, unequilateral, larger above the base at the upper side, tapering gradually upward to a slightly reflexed or straight acumen, rounded and narrowed to a very short margined petiole or sessile; nervation and areolation of the genus. The leaf bears about 6 pairs of alternate leaflets; the upper lateral ones erect along the terminal, the others half open. This species is represented by a large number of specimens.

Habitat.—Middle Park, *Dr. Hayden*; near Florissant, South Park, *Prof. Cope.*

SAPINDUS CORIACEUS, *sp. nov.*

Leaflets thick, large, oblong-lanceolate, entire, with borders reflexed; slightly unequilateral and scythe-shaped, short-petioled; middle nerve thick; secondary veins open, scarcely discernible; surface polished. This species is distinct by the thickness and leathery texture of the leaves, which are long comparatively to their width. All the leaflets are isolated or separated from the main rachis.

Habitat.—Elko Station, *Prof. Cope.*

STAPHYLEA ACUMINATA, *sp. nov.*

Leaves trifoliate, at the top of an elongated common pedicel; lateral leaflets opposite, rounded to the short-petioled base, ovate-lanceolate acuminate, crenulate to near the base; medial or terminal leaflet longer-pointed, attenuated to the base, with a longer pedicel; secondary veins alternate, camptodrome, curving to and along the borders, with slender ramifications entering the teeth. The areolation of this leaf, the form of its leaflets and their relative position, &c., are similar to those of the living American *S. trifoliata*, L. The species merely differs by the longer tapering point of the leaflets and the short petiole of the middle one; the divisions of the borders are of the same kind.

Habitat.—Middle Park, *Dr. Hayden.*

ILEX SPHENOPHYLLA(?), Heer.

A very small leaf, 12 millimeters long, 7 millimeters broad, oval, rounded in narrowing to the point and to the base; distantly acutely-dentate by three or four pointed or spinulose teeth on each side; secondary veins opposite, craspedodrome, simple, passing up in a slight curve to the point of the teeth. The identification of this leaf with Heer's species, represented (Flor. Tert. Helv., III, p. 73, Pl. cxxii, Fig. 24,) by still smaller leaves without any trace of nervation, is uncertain.

Habitat.—Middle Park, *Dr. Hayden.*

ILEX SUBDENTICULATA, *sp. nov.*

Leaves coriaceous, linear-lanceolate, acuminate? (point broken,) irregularly denticulate from the middle upward with small, sharp-pointed teeth; penninerve; lateral veins distant, opposite, curving up under an acute angle of divergence from the middle nerve, and at a distance from the borders, forming, by anastomose with the veins above, a double festoon along the borders, and entering the teeth by outside, small branchlets. This species is closely related to *I. denticulata*, Heer, (Flor. Tert. Helv., III, p. 72, Pl. cxxii, Fig. 20,) differing, however, by the taper-pointed or acuminate form of the leaf; the more numerous teeth descending lower on the borders; the more distant and all opposite secondary veins, which curve farther inside and at a more acute angle of divergence, &c. The nervation is, however, of the same type. The same shale bears a small, round, crushed fruit, representing, apparently, a pulpy berry, bearing one or two ovate-pointed seeds similar to those of this genus. The berry is 5 millimeters wide; the seeds $1\frac{1}{2}$ millimeters broad near the rounded base, and 3 millimeters long.

Habitat.—One mile west of Florisant, Colorado, *Dr. A. C. Peale.*

ILEX UNDULATA, *sp. nov.*

Leaf narrowly oblanceolate, pointed, tapering downward to a short petiole; borders undulate, obtusely dentate in the upper part of the leaf, entire from the middle; nervation of the same type as that of the former. It may represent a variety of the same species.

Habitat.—This specimen is without label; mixed with those of Middle Park.

PALIURUS FLORISANTI, *sp. nov.*

Leaf small, $2\frac{1}{2}$ centimeters long only and 1 centimeter broad, ovate-pointed(?), (point broken,) rounded at the base to a short, thick petiole, slightly crenulate all around, triple-nerved; lateral primary veins from above the base of the leaf curving up and following quite near the borders to above the middle, where they anastomose with the lowest pair of secondary veins, also opposite; all curving along the borders, camptodrome. The leaf has the same areolation as those of *P. aculeatus*, Lam., of Europe, from which it merely differs by its round base, the lower veins closer to the borders, and the secondary veins from the middle only of the leaf and nearly opposite.

Habitat.—Near Florisant, South Park, *Prof. Cope.*

RHUS(?) DRYMEJA, *sp. nov.*

Leaves narrowly lanceolate, acuminate, equally acutely serrate, penninerve; lateral veins close, numerous, simple, craspedodrome, parallel from the base, on an acute angle of divergence; areolation in primary quadrate rectangular areas, divided into small irregular quadrate or polygonal areolæ. I doubt that this form, represented by numerous well-preserved thickish leaves, may be referable to a species of *Rhus*. It is comparable to *Quercus lonchitis*, Ung., in Fl. of Sotzka, (p. 33, Pl. ix, Fig. 1);

the leaves, however, are smaller and generally unequilateral, either narrowed to the short thick petiole or rounded to it, at least on one side, like the leaflets of a compound leaf.

Habitat.—Middle Park, *Dr. Hayden.*

RHUS HAYDENII, *sp. nov.*

Leaf pinnately divided in alternate linear or lanceolate, acute, entire leaflets, from a broadly alate rachis, to which they are joined in decurring; terminal leaflet of the same size and form; nervation pinnate, camptodrome. This fragment of a compound leaf represents a fine and remarkable species. It is about 5 centimeters long, with a broadly-winged rachis 3 millimeters wide on each side of the thin, middle nerve, with three pairs of alternate leaflets 4 to 6 millimeters broad, 2½ centimeters long, lanceolate, obtusely-pointed, nearly at right angle to the main rachis, which they join by an acute sinus in the upper side and a decurring base on the lower one. The camptodrome nervation is similar to that of *R. copallina*, L.; the alar tissue of the rachis is also marked by forking parallel veinlets, as in the same species.

Habitat.—Middle Park, *Dr. Hayden.*

PTEROCARYA AMERICANA, *sp. nov.*

Fragment of an oblong-lanceolate leaflet, slightly scythe-shaped, with crenulate border, and camptodrome nervation. The outline of the leaflet, though the lower and upper parts are destroyed, is, like the nervation, well defined. It is comparable to the leaves published by Gaudin, in Cont. (I, p. 40, Pl. ix, Fig. 2,) under the name of *P. Massalongi.* The substance of the leaflet is thin, the secondary veins more or less distant, curving in ascending to the borders, and following them in successive bows, anastomosing with branches of intermediate shorter veins; nervilles distinct, nearly at a right angle to the secondary veins. Except that the borders of this leaflet are not as deeply serrulate, and that the secondary veins curve nearer to the borders, there is not any noticeable difference between the American and the Italian form.

Habitat.—Middle Park, *Dr. Hayden.*

PODOGONIUM, species.

The collection has, representing this genus, a capsule, with its pedicel. It is, however, broken in the middle, and its specific relation undiscernible. There is also, from another locality, a fragment of a lingulate leaflet, with a close, thin camptodrome nervation, comparable to the leaves of *P. Knorrii*, Heer.

Habitat.—Middle Park: the leaflet, *Dr. Hayden*; the fruit, Florisant, South Park, *Dr. Peale.*

CÆSALPINIA(?) LINEARIS, *sp. nov.*

A branch of a compound leaf, with a narrow filiform rachis, bearing seven pairs of small, opposite, linear leaflets, sessile, rounded to the point of attachment, sharp-pointed, concave or scythe-shaped at the upper side, thickish, without trace of nervation of any kind. I know nothing to which this fragment could be compared. It resembles a branch of distichous conifer; but the mode of attachment of the leaflets, rounded to the base, all opposite; their scythe-shaped form, &c., are at variance with the characters of conifers. It is distantly related to species of *Cæsalpinia*, like *Cadia varia*, Heer, or some *Acacia*, like *A.*

parschlugiana, Heer, of the European Miocene, but remarkably distinct by the absence of a midrib, whose place is scarcely indicated by a depression in the middle of some of the leaflets.

Habitat.—Florisant, South Park, *Prof. Cope.*

ACACIA SEPTENTRIONALIS, *sp. nov.*

Leaflet small, entire, coriaceous, rigid, with a rough surface; oblanceolate, rounded to a short acumen or mucronate, gradually tapering downward to the base; nervation pinnate; lateral veins very thin, acrodrome, sparingly branching, anastomosing by cross-veinlets in passing up to near the point where they curve toward the middle nerve. This leaflet is, for its thick, rigid substance and its nervation, comparable to *A. rigida*, Heer., (Fl. Tert. Helv., III, p. 133, Pl. cxl, Fig. 22,) differing, however, by its form.

Habitat.—South Park, near Castello Ranch, *Dr. Hayden.*

LEGUMINOSITES, species.

A small legumen, which is open, and shows its two valves, linear, oblong, truncate, mucronate on one side, narrowed on the other to a short pedicel; substance cartilaginous; inner face smooth, shining. The exact form of this and the two following remains is not well comprehensible from mere description.

Habitat.—Elko, *Prof. Cope.*

CARPOLITHES, species.

An oblong-obtuse, flattened fruit, or nutlet, truncate at its base, somewhat more enlarged on one side, marked from the base to above the middle by small striæ, slightly diverging in ascending.

Habitat.—West of Florisant, *Dr. A. C. Peale.*

SEMEN, species.

An agglomeration of four oval, small seeds, 3 to 4 millimeters long, half as wide, obtusely-pointed, striate.

Habitat.—Middle Park, *Dr. Hayden.*

SPECIES WHOSE REFERENCE TO THE FORMER GROUPS IS UNCERTAIN.

LASTRÆA STYRIACA, Heer.

Fragments of ultimate linear pinnæ, pinnately alternately lobed; lobes oval-obtuse, disjointed to near the middle, pinnately-veined; veins 8 pairs, simple, curving inward in going up to the borders, thin, distinct. The species is represented by a number of fragments in silex, all very distinct. By the form of the leaflets and their nervation, they are referable to this species, very common in the Miocene of Europe. The pinnules, however, are somewhat more disconnected than seen in the figures, (Flor. Tert. Helv., I, Pl. vii–viii.)

Habitat.—Blake's Fork, Uintah Mountains.

MUSOPHYLLUM COMPLICATUM, *sp. nov.*

Stem thick, wrinkled-striate in the length, bearing imbricated and amplectant leaves, folded upon another, especially near the point of union to the stem, opening in right angle, variable in size, obtuse; veins simple, three-fourths of a millimeter distant, parallel; crossed in right angle by obscure veinlets. The stem divides at its base into thick diverging rootlets, curving to an horizontal direction. Though the specimens representing this species are very numerous and very large, I could not obtain one showing exactly the size and the form of these leaves. They appear either folded around a thick stem, from which they diverge, or on both sides of a thick rachis extending along it like wings, two to three centimeters wide on each side. From the fact that large specimens are covered by fragments of these leaves crushed and folded upon another, without any trace of middle nerves or peduncles, the leaves must have been of great size. Their substance is not very thin. The surface is per-place covered with an epidermis which shows the veins as crossed by veinlets at right angle. When the epidermis is destroyed, this character is not observable; it may, therefore, result of a wrinkling of the epidermis. The species is related to *Musa Bilinica*, Ett., (Bil. Fl. p. 28, Pl. vi, Fig. 11, and Pl. vii, Figs. 4–5;) differing, however, by essential characters.

Habitat.—Roof-shale of a thin coal, with the following species:

SAPINDUS OBTUSIFOLIUS, *sp. nov.*

Leaves compound, pinnate, apparently long; leaflets alternate, very variable in size, from 1½ to 7 centimeters long, and from 6 millimeters to 3½ centimeters broad, coriaceous, perfectly entire, sessile, unequilateral, ovate-lanceolate, obtusely-pointed; nervation camptodrome; lateral veins at a broad angle of divergence, curving in passing up to the borders and following close along them by a series of undulations; areas large, equilateral; ultimate divisions obsolete. This fine species differs from any fossil published as yet. The leaves have been apparently very large; some of the detached leaflets greatly differing in size from the few ones which were obtained still attached to the main rachis or pedicel.

Habitat.—The same locality as the former; top of hills, apparently overlying the coal-bearing strata of Rock Springs, seen to the east, five to six miles distant. The clay beds of this locality, with an abundance of silicified and petrified wood, the thinness and poor quality of the lignite beds, mark this place as referable to the Upper Lignitic measures. Though I worked at the locality for an entire day with a miner, I could not find in the shale any other distinct vegetable remains but the two species described here. As yet, we have nothing related to them from the lower lignitic flora.

§4.—CLIMATE OF THE AMERICAN TERTIARY AS REPRESENTED IN ITS FLORA.

That the flora of a country is in correlation to local atmospheric circumstances; that ancient floras, too, bear characters which relate to the same cause, is an axiomatic assertion which does not need any discussion. In considering the development of vegetable types from the first apparition of land-plants, as far as this origin is known, it has been admitted also that the point of departure of the vegetation has been from the simplest organisms, passing up to more and more complex ones in ascending the series of the formations. According to this principle, the first representatives of dicotyledonous plants, which seem to have made their appearance near the base of the Cretaceous, but which have not been remarked as yet,* have been theoretically considered as being of a

* Professor Heer has, from the Lower Cretaceous of Greenland, a leaf resembling a *Populus*, mixed still with Jurassic or Wealden types.

very simple organization, or, so to say, in an adventive state of development, prepared in that way to rapidly undergo a series of modifications under every kind of physical influences. There is as yet scarcely any document in confirmation of this hypothesis and still less in contradiction of it. It is, in any way, adaptable to the explanation of some peculiar analogies remarked in the characters of the geological floras.

The vegetation of the Dakota group has a distant relation to that of the Upper Cretaceous flora of Europe by identity of a few of its species, especially ferns. But, as yet, little is known of the succession of the vegetable groups during the European Cretaceous, and of the relations of plants to the geological divisions of that epoch; and though the analogies may become more marked by future discoveries or publications, it is only from the data furnished by the American Cretaceous flora that we can get some kind of criterion of the climatic circumstances which have marked its general characters.* The descriptions of the species of this flora and the details in regard to their relation, as published in our flora of the Dakota group,† evidently show its relation to a moderate climate, about of the same average degree as that of the middle region of North America. A number of Cretaceous genera are still represented in our arborescent vegetation.

From the Dakota group upward, there is no trace of land-vegetation in the whole North American continent until we reach the Lower Lignitic formation. All the intermediate strata are marine, and the series of animal remains, which they have preserved in great abundance, are uninterrupted and uninterruptedly Cretaceous in their characters as high as the Lignitic. Animal Cretaceous remains have been found, as remarked formerly, even in shale overlaying Lignitic deposits. Now, in comparing fossil plants of the first or lowest group of the Lignitic, we should expect to find, merely considering its immediate succession to strata of Cretaceous age, a flora with some distinct analogy to that of the Dakota group: most of its genera, some of its species, too. But it is not the case. Some genera, of course, are represented in both floras, but by different types; and they do not have any identical species, nor even any closely-related forms. There is in the general character a kind of related *facies;* but specific types of the former floras seem to have been destroyed during the prevalence of the marine Cretaceous period, and above its fucoidal sandstone, even within its upper strata, and in connection with Lignitic deposits, there appears a new flora without positive relation with former vegetable types, and with but few of those of subsequent groups of plants or younger geological floras. This anomaly may be explained in two ways; either by supposing that during the prevalence of the marine formations, or by the submersion of the land, all the genera and species of the Cretaceous have been annihilated, and that a new generation of vegetable types has covered the new land as fast as it appeared above the surface of the water; or that during the period of the marine Cretaceous, the climate has been gradually modified, and that, therefore, the land at its first apparition has been invaded by a vegetation in harmony with the climatic circumstances governing this new epoch. This last supposition seems the only one admittable, the more so as it does not consider the hypothesis of a general destruction of vegetable types and of subit renovation of others or of the creation of a new vegetable world.

* Two memoirs of the Lower and Upper Cretaceous floras of Greenland have been prepared and are now in the way of publication by Professor Heer.

† Memoir on the fossil plants of the Cretaceous Dakota group of the United States, (1874.)

But where have the new types come from, and where have they originated?

The climatic difference indicated by the characters of the North American Cretaceous flora, in regard to that of the Lower Lignitic, may be exposed in degrees of latitude rather than by thermometrical figures of an average temperature. It is about the same as that between Ohio and South Florida. In the Lower Lignitic, the palms compose a large proportion of the flora. This family of plants is still represented in our present flora by species of *Chamœrops* and *Sabal*. But they mostly inhabit the shores of the Gulf of Mexico, in South Carolina, and especially South Florida. They are scarcely found inland. The highest north station of *Sabal* is in the swamps, at the mouth of the Arkansas River, and here it is a mere dwarf, not above one to two feet high, vegetating under the deep shade of canes and swamp-trees. With palms the Lignitic has 15 species of *Ficus* of a type related to subtropical forms of this genus. Then *Artocarpidium*, *Pisona*, a number of *Diospyros*, large-leaved species of *Viburnum*, *Magnolia*, and *Dombeyopsis*, with *Rhamnus*, species of southern types. There is not, however, in the flora, any true tropical form; nor do I find any of the so-called Indo-Australian types. *Cinnamomum* and *Laurus* species are more numerous than in the Dakota group, but scarcely of a different type. The distribution of these two genera, however, does not appear to have had a marked relation to climate in the geological times. *Diospyros* and *Magnolia* are also represented in the Dakota group, but the forms or species are very distinct and not as numerous. Many species of *Rhamnus* of the Lower Lignitic are characterized, most of them at least, by thick, close secondary veins, referring these, for analogy, to the present *R. Carolinianus* and *Berchemia volubilis*, whose range of distribution is from Florida to North Carolina and South Arkansas. The difference of temperature is, therefore, in the average, equal to that marked in about 10° to 15° of latitude. It is, indeed, a small difference in considering the distribution of the floras of the Dakota group, and of the subsequent groups of the Tertiary, and it would be easy to explain the gradual invasion of another kind of vegetation from a distance equaling the 15° of latitude upon the new land of the Tertiary, and after the disappearance of the anterior vegetable types, if only the pre-existence of such a flora was admittable. There is no difficulty to account for a higher degree of temperature for the Lower Lignitic in considering the flora of the Dakota group as a land-flora, or at least as a flora covering the coast of an upland of wide extent, therefore under the influence of a dry atmosphere. On the contrary, the Lower Tertiary land emerging from an extended sea-surface, as low swamps, under a foggy or very wet atmosphere, should have its climate tempered in a proportional degree, and its vegetation an insular rather than a continental one. But this does not explain the disappearance of the more marked vegetable types of the Dakota group, and still less their re-appearance in the upper stage of the Tertiary.

The flora of the second group*, especially characterized by the plants of Evanston and Spring Cañon, preserves some relation to that of the first by the palms. Remains of plants of this family are, however, in this second group, very rare, and represent mostly fruits, which, though identical with organs of the same kind found at Golden, Black Butte, and the Raton, with Sabal leaves, may, however, belong to some other kind of vegetable. There is, besides, a diminished proportion of the leaves referable to subtropical types. With this the second group has

* See above: *Remarks on species of the second group.*

some species and representatives of genera which have been described from the Dakota Cretaceous, *Cinnamomum Scheuchzeri*, *Liriodendron*, and *Sassafras*, and it has also some of its species identical with those of the Arctic Miocene. Its *facies*, therefore, positively indicates a somewhat colder temperature than that of Lower Lignitic.

With the third group, the palms have disappeared entirely, as well as the subtropical types of the Lower Eocene. Its flora has also a *Liquidambar*, *L. gracile*, closely allied to a Cretaceous species, *L. integrifolium*, and with this it has a more marked predominance of arctic forms or species identical with those of the Miocene of Greenland and Alaska, as seen in the remarks on the tables. The lowering of the temperature is there still more marked than with the second group. In the whole extent of the Lignitic formations we can see, therefore, from the character of the successive floras, a slow decrease in the degrees of temperature, accountable, it seems, to the diminution of atmospheric humidity in proportion to a gradual consolidation and drainage of the land. The same phenomenon is indicated by the deposits of Lignitic beds, which, though of as great thickness in the second and third groups, cover less extensive areas.

The *facies* of the flora of the fourth group evidently represents the colder climate of a mountainous region, by the superabundance of conifers as the essential constituents of the forests of that epoch. It has, besides, many species of shrubs, *Salix*, *Myrica*, *Comptonia*, *Ilex*, *Rhus*, which generally form the undergrowth of pine-woods, or border the swamps and streams intersecting them, and in accordance, a less proportion of trees with deciduous leaves. This vegetation of the Upper Tertiary recalls by its character that of the Adirondacks of New York or of the Black Mountains of North and South Carolina, where each knob is overgrown by one species of conifers, here and there intermixed with poplars, birches, sometimes oaks and beeches, and where the undergrowth scarcely allows to penetrate in the dark recesses of the forests. As remarked in describing and comparing the species of this group, the flora of each place where fossil plants have been obtained is composed of some species of conifers which are not represented at the other localities. In the forests of the plains, conifers of a same kind are generally extensively and uniformly distributed, covering wide areas, as in some parts of Europe and of North America, especially in the maritime pine-woods of the South and the northern forests of the cold plains of Canada, Norway, &c. But in the mountains even at our time the forests are composed of numerous groups of a predominant species of conifers, represented in separate and limited areas, and varying in accordance to altitude, exposition, degree of declivity, &c. The limitation of conifer-species to different localities of our Upper Tertiary is thus characteristic of a mountain-flora.

In admitting, as positively proved, the exact and constant relation of the flora of a country or of a land-surface with the climatic circumstances of the same localities, it is easily understood how doubtful are the conclusions taken concerning the relation of geological epochs in comparing the fossil floras of two continents. The four groups of our Tertiary are characterized by a succession of types bearing constant increasing analogy to those our present flora without the admixture of foreign vegetable forms, which imprint some local floras of Europe with peculiar and distinct *facies*. This indicates for this continent a long continuance of the same climatic circumstances without notable modification. These circumstances have not been of necessity the same in Europe during the same period of time. There may have been, for example, at the epoch of the Lower Tertiary or Eocene, a higher temperature, influenced by proximity to the sea, by its currents, by slanting areas exposed to the sun, &c., and of course a corresponding flora, Indo-Australian or tropical, &c., while, under different influence, we had at the same epoch a more moderate temperature and a flora with homologous types, related to those appearing later in Europe, when the temperature was at a lower degree, in the upper Miocene epoch, for example. This explains, of course, the non-correlation of vegetable types at epochs which are recognized as synchronous by their animal fossils, and, therefore, contract our deductions of synchronism of strata, as indicated by identification of fossil remains, into more narrow limits. It is probably for this reason that, in comparing the data furnished by our ancient floras with those of Europe, we have constantly recognized a kind of precedence of types which may be merely the expression or exposition of a difference of climatic circumstances at the same epochs. Of this, however, we have to learn a great deal more on those floras of old before we are able to take any reliable conclusions, and for this reason, also, it is of importance to limit our deductions on what we may learn in considering our North American fossil floras.

Paleontological data, animal and vegetable, have demonstrated, for the geological times, as far up as the Lower Tertiary, or at least the Upper Cretaceous, a uniformity of climate over the whole north hemisphere, from the pole to the equator, if not over the whole world. The causes of this phenomenon are multiple and not yet satisfactorily explained. In the flora of the Dakota group, and also in that of the second and third groups of the Tertiary, this isothermal *facies* is remarkably proved by identity of genera with those of the flora of the north, or as far up as remains of fossil plants have been found, especially with that of Greenland. The Cretaceous flora of Come, described by Heer in his Arctic Flora, is represented only by species of ferns and conifers, which do not have any relation to the plants of the Dakota group, except perhaps by one single species, *Sphenopteris Johnstrupi*, which is comparable to *Hymenophyllnm cretaceum.* This flora of Come may be referable to a lower stage of the Cretaceous, as it has no remains of dicotyledonous leaves. In an upper flora of the same country, Professor Heer finds mostly dicotyledonous leaves, and recognizes them as referable to many of the genera represented in our Dakota group. As the memoir of those plants is not yet published, it is not known how intimate the relation may be; but the generic identity is enough already to indicate analogous climatic circumstances in Greenland and North America at this Upper Cretaceous epoch. The flora of our Lower Lignitic, the oldest of the American Tertiary, is as yet without relation with any northern flora known until now. But that of the second group and of the third are related, as remarked above, with the Miocene Greenland flora by a number of species and typical forms, which are characteristic enough to show that a same climate influenced at this epoch the vegetation of both countries. Therefore, from this, it seems that as far up as the Miocene period the isothermal zone extended from the tropic to the pole, or that at that epoch the same climatic circumstances have governed the vegetation of the North American continent.

The relation of the floras to the climate being forcibly recognized in local differences, or analogies of vegetable forms, it suggests another question, that of the origin of the groups of vegetables characterizing either different stages of the Tertiary or different localities of the same epoch.

Our flora of the Dakota group has for its essential representatives

(I consider dicotyledonous species only) leaves of a coarse coriaceous texture, mostly with entire borders. A character of the same kind is recognized in the flora of the Lower Lignitic group, which, like the former, has very few dicotyledonous leaves with serrate borders, a large proportion of coriaceous leaves, and also species of *Viburnum* with borders of leaves equally cut by short-pointed teeth turned outside, a same kind of dentation exactly which is remarked in a few dentate species of the Dakota group. In the European Cretaceous flora, as represented by *Credneria*, *Ettinghausenia*, &c., of the Quadersandstein of Germany, the leaves have a *facies*, which, though different in some points, could be, however, compared with that of a few species of our Cretaceous; for example, *Ettinghausenia Sternbergii*, Stiehler, or *Phyllites repandus*, Sternb., (figured in vol. ii, Tab. xxv, of Fl. der Vorwelt,) could be admitted as an original type of the multiple forms of *Sassafras* of the Dakota group. But when we look further and come to the floras of the lowest Tertiary of Europe, that of the lower Sezane for example, which, by the presence of Cretaceous and Tertiary types, seem to indicate a flora of transition between these two formations, and is recognized as Lower Eocene, we find characters pointing out, I think, to a multiple kind of derivation. This Sezane flora has its dicotyledonous types represented by 21 genera, with 47 species, with more or less serrate or doubly-serrate and dentate leaves, and 11 genera, represented by 20 species, with entire-bordered leaves; therefore, a large predominance of leaves marked by a character mostly absent from the Dakota group and Lower Lignitic American floras. Considering this Eocene flora of France only, with its species of *Betula*, 2; *Alnus*, 3; *Ulmus*, 2; *Populus*, 1; *Salix*, 3; *Aralia*, 6; *Greviopsis*, 5; *Juglandites*, 4; *Celastrites*, 4; *Rhamnus*, 1; &c., all, even *Salix*, *Juglandites*, *Rhamnus*, with serrate leaves, it would be rational to suppose that the original types of the dicotyledonous flora did represent essentially serrate leaves; while we had reason to admit a contrary conclusion from the characters of our Cretaceous and Lignitic floras, whose types, even from the same genera, *Juglans*, *Salix*, *Populus*, are represented by entire-leaved species. Also, in the dentate leaves of the North American Cretaceous and Eocene, the type is distinct. With very few exceptions, these have the peculiar dentation remarked in the description of *Greviopsis Haydenii* of Nebraska, and of *Viburnun marginatum* of Black Butte. I have compared this last species to *V. giganteum* of Sezane, but only for the size of the leaves and the character of the nervation, not for the division of the borders, as seen above; for the Sezane species has long, turned-upward teeth, some of them doubly dentate, a character in accordance with most of the other kind of leaves of this European group. How to account for discrepancies of this kind? Is the Sezane flora representative of a formation absent from the American geology, or not yet recognized in it; of a land-formation which, under different climatic influences, could have harbored the same types as the Sezane ones, introduced by some kind of agency? This is evidently not the case, as the series of the Cretaceous strata from the Dakota group to the Lignitic is uninterrupted, and especially as both successive floras are related by a general character far different from that of the contemperaneous floras of Europe and of those of intermediate epochs. Now, admitting that the succession of generic types indicates continuous development or multiplication of forms and characters in ascending from the lowest strata of the geological formations, shall we say that a single form or type or species has been at different times the first and only representative of each group, though wide and multiple in its representatives it may be now? Or, considering merely the dicotyledonous plants, which make their first appearance at the beginning of the Cretaceous, are they all derived from the modification of a same lower form, developed at the same or at different localities under influences of the same kind? I do not think it possible to suppose that the first leaf representative of a dicotyledonous has appeared only at one place of the surface of the earth, nor that it has been derived from a same organism over the whole world, nor that the external first causes of modification have been the same. Therefore, even admitting the theory of successive transformation of vegetable types in a kind of ascending scale, it would be necessary to consider as multiple, local, varied in forms, the first dicotyledonous representatives. If this is true for the dicotyledonous plants, it has to be equally admitted for plants of a lower type. Simple as they were, then, in their characters, they did hold, as seeds do, all the future typical conformations of their offsprings, resulting of influences of divers natures; but as it is the case with seeds of different kinds, the result of their multiplication of growth should, of course, have been represented by groups of vegetables of different characters. This would account for the diversity of floras of the same epoch at distant localities, or for the isolation and dissimilarity of types in the flora of two continents in synchronous formations. I believe, therefore, that the disaccord remarked in the floras of geological epochs, and which have been explained by displacement of floras, or what is called a wandering of species, may be, in many cases at least, attributed to diversity of original forms. The more we descend toward the so-called primitive vegetable types, or the more simple have been the organism of plants, the more easily they should have been modified under local influences. A change of climate of a few degrees, which might have caused the disappearance or extinction of some species of plants, should have forced the deformation of others or the birth of new ones in a proportional degree. Though the intermediate links which connect ancestors and descendants in vegetable types are not always recognizable, even in the oldest fossil floras, it is certain that all the groups have a general family-*facies* modified by some new and discordant forms of unaccountable origin. In our Lignitic, the group of Evanston, for example, introduces to the Tertiary flora the serrate leaves, its *Carya*, *Alnus*, *Betula*, &c. That of Carbon comes after with *Acer*, *Ulmus*, and other new types. Have they been brought up from Greenland, from Europe, or from another country, or have they appeared for the first time where we find them now? They must have had their birth at some place, anyhow; and I do not see why this birthplace should not be accepted for the localities where the types are recognized, rather than to suppose them born elsewhere and transported hereafter, adding to the problem a new proposition, which renders its solution still more difficult. As said above, the question is merely touched upon, as I do not wish to take ground either for or against the present system, now generally admitted, of the succession of species, or of their development by modification of form under any kind of influence. My purpose is merely to point out the importance of the study of our ancient North American floras, represented by more homogeneous groups in a more regular succession, less diversified by geological disturbances, and which, therefore, may afford some more reliable data for consideration. The history of the vegetation of the earth is in intimate relation to that of the human races. The proverb, "All flesh is grass," is explainable in this way: that the vegetation of every epoch is in immediate relation to the synchronous beings; that vegetable life comes first and that animal life is dependent from it; that therefore the history of the vegetation from its origin, or the vegetable paleontology, should not be left aside in considering the successive phases of animal life in relation to the history of man.

REPORT ON THE VERTEBRATE PALEONTOLOGY OF COLORADO.

By Edward D. Cope, A. M.

Philadelphia, *July* 12, 1874.

Sir: I send herewith a report on the stratigraphical relations and vertebrate paleontology of the formations which represent the Cretaceous, Eocene, Miocene, and Pliocene periods in Colorado, with a few species from other localities added. This essay is based on material collected by myself during a part of the summer and autumn of the year 1873, under the auspices of the geological survey of which you are director. This represents the following numbers of species from the respective formations, to which I have added the number from each which is believed to have been first introduced to the knowledge of paleontologists:

Formation.	Total.	New.
Pliocene	21	9
Miocene	75	59
Eocene	15	7
Cretaceous	38	19
Total	149	94

Hoping that the report will subserve the objects of the survey, I remain, with respect,

EDWARD D. COPE,
Paleontologist.

Dr. F. V. Hayden,
Geologist in Charge, &c

CHAPTER I.

INTRODUCTION.

The water-shed between the South Platte River and Lodge Pole Creek is composed superficially of formations of the Pliocene epoch as defined by Hayden. The latter stream flows eastwardly through the southern parts of Wyoming and Nebraska, and empties into the South Platte near Julesburgh, Nebr. The territorial and state boundaries traverse this water-shed from west to east. The springs on its southern slope, which form the sources of the northern tributaries of the South Platte, issue from beneath the beds of the formation above named. At or near this point is an abrupt descent in the level of the country, which generally presents the character of a line of bluffs varying from two to nine hundred feet in height. This line forms the eastern border of the valley of Crow Creek until it bends to the eastward, when it extends in a nearly east and west direction for at least sixty miles.* At various points along it, portions have become isolated through the action of erosion, forming "buttes." Two of these, at the head of Middle Pawnee Creek, are especially conspicuous landmarks, forming truncate cones of about 900 feet in elevation, as Mr. Stevenson, of the survey, informs me. They are called the Pawnee or sometimes the White Buttes; near them stand two others, the Castle and Court-House Buttes.

The upper portion of this line of bluffs and buttes is composed of the Pliocene sandstone in alternating strata of harder and softer consistence. It is usually of medium hardness, and such beds, where exposed on both the Lodge Pole and South Platte slopes of the water-shed, appear to be penetrated by innumerable tortuous, friable, siliceous rods and stem-like bodies. They resemble the roots of the vegetation of a swamp, and such they may have been, as the stratum is frequently filled with remains of animals which have been buried while it was in a soft state. No better-preserved remains of plants were seen. The depth of the entire formation is not more than 75 feet, of which the softer beds are the lower, and vary in depth from 1 foot to 20. The superior strata are either sandstone conglomerate or a coarse sand, of varying thickness and alternating relations; the conglomerate contains white pebbles and rolled Pliocene mammalian remains.

This formation rests on a stratum of white, friable, argillaceous rock of Miocene age, probably of the White River epoch, as I believe, from the presence of the following species, which I detected in it: *Hyænodon horridus*, *H. crucians*, *Oreodon culbertsonii*, *O. gracilis*, *Pœbrotherium wilsonii*, *Aceratherium occidentale*, *Hyracodon nebrascensis*, *Anchitherium bairdii*, *Palæolagus haydenii*, *Ischromys typus*, *Mus elegans*, &c. The formation extends to a depth of several hundred feet, and rests on a stratum of a fine-grained, hard, argillaceous rock of a dark-brown color. Some of its strata are carbonaceous, and contain vegetable remains badly preserved; others are filled with immense numbers of fresh and brackish water shells, including oysters. I do not know the depth of this bed, but followed it to the southward until it disappeared beneath the Loess of the South Platte. The age of this formation is identical with that which underlies the fresh-water basins of Dakota and Wyoming according to Hayden, and concerning which difference of opinion

* See Berthoud, Proceed. Acad. Nat. Sci. Phila., 1872, p. 48, where the bluffs are mentioned.

exists among geologists. I, however, succeeded in procuring a number of fossil vertebrates from it, which not only prove conclusively its Mesozoic age, but its horizontal identity with the reptile-bearing Fort Union beds of the Upper Missouri. This formation, which has been usually regarded as Tertiary, I determined to be Cretaceous in 1869, and the present discoveries establish that view as correct. The fossils which are described in the following pages represent *Dinosauria* of three species, a crocodile, and several tortoises, identical specifically with those obtained by Dr. Hayden on the Missouri, Big Horn Rivers, &c. Some of the shells I submitted to Mr. Conrad, and he pronounces them to be *Cyrenas*.

South of the South Fork of the Platte, the Cretaceous beds have an extensive development, and south of the Kansas Pacific Railroad contain some beds of pretty good coal. The high tract of land which extends east from the Rocky Mountains, and constitutes the "divide" between the waters of the Platte and Arkansas, is composed of Tertiary strata lying nearly horizontal. A few days' exploration among them revealed chiefly hard, coarse sandstones and conglomerates, which belong to the Monument Creek group of Hayden. The more elevated hills nearest the mountains are capped by a light-colored trachytic rock, believed to be of volcanic origin. While it overlies the Monument Creek formation, the sandstone of the latter not infrequently incloses angular fragments of a similar rock, showing that the outflow commenced prior to the period of its deposit, and continued subsequently. The age of the Monument Creek formation in relation to the other Tertiaries not having been definitely determined, I sought for vertebrate fossils. The most characteristic one which I procured was the hind leg and foot of an *Artiodactyle* of the *Oreodon* type, which indicated conclusively that the formation is newer than the Eocene. From the same neighborhood and stratum, as I have every reason for believing, the fragment of the *Megaceratops coloradoensis* was obtained. This fossil is equally conclusive against the Pliocene age of the formation, so that it may be referred to the Miocene until further discoveries enable us to be more exact.

Fresh-water strata of probable Eocene age were, however, detected by both Dr. Hayden's party and my own in the South Park. These consist of laminated argillaceous shales of soft consistency, in which great numbers of fishes and plant-impressions are preserved. The fishes are referable to only two species, *Amyzon commune* and *Rhineastes pectinatus*, and are described in chapter II. They are nearly related to species of the Elko shales and Bridger formation, and I suspect that their age is Eocene.

From Trout Creek, near Fairplay, we procured a number of invertebrate fossils of Lower Cretaceous age, a few of which are described by Mr. Conrad in chapter II.

Thus it appears that, in Colorado as in Dakota, the formations of the Loup Fork, White River, and Fort Union epochs are present, and display a similar succession of life, and that the corresponding horizons display identity in the generic and often specific forms of life. They also exhibit the same marked faunal distinctness from each other in Colorado as in Dakota, and the Colorado fauna displays the same strong diversity from the Eocene fauna of Wyoming in respect to the genera, families, and orders which can be compared.

CHAPTER II.

THE CRETACEOUS PERIOD.

SECTION I.—ON THE MUTUAL RELATIONS OF THE CRETACEOUS AND TERTIARY FORMATIONS OF THE WEST.

The subject which it is proposed here briefly to discuss is one which has excited considerable interest for several reasons. One of these is, that there exists some discrepancy in the evidences as to the true age of beds at the summit of the Cretaceous period and base of the Tertiary in the Missouri and Rocky Mountain regions, and hence a difference of opinion. Another is, that the question of continuity in topographical, and hence of faunal and floral, relations, will be largely elucidated by a proper determination of the beds in question, both geologically and paleontologically. I have endeavored to attain some results in the latter field in the department of *Vertebrata*, which are here presented, with some stratigraphical observations made at localities either little or not previously studied.

Messrs. Meek and Hayden have classified the vast thickness of the Cretaceous system, recognizing five epochs as quite distinctly defined. These are as follows:

I. THE DAKOTA GROUP, (No. 1.)—The present list does not include any species as discovered in this formation. Developed on the Missouri and on the Rio Grande, New Mexico.

II. THE BENTON GROUP.—Seen on the Missouri River by Hayden, and stated by him to extend to the Smoky Hill River, in Kansas, and to Texas. I have determined only three species from it, namely: *Hyposaurus vebbii*, a crocodile; *Apsopelix sauriformis*, a clupeoid; and *Pelecorapis varians*, a ctenoid fish. Other species of fishes occur in the same formation in Kansas.

III. THE NIOBRARA GROUP.—From the Missouri, Kansas, and Texas, according to Hayden. Confirmatory of the last locality are remains of *Pythonomorpha* from that State, discovered and sent to me by Mr. A. R. Roessler. I have also described a species of that order as common to Eastern New Mexico and Western Kansas; and Hayden and Leconte state that it appears north of the Arkansas in Southern Colorado. Vertebrate remains are abundant in this formation, and it has furnished a majority of those investigated by paleontologists. They are distributed as follows, among the orders of *Vertebrata*:

Aves:	
Natatores	2
(?) *Saururæ*	2
Reptilia:	
Dinosauria	1
Pterosauria	4
Sauropterygia	3
Testudinata	3
Pythonomorpha	27

Pisces:

Isospondyli	31
Selachii	10

IV. THE PIERRE GROUP.—In Nebraska and Dakota, and Middle Colorado south of the divide between the waters of the Arkansas and Platte Rivers. Also the lower bed of Greensand of New Jersey. Besides the numerous remains of reptiles and fishes found in New Jersey, this formation contains saurian (mosasauroid) remains in Colorado. Weber River, Wyoming,* below the coal.

V. THE FOX HILLS GROUP.—Extended in Central Dakota; on the Arkansas and tributaries in Southern Colorado; and as the second Greensand bed in New Jersey.†

VI. THE FORT UNION OR LIGNITE GROUP.

With this epoch we enter debatable ground, and begin to consider strata deposited in brackish or fresh waters, which were more or less inclosed by the elevation of parts of the Rocky Mountains and other western regions, and which are therefore more interrupted in their outlines than the marine formations which underlie them. Dr. Hayden has recognized and located a number of formations of this character, to some of which he has applied the name of "transition-beds." That the period of their deposit was one of transition from marine to lacustrine conditions is evident, and that a succession of conformities in position of beds may be traced from the lowest to the highest of them, and with the Tertiary strata above them at distinct localities, beginning at the south and extending to the north, is also proved by Hayden and others. It appears impossible, therefore, to draw the line satisfactorily without the aid of paleontology; but here, while evidence of interruption is clear, from the relations of the plants and vertebrate animals, it is not identical in the two cases, but discrepant. I therefore append a synopsis of the views expressed by authors, with a presentation of the evidence which is accessible in my department. I am aware that the combination I shall make is of a highly inflammable character, because it not only relates to the most combustible deposits of the West, but also to the "*partie honteuse*" of contemporary geologists and paleontologists. But should any inflammation ensue, I hope it will be attributed to the nature of the materials employed, rather than to any inattention on the part of the author to the just claims of his friends.

Hayden has named the following as distinct epochs of transitional character, all of which he originally referred to the Tertiary period. I give them in the order of age which he has assigned to them.‡ (1.) Placer Mountain; locality, New Mexico. (2.) Cañon City coals, Southern Central Colorado. (3.) Fort Union, or Lignite group; Dakota, Montana, and Wyoming. (4.) The Bitter Creek series; embracing the Bitter Creek coals, Wyoming. (5.) Bear River group, Western Wyoming. To these may be added the Judith River beds of Montana, which Dr. Hayden has placed with reservation below the Fort Union series, leaving their final location for future discoveries.

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* Hayden's Annual Report, 1870, p. 167.

† For a review of the extinct reptiles of this epoch, see the author's Extinct Batrachia, Reptilia, &c., N. Am., 1870.

‡ Geological Survey of Colorado, 1869, p. 90.

No vertebrate remains having come under the author's notice from the Placer Mountain and Cañon City formations, no further notice can be here taken of them beyond the statement that they are, as Meek indicates, of Cretaceous age, not far removed from the horizon of the coals of Weber River, Utah. The presence of ammonites and baculites above and below them has indicated such a conclusion to Leconte,* as it has in the case of the Weber River beds to Dr. Hayden.† To near the same horizon is perhaps to be referred the coal observed by Professor Marsh‡ on the south side of the Uintah Mountains in Utah, which were overlaid by strata containing *Ostrea congesta*. This may, indeed, be referred to a still older period, as that oyster is characteristic of No. 3, according to Meek and Hayden. The Placer Mountain and Cañon City groups are nearer to No. 5, but the precise relation to it has not yet been determined. I therefore proceed to the Fort Union group as No. 6.

This extended deposit is stated by Hayden§ to extend from the Missouri Valley to Colorado, passing under Tertiary beds by the way. That this is the case has been confirmed by the researches conducted in the northern and eastern portions of Colorado during the season of 1873 by the writer.|| I present comparative lists of the vertebrate species known from the Platte and Missouri Valleys in the respective Territories:

COLORADO.	DAKOTA.
Compsemys victus.	*Compsemys victus.*
Adocus lineolatus.	*Adocus lineolatus.*
Plastomenus punctulatus.	*Plastomenus punctulatus.*
Plastomenus insignis.	* *
Trionyx vagans.	*Trionyx vagans.*
* *	*Ischyrosaurus antiquus.*
* *	*Plesiosaurus occiduus.*
Bottosaurus perrugosus.	* *
Polyonax mortuarius.	* *
Cionodon arctatus.	* *
? *Hadrosaurus occidentalis.*	*Hadrosaurus occidentalis.*

The identity and correspondence of the species indicate that these remote localities contain the remains of the same fauna. Further, the presence of the orders *Sauropterygia* and *Dinosauria* establishes conclusively the Cretaceous and Mesozoic character of that fauna.¶ This reference was made by the writer in 1869, and was at that time opposed to the views extant, both geological and paleontological. The following exhibits the state of opinion on this point at that time:

1856. Meek and Hayden, Proceedings Academy Philadelphia, p. 63; referred them to the Tertiary.

1856. Meek and Hayden, *loc. cit.*, p. 255; Lignite referred to the Miocene.

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* Report on the Geology of the Smoky Hill Pacific Railroad Route, 1868, p. 66.

† Annual Report, 1870, p. 168.

‡ See an interesting article by Prof. O. C. Marsh on the Geology of the Eastern Uintah Mountains; Amer. Jour. Sci. Arts, March, 1871.

§ Annual Report, Colorado, 1869, p. 89.

|| See Bulletin of the United States Geological Survey, 1874, p. 10.

¶ Two species are provisionally referred to the Tertiary genus *Plastomenus*, but are too fragmentary for final determination.

1856. Meek and Hayden, *loc. cit.*, 113; referred to Lower Tertiary.

1856. Leidy, *loc. cit.*, p. 312; *Thespesius occidentalis*, (*Hadrosaurus*,) referred to the Mammalia and regarded as perhaps *Dinosaurian*.

1856. Leidy, *loc. cit.*, 1856, p. 89; *Ischyrosaurus* referred to the Mammalia as a *Sirenian*.

1860. Hayden, Transac. American Philosoph. Society, repeats former conclusions, and Leidy refers *Thespesius* more decidedly to the *Sauria*.

1868. Hayden, Amer. Journal Science Arts, 1868, p. 204; Lignites, regarded as Tertiary, from both vegetable and *animal remains* from the Missouri and the Laramie Plains.

1868. Leconte, Exploration of the Smoky Hill R. R. Route, p. 65; the Colorado beds are "older than those of the Missouri or Great Lignite bed of Hayden, which are probably Miocene," &c.

1869. Cope, Trans. Amer. Philos. Soc., pp. 40, 98, 243; supposed mammalian remains proved to be reptilian, and the formation referred to the Cretaceous.

1871. Newberry, in Hayden's Annual Report, pp. 95, 96; Lignite flora regarded as Miocene.

1874. Cope, *loc. supra cit.*; Lignite of Northern Colorado referred to the same horizon.

The Judith River beds may be noticed in this connection. They have yielded but few vertebrate remains, namely, six species of *Reptilia*. Four of these are *Dinosauria*, and hence diagnostic of the Mesozoic age of the formation. The presence of a species, *Hadrosaurus mirabilis*, Leidy, closely allied generically and *specifically* to a species (*H. foulkei*) of Cretaceous Nos. 4 and 5 of New Jersey, induces me to believe that the formation is Cretaceous, and such would appear to have been the suspicion of Messrs. Meek and Hayden when they originally described the deposit and its invertebrate fossils. Leidy suspected that the species "indicate the existence of a a formation like that of the *Wealden* in Europe."* Meek and Hayden† remarked, "We are inclined to think with Professor Leidy that there may be at the base of the Cretaceous system a fresh-water formation like the *Wealden*. Inasmuch, however, as there are some outliers of fresh-water Tertiary in these lowlands, we would suggest that it is barely possible these remains may belong to that epoch." From the stand-point of the writer, these beds would be at the top of the Cretaceous, and more or less related to the Fort Union epoch. Mr. Meek expresses himself‡ cautiously with reference to the age of the Fort Union and Judith River formations, as follows: "The occurrence of" fossils specified "at the Judith River localities would certainly strongly favor the conclusion not only that this Judith formation, the age of which has so long been in doubt, is also Cretaceous, but that even the higher fresh-water Lignite formation at Fort Clark and other Upper Missouri localities may also be Upper Cretaceous instead of Lower Tertiary. That the Judith River beds may be Cretaceous, I am, in the light of all now known of this region of the continent, rather inclined to believe. But it would take very strong evidence to convince me that the higher fresh-water Lignite series of the Upper Missouri is more ancient than the Lower Eocene. That they are not is certainly strongly indicated not only by the modern affinities of their molluscan remains, but also by the state of preservation of the latter," &c. It is thus evident that the paleontologists as well as stratigraphers have continued to regard the

* Proceedings Academy Philadelphia, 1856, p. 73.
† *Loc. cit.*, 1856, p. 114.
‡ Hayden's Annual Report, 1872, p. 450.

Lignite series as Eocene and not Cretaceous, as is and has been maintained by the writer since 1868.

VII. THE BITTER CREEK SERIES, mentioned by the writer as a distinct group in the Proceedings of the American Philosophical Society, 1872, (published on August 12,) is apparently regarded by Mr. Meek also as representing a distinct epoch.* He says, "The invertebrate fossils yet known from this formation are in their specific relations, with possibly two or three exceptions, new to science and different from those yet found either at Bear River, Coalville, or, indeed, elsewhere in any established horizon, so that we can scarcely more than conjecture from their specific affinities to known forms as to the probable age of the rocks in which we find them." On this account, and because of the great stratigraphical differences exhibited by the Bear River and Evansston coal-strata, I have followed Hayden in regarding the Bear River group on the west side of the Bridger basin as representing a distinct series of rocks, with present knowledge. On this account I omit, as heretofore, allusion to determinations of age of the latter formation as irrelevant in discussing the age of the Bitter Creek epoch.†

My own observations on the relations of these rocks, made during the summer of 1872, have been in measure anticipated by the detailed reports of Messrs. Meek and Bannister,‡ which, with the older observations of Dr. Hayden and Mr. Emmons, (of King's survey,) leave little to be added. However, as none of these gentlemen paid especial attention to the vertebrate paleontology, the bearing of this department in relation to the stratigraphy remains to be explained.

As Dr. Hayden remarks, the Union Pacific Railroad, at Black Butte station, passes through a monoclinal valley, the rocks on both sides having a gentle dip to the southeast. This dip continues to the eastward to near Creston, where the beds pass under the newer Tertiary strata. Following the railroad westward from Black Butte, the same dip continues to near Salt Wells, where we cross an anticlinal axis, the dip of the strata being gentle to the northwest. There are minor variations in the dip, but the general result is as stated. They disappear five miles east of Rock Spring station, beneath the latter beds of the Green River Tertiary, which at this point presents a line of strike extending northeast and southwest across the railroad in the form of a range of bluffs of considerable elevation. They are composed of lighter-colored and softer material than the Bitter Creek strata. The latter consists of alternating beds of hard and soft sandstone, with argillaceous and carbonaceous strata. The upper part of the series contains eleven coal-strata; at Rock Spring I was informed that the upper was ten feet in thickness, and the next four feet. Returning eastward, the heavier bedded sandstone is low in the series at Point of Rocks, in consequence of the southeast dip; and the upper beds are softer and abound in fossil shells. At Black Butte station, the heavy sandstone bed disappears from view toward the east, and the eleven coal-strata appear above it. About twenty feet above the sandstone, between two of the thinner beds of coal, the bones of the *Agathaumas sylvestris* were found imbedded in leaves and sticks of dicotyledonous plants, cemented together by sand and clay. Where the heavy sandstone bed disappears below the level of the track of the railroad, in the course of its eastern dip, a thin

* Hayden's Annual Report, 1872, pp. 459, 461, published April, 1873.

† This course has been misunderstood by Mr. Meek and others as implying a design to ignore those determinations. Both Mr. Emmons and Mr. Meek are clear in the expression of their conclusions as to the age of the Bear River epoch.

‡ See Hayden's Annual Report, 1872, pp. 457, 525.

bed of coal just above it soon follows; then a bed of shells containing oysters, more and less numerous at different points, may be traced for some distance before it also disappears. Near the latter point, a bed of melanian and other fresh-water shells is seen a few feet above them.

A section, carried for eight miles south of Black Butte station, exhibits the relation of the Bitter Creek series to the superincumbent Tertiaries very instructively. The whole series rises slightly to the southward, and more distinctly to the westward, so as to form an escarpment as the eastern border of an open valley, which extends south from the railroad just west of the station. The heavy bed of sand-rock is here as elsewhere the landmark and stratigraphical base-line. Moving south from the railroad, we keep along the strike of the lower coal-beds. Just above the sandstone bed the softer stratum thickens, and six miles from the station is covered with the *débris* of immense numbers of *Leptesthes crassatelliformis.* Passing over the edges of the strata toward the southeast, I counted eight beds of coal, separated by various short intervals, the eighth being the heaviest, and five or six feet thick. Above this one, three thin beds of lignite were crossed in succession, each accompanied with an abundance of leaves of chiefly dicotyledonous plants. Then came the ninth bed of coal, and then in order three more beds of lignite, with abundant leaves. During this time the ascent became less steep, and a number of level tracts were passed before reaching the upper bed of lignite. Beyond this I passed another short flat, which was marked by a number of worn banks of the light ash-color that distinguishes the material of the bluffs of the Green River Tertiary which overlie the coal-series near Rock Springs. I had not ridden a quarter of a mile before reaching a low line from which one of my men picked up a jaw of a small mammalian allied to the Bridger *Hyopsodus*, or *Hyracotherium* of the Eocene of France and Switzerland, and a number of *Paludina*-like shells. I had thus reached the summit of the Bitter Creek formation, which did not appear to be much more than three hundred and fifty feet above its base at the railroad. In full view, a mile or two to the south, rose the first of the benches which constitute the levels of the Green River formation. Between this and the first mammal-producing bed rose three banks, one beyond the other, measuring altogether one hundred and twenty feet; perhaps the lowest was ten feet above the first bank, and this one not more elevated above the last lignite and leaf bed. In all of these, I found bones of Green River *Vertebrata* exceedingly abundant, but all dislocated and scattered, so as to be rarely in juxtaposition. These consisted of the following species:

FISHES:

Clastes (?) *glaber.*

REPTILES:

Emys megaulax.
Emys pachylomus.
Emys euthnetus.
Trionyx scutumantiquum.
Alligator heterodon.

MAMMALS:

Orotherium vasacciense, and fragments of others too imperfect for determination.

In the third bank, in immediate juxtaposition with the remains just enumerated, I found another thin bed of lignite, but this time without any visible leaves. In a fourth line of low bluffs, a little beyond, I found that remarkable mammal *Metalophodon armatus*, with its dentition nearly complete, in connection with fragments of other mammals and reptiles.

Behind these rises the first line of white bluffs, already described, which extends away to the east; to the west it soon terminates in a high escarpment, in north and south line with that of the Bitter Creek beds, already mentioned as bounding a north and south valley. This and the superjacent strata, which we pass over in going south, *appear* to be conformable to those of the Bitter Creek series beneath them. I say "appear," for slight differences of dip are not readily measured by the eye; yet I suspect that the conformability is very close, if not exact, and similar to that mentioned by Meek and Bannister as exhibited by the beds of the Washakie group, which lie upon the coal-series east of Creston. The white bluffs add perhaps one hundred feet to the elevation. On their summit is a thin bed of buff clay and sand rock, similar to the upper strata of the Bitter Creek series, and containing numerous shells and some scattered teeth and scales of fishes. I called Mr. Meek's attention to the specimens of these shells which I sent him, and his reply was that most were of identical species with those of the coal-series, Cretaceous, and that they presented no general peculiarity.

At a short distance to the southward, another line of white bluffs extends across the line of travel. This is not more elevated than the preceding one; I only found remains of tortoises on it. Several miles to the south we reach another bench, whose bluffy face rises four or five hundred feet in buttress-like masses, interrupted at regular intervals by narrow terraces. This line is distinguished for its brilliantly-colored strata, extending in horizontal bands along the escarpment. They are brilliant cherry-red, white, true purple, with a bloom-shade, yellow, and pea green, forming one of the most beautiful displays I ever beheld. The lower portions are bright-red, which color predominates toward the west, where the bluffs descend to a lower elevation. I found on them remains of a turtle, (*Emys euthnetus*, Cope,) and some borings of a worm in a hard layer. On top of these are clay and slate rocks of a muddy-yellow color, with their various ledges rising to perhaps two hundred feet. Continuing now to the southeastward along the old stage-road, we cross South Bitter Creek at the old Laclede station. Some miles south and east of this point we cross a band of buff sandstones, forming a bluff of fifty or more feet in elevation. Below it lie more white or ashen beds, which contain remains of mammals and turtles rather decayed. A short distance beyond these, and forty miles from Black Butte station, we reach the base of the enormous pile of sediment which I have called the Mammoth Buttes. These form a horseshoe-shaped mass, the concavity presenting south and eastwardly, the summit narrow, serrate, and most elevated to the east, and desending and widening toward the south. I estimated the height of the eastern end to be at least one thousand feet above the plain surrounding it. Numerous mammalian remains* demonstrated that this mass is a part of the Bridger Eocene, although, as Mr. Emmons, of King's survey, informs me, no continuous connection with the principal area west of Green River can be traced. The total thickness of the Green River and Bridger formations on this section cannot be far from twenty-five hundred feet, at a very rough estimate.

The point of transition from the Cretaceous to the Tertiary deposits, as indicated by the vertebrate remains, is then in the interval between the last plant-bed at the summit of the buff mud-rocks and the mammal-bone deposit in the lowest of the ash-gray beds. Below this line

* See The Monster of Mammoth Buttes, Penn Monthly Magazine, 1873, August.

the formation must be accounted as Cretaceous, on account of the presence of the Dinosaurian *Agathaumas sylvestris*; and those above it, as I have already pointed out, Eocene,* on account of the types of *Mammalia* contained in them.

The authorities on the Bitter Creek formation have presented views more or less at variance with those entertained by the writer, or of such dubious character as to fall very far short of the requirements of evidence. Dr. Hayden has regarded them as Tertiary and as transitional from Cretaceous to Tertiary. Mr. King, in his very full article on the Green River basin, definitely refers the lower part of the series to the Cretaceous, in the following language: † "We have, then, here the uppermost members of the Cretaceous series laid down in the period of the oceanic sway, and quite freely charged with the fossil relics of marine life; then an uninterrupted passage of conformable beds through the brackish period up till the whole Green River basin became a single sheet of fresh water." He regards the line of the upper bed of oysters as the summit of the Cretaceous, and the superimposed beds as Tertiary, in the following language, (p. 453:) "while the fresh-water species, which are found in connection with the uppermost coal-beds, seem to belong to the early Tertiary period." He thus places the line some distance within what I have regarded as the Cretaceous boundary; what the significance of this conclusion is will be subsequently considered.

Mr. Lesquereaux, as is known, regards these beds as Tertiary, not only on account of their vegetable fossils, but also on account of the stratigraphic relations of the formation. His conclusion to this effect is consistent throughout, and is a fact of the highest importance in this connection.

Mr. Meek has fully discussed the age of this series in his interesting article in Hayden's Annual Report for 1872, the general tenor of which is indicated by the passage I have quoted from the opening of his remarks in the beginning of the present notice of the Bitter Creek beds. His opinions may be cited as follows: In the Annual Report for 1870, he determined the beds visible at Hallville as Tertiary; in that of 1871, three species of oysters from other parts of the Bitter Creek beds are placed in the Cretaceous list, each one with question as to the identification of species, a point, it is to be noticed, equivalent in the case of oysters to question of the age of deposit. The remarks in his report, as well as those in Mr. King's report, refer either to the much lower Weber River coal or to the different area of the Bear River group, and are consequently noticed under that head.

In a paper on the age of these beds, published August 12, 1872, the writer asserted the Cretaceous age of the series. On this Dr. Bannister, the companion of Mr. Meek, writes‡ that "Mr. Meek, and, I believe, Mr. Emmons also, had considered that these beds might be Cretaceous, but this was rather on account of the change in the fossil fauna from purely fresh-water, as in the characteristic Tertiary of this region, to brackish-water marine, and the specific affinities of a few of the fossils to California Cretaceous species, than from any very positive evidence. As far as I know, the only evidence of this kind is the identification by Professor Cope of the saurian remains found by us at Black Butte."

It only remains to observe that the strata and coal of the Bitter Creek group of the Cretaceous are either wanting on the western and southern

* On *Bathmodon*, an extinct genus of ungulates, Feb. 16, 1872, Hayden's Annual Report, 1870, p. 431; Annual Report, 1872, p. 645.

† Exploration of the Fortieth Parallel, p. 458.

‡ Annual Report, 1872, p. 534.

borders of the Green River basin, or are concealed by the superincumbent Tertiaries. Instead of these, a comparatively thin bed of apparently unfossiliferous quartzite or sandstone lies at a high angle against the bases of the Uintah* and Ham's Fork Mountains respectively, on beds of Jurassic age, which are probably Cretaceous No. 1, (Dakota.) The beds observed by Professor Marsh on the south side of the Uintah Mountains, on Brush Creek, belong neither to the Dakota nor Bitter Creek epochs, but perhaps to No 3, if, as Professor Marsh asserts, the oyster found in a superjacent stratum is *Ostrea congesta*, Con.; it is in any case of no later date than the Canyon City or Weber River coals. Hence the assumption of some writers that this discovery determined the age of the Bitter Creek series to be Cretaceous is without foundation in fact.

VIII. THE BEAR RIVER GROUP of Hayden occupies, according to him, a distinct basin, to the west of an anticlinal axis, which separates it from that of Green River. It is buried under Tertiary beds, the age of which has been a question of interest, and will be hereafter considered. In order to determine the relations of the two basins, a section was carried across the rim of the eastern, starting from the Fontanelle Creek, eighty miles north of the Union Pacific Railroad, and continuing toward the upper waters of Ham's Fork of the Green River to the westward. My notes are as follows:

The beds of the Green River epoch dip gently from the point where my last notes left them near the Rock Spring station, toward the northwest all the way to Green River. The upper strata become slaty in character, and descend to the water-level at the river, where they form a high bluff. In these slates occur the fish-beds discovered by Dr. Hayden, as well as the insect-beds noticed by Messrs. Denton and Richardson. They are worn into towers and other picturesque forms at Green River City. (See Hayden's Annual Report, 1870.) Passing north from the railroad, up the valley of Green River, the slates display a gentle dip to the north, and eighteen miles beyond have disappeared from view. On both sides of the river, huge mesas of the Bridger formation come into view; those on the east extending to the Big Sandy River, and those on the West to Ham's Fork. At Slate Creek, farther to the north twenty miles, a yellowish-brown sandstone rises into view, and continues to increase in importance toward the north. At the mouth of Fontanelle Creek, it rises on the east side of the river to a height of perhaps two hundred and fifty feet, but sinks toward the north and east from near the mouth of Labarge Creek, fifteen miles up the river. North of Labarge, a similar bed of sandstone rises again, and is immediately overlaid by white shales resembling those of the Green River epoch, which have here a great thickness. Opposite the mouth of the Labarge, their lower strata are bright-red, but on the west side of the river the sandstone only is visible. All the beds rise to the north, the red beds forming the summits of the cliffs in that direction.

In passing up Fontanelle Creek to the westward, the heavy beds of buff sandstone gradually descend, and the white shales come into view. I examined the former for lignite and coal, but found none. There are several thin beds of a tough carbonaceous material in the white shales, (which I take to be of the Green River epoch.) In the lower strata, in this locality as well as on the east side of Green River, above the mouth of Labarge Creek, are numerous remains of fishes similar to those of Green River City, with insects and their larvæ, shells like *Pupa*

* See Hayden's Annual Report, 1870; Marsh, American Journal of Science and Arts, March, 1871.

and *Cyrena*, and millions of *Cypris*. The larvæ are dipterous, some nearly an inch long, and others minute, and in prodigious numbers. With them are found stems of plants, but no leaves. These beds rise with a very gently dip, and twenty miles from the mouth of the creek terminate against steeply-inclined strata of earlier age. At this point the lower beds exhibit the bright-red colors that are so often seen in the lower parts of the formation at other points. The uplifted beds form a ridge of high hills having a north by east and south by west trend, through which the Fontanelle cuts its way in a deep cañon. This range is monoclinal, the strata dipping 45° east, and their outcrop on the summit and eastern face. The first bed which forms the surface of the incline is rather thin, and is composed of a reddish quartzite without fossils, no doubt of Cretaceous age. Below it is a stratum of highly fossiliferous bluish limestone of Jurassic age, containing *Pentacrinus asteriscus*, M. and H.; *Trigonia*, &c. Below this a reddish sandstone presented a similar thickness, which may represent the Trias, which rests on a bluish-shale formation. We have now reached the base of the western side of the hills; from their summit we have had a beautiful and interesting view of geological structure. The valley, of three or four miles in width, is bounded on the west side by a range of low mountains, whose summits are well-timbered. The valley is excavated at an acute angle to the strike of the strata, so that as far as the eye can reach to north and south successive hog-backs issue *en échelon* from the western side, and run diagonally, striking the eastern side many miles to the southward. At the cañon of the Fontanelle, six of these hog-backs occupy the valley, and the number varies as we proceed down the valley. The structure changes from the same cause as we explore in either direction. The dip of all these hog-back strata is to the west and slightly north, less steep at the eastern side, but reaching 45° and a still higher angle at the middle and west side of the valley. There appears to be an anticlinal near the base of the eastern range, which has been deeply excavated; from its western slope (in the valley) the upper beds, even in the eastern range, have been carried away, leaving only probable Triassic and Carboniferous strata exposed. In one of these latter I found a well-marked horizon of carbonaceous shales extending as far as I explored them. Toward the western side of the valley, the descending strata are sandstones, but whether identical with that of the eastern hills of Cretaceous age I could not ascertain. Lower down the valley (to the south) similar beds form a high vertical wall of very light color, the scenery resembling that of the Garden of the Gods in Colorado. I suspect that the existence of more than one fold can be demonstrated in these hog-backs and mountains.

The result which bears on the history of the Bear River group is, that on this side of the Green River basin the Bitter Creek epoch is either wanting or represented by a thin layer of red quartzite, (or perhaps Cretaceous No. 1,) and that no coal of Cretaceous age exists along its western rim. After following the valley to Ham's Fork River, and proceeding a short distance along it toward the southeast, I crossed a thin bed of coal in the upturned edges of the same beds crossed in the valley above. The discovery of the extension of the fish and insect beds sixty miles north of the principal localities is a point of interest in Tertiary geology.

The Ham's Fork Mountains form the divide between the waters of Green and Bear Rivers respectively, and are passed by the Union Pacific Railroad at and west of Aspen station, as is described by Dr. Hayden, (Annual Report for 1870, p. 149.) He here points out that the distinctness of the two basins was marked during the Tertiary period, and hence names the deposits of the western area the Wahsatch group, regarding it at the same time as synchronous with those of the Green River epoch. The writer has attained the same opinion on paleontological grounds, and has hence employed the same name for both areas, namely, the Green River epoch.*

As already stated,† the upper or red-banded Tertiary beds of this locality yielded the following species:

Perissodactyle bones, two species.
Orotherium vasacciense.
Crocodilus, sp.
Alligator heterodon.
Trionyx scutumantiquum.
Emys testudineus.
    gravis.
Clastes (?) *glaber.*
Unio, two species.

The lower sandstone beds yielded the following mammals:

Bathmodon radians.
    semicinctus.
    latipes.
Orotherium index.‡
Phenacodus primævus.

West of the contact of Bear River with the Tertiary bluffs, the strata consist of sandstone and conglomerates, and dip at about 30° to the northeast. Five hundred feet vertically below the *Bathmodon* bed, a stratum of impure limestone crops out, forming the slope and apex of a portion of the bluff. In this I found the following vertebrates:

Reptiles: *Trionyx scutumantiquum.* *Emys ? euthnetus.*
Fishes: *Rhineastes calvus.* *Clastes glaber.*

In comparing this list with that given for the lower beds of the Green River epoch, where they overlie the Bitter Creek coal, such resemblance may be observed as is sufficient to indentify the two series.

This is the nearest to a determination of the age of the Evanston coal-bed, which Hayden regards as the most important west of the Missouri River, that I have been able to reach. From the limestone just described to the coal-bed, two miles to the west, the strata are very similar in character, and apparently conformable, so that they appear to belong to the same series. Dr. Hayden confesses his inability to correlate them with those of Bear River City and Weber River, but discovered remains of plants which were identified with some of those known to occur in the Fort Union beds, on the Laramie Plains, and the Upper Missouri. If this be the case to a sufficient extent, the Evanston coal must be referred to that division of the Cretaceous period. This conclusion is, however, only provisional, and Dr. Bannister's remarks* are much to the point. He says, "In the upper beds northeast of Evanston," (the ones I describe above,) "there seems to have been a considerable disturbance besides the mere tilting of the beds, and from the altered direction of the strike § we were led to suspect considerable lateral dis-

* Proceedings Acad. of Nat. Sciences, 1872, p. 279.
† Proceedings American Philosophical Society, 1872, p. 473.
‡ Cope, Paleontological Bulletin, No. 17, 1873.
§ Hayden's Annual Report, 1872, p. 541.

placement with faulting, which might very possibly cause the appearance of the same beds both here and at the coal-mines, although at first sight these would appear much higher in geological position. * * * I do not know the grounds of Professor Cope's reference of the coal at this point to the Cretaceous, while he admits the Tertiary age at least of some of the overlying sandstones; but as we found no break nor line of demarkation in the whole 2,000 feet or more which we examined, and found our fossils in coal-bearing beds immediately above and conformable to the main coal, the facts, so far as they are known to me, do not seem sufficient for such identification."* This point offers, therefore, a more complete continuity in stratification and mineral character from the Cretaceous to Tertiary deposits than any other which I have had the opportunity of examining.

CONCLUSION.†

Having traced the transition-series of the coal-bearing formations of the Rocky Mountain region from the lowest marine to the highest fresh-water epochs, it remains to indicate conclusions. I have alluded but cursorily to the opinions of Mr. Lesquereux and Dr. Newberry as based upon the study of the extinct flora. They have, as is well known, pronounced this whole series of formations as of Tertiary age, and some of the beds to be as high as Miocene. The material on which this determination is based is abundant, and the latter must be accepted as demonstrated beyond all doubt. I regard the evidence derived from the mollusks in the lower beds and the vertebrates in the higher as equally conclusive that the beds are of Cretaceous age. There is, then, no alternative but to accept the result *that a Tertiary flora was contemporaneous with a Cretaceous fauna*,‡ *establishing an uninterrupted succession of life* across what is generally regarded as one of the greatest breaks in geologic time. The appearance of mammalia and sudden disappearance of the large Mesozoic types of reptiles may be regarded as *evidence of migration, and not of creation.* It is to be remembered that the smaller types of lizards and tortoises continue, like the crocodiles, from Mesozoic to Tertiary time without extraordinary modification of structure. It is the *Dinosauria* which disappeared from the land, driven out or killed by the more active and intelligent mammal. Herbivorous reptiles like *Agathaumas* and *Cionodon* would have little chance of successful competition with beasts like the well-armed *Bathmodon* and *Metalophodon.* There is good reason for believing that this incursion of mammalia came from the south.

It then appears that the transition-series of Hayden is such not only in name but in fact, and that paleontology confirms, in a highly satisfactory manner, his conclusion, "already shown many times, that there is no real physical break in the deposition of the sediments between the well-marked Cretaceous and Tertiary groups." §

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* Hayden's Annual Report, 1872, p. 541.

† See Bulletin U. S. Geol. Survey Terrs., No. 2, p. 16.

‡ The circumstance of the discovery of a mesozoic dinosaur, *Agathaumas sylvestris*, with the cavities of and between his bones stuffed full of leaves of Eocene plants, (Lesquereux,) would prove this proposition to be true, had no other fossils of either kind ever been discovered elsewhere.

§ Annual report, 1870, p. 166. For instance, Geol. Surv. Colorado, 1869, p. 197, Dr. Hayden observes, "There is no proof, so far as I have observed in all the Western country, of true non-conformity between the Cretaceous and Lower Tertiary beds, and no evidence of any change in sediments or any catastrophe sufficient to account for the sudden and apparently complete destruction of organic life at the close of the Cretaceous period."

Since the above was written, a paper* by Prof. J. S. Newberry has appeared, in which he gives full expression of his views as to the ages of the different extinct floras of the West. He points out clearly that the flora of the Fort Union beds is part of that which is extensively distributed over the northern hemispheré, and which is believed to characterize the Miocene period in Europe. He states that characteristic structural parallelism between American and European plants does not obtain in the preceding periods of the Eocene and Cretaceous, and that the flora found in the lower part of our Cretaceous formations, as determined by animal remains, is "somewhat more closely allied to the Tertiary flora than are the plants found in the Cretaceous of Europe." He does not make any botanical determination of the age of the fossil plants of the Bitter Creek series, nor of the lignite beds of Colorado. He, however, objects to regarding any of the floras found below the Fort Union formation as Tertiary in the following language, (p. 402:) "The lignites and plant-beds of New Mexico, which I have called Cretaceous, but which are referred by Mr. Lesquereux to the Tertiary, are, for the most part, derived from the lower portions of our Cretaceous series, and are overlaid by many hundred feet of strata unquestionably Cretaceous, in which all the typical forms of Cretaceous *animal life* are abundantly represented. Whether the great lignite deposits of Colorado should be considered Tertiary or Cretaceous, it is perhaps not yet possible to decide; but in the absence of any distinctive or unmistakable Eocene plants, if the strata which contain them shall be found to include vertebrates or mollusks which have a decidedly Mesozoic character, we shall be compelled to include them in the Cretaceous system. Mr. Lesquereux has met the statements of Professors Meek, Cope, and Marsh by pointing to his two hundred and fifty species of fossil plants, claiming that they far outweigh the testimony of the animal remains. In fact, however, these fossil plants have very little bearing on the question. They are probably all distinct from European Cretaceous and Eocene species, and the genera to which they are supposed to belong afford only negative evidence of the strata that contain them."

Thus it is evident that Professor Newberry appeals to the evidence furnished by the animal remains as basis of determination of the epochal type of the contemporary vegetable life. In further illustration of his view he says, (p. 404:) "Whatever plants are found with *Zeuglodon cetoides*, *Cardita planicosta*, *Orbitoides mantellii*, &c., we must accept as Eocene, even should they have no intrinsic Eocene characteristic. So in regard to our Cretaceous flora. While it is altogether new, its varied character and *modern aspect* simply give us a new revelation in regard to the vegetation of the Cretaceous world; for, while the fauna of that world contains *Ammonites*, *Baculites*, *Inoceramus*, &c., we are forced to call it Cretaceous."

It certainly appears to me to be introducing a new element into paleontological reasoning to estimate the age of one class of fossils by reference to the structural characters of another. Every flora and fauna, and every genus in them, offers its own intrinsic evidence as to age or relation to other genera of preceding, contemporary, and succeeding time; and all that we can affirm of the relations of the life of any given deposit or age are the sums or results of the various parts of such flora and fauna. In the present case, the evidence brought forward by Dr. Newberry from his own stand-point as a distinguished student of extinct vegetation, and upon which I necessarily rely, is: (1.) That the floras of the

* American Journal of Science and Arts, 1874, p. 399.

European Eocene and Cretaceous are not represented on this continent so far as known. (2.) That the flora found below the remains of a Cretaceous fauna more nearly resembles the Tertiary flora than it does that of the European Cretaceous. (3.) That the flora of the Fort Union beds is undoubtedly Miocene.

These facts are confirmatory of my previous conclusion, "that a Tertiary flora was contemporary with a Cretaceous fauna in the transition-period of the Rocky Mountains." If a flora below the Cretaceous of New Mexico resembles a Tertiary one, how much more probable is it that the floras of the Lignites of Colorado and Wyoming are such, as they are known to be of later age than those of New Mexico, and to be at the summit of the Cretaceous series, as indicated by animal remains. And if the flora of the Fort Union beds be Miocene, that of the identical horizon in Colorado must be Miocene also; and if the vegetation below this flora be so distinct from it, what is more probable, according to the evidence adduced by Dr. Newberry, than that they are Eocene, as maintained by Mr. Lesquereux? That such should be the case is in harmoney rather than in conflict with the facts presented by the existing life of the earth, where we have the modern fauna of the northern hemisphere contemporary with a partly Eocene and partly Mesozoic fauna in the southern.

Prof. J. W. Dawson, in his late interesting annual address before the Natural History Society of Montreal, thus comments on the above conclusion.* He says that the mixture of Mesozoic animals with Tertiary plants "depends on the general law that in times of continental elevation newer productions of the land are mixed with more antique inhabitants of the sea." * * "Thus it must have happened that the marine Cretaceous animals disappeared first from the high lands and lingered longest in the valleys, while the life of the Tertiary came on first in the hills, and was more tardily introduced on the plains." Were the Mesozoic reptiles of the Fort Union and Bitter Creek beds marine or even aquatic in their character, their co-existence with a Tertiary flora would, indeed, be quite explicable on Professor Dawson's view. But they are in the most important and diagnostic species—the *Dinosauria*—terrestrial in their habits, and in several cases vegetable feeders, browsing on the very foliage in which their bones were found enwrapped.

SECTION II.—THE VERTEBRATA OF THE FORT UNION CRETACEOUS OF COLORADO.

DINOSAURIA.

AGATHAUMAS, Cope.

Proceedings of the American Philosophical Society, 1872, p. 482.

The characters of this genus are derived from the typical species *A. sylvestris*, which is represented by dorsal and lumbar vertebræ, and an entire sacrum, with the ilia—one nearly entire—ribs, and a number of bones, the character of which has not yet been positively ascertained. One of these resembles the proximal part of the pubis; others, portions of the sternum, &c.

On eight, and perhaps nine, vertebræ anterior to the sacrum, there is no indication of the capitular articular face for the rib. This facet is found, as in *Crocodilia*, at or near the base of the elongate diapophyses. The centra are slightly concave posteriorly, and still less so on the anterior face, with gently convex margins. The neural canal is very small,

* May, 1874, p. 9.

and the neural arch short and quite distinct from the centrum, having scarcely any suture. The neural arch has a subcubical form, partly truncated above by the anterior zygapophyses. In like manner, the bases of the combined neural spine and diapophyses are truncate below by the square-cut posterior zygapophyses. The diapophyses are long and directed upward; they are triangular in section.

There are eight, and perhaps nine, sacral vertebræ, which exhibit a considerable diminution in the diameter of the centra. The diapophyses and neural arches are shared by two centra; the anterior part of the latter bearing the larger portion of both. The diapophyses are united distally in pairs, each pair inclosing a large foramen; the anterior is the most massive; rest on the ilium; the posterior pair the most expanded; the superior margins of its posterior edge form an open V, with the apex forward on the neural arch of the fifth vertebra. On the last sacrals, the diapophyses rise to the neural arch again. The exits of the sacral spinal nerves are behind the middles of the centra, and continue into grooves of the sides in all but the last vertebræ. The reduced and rather elongate form of the last sacral vertebræ induces me to believe that this animal did not possess such large and short caudal vertebræ as are found in the genus *Hadrosaurus*, and that the tail was a less massive organ.

The ilium is much more elongate than the corresponding element in *Hadrosaurus*, *Cetiosaurus*, or *Megalosaurus*. Its upper edge is turned and thickened inward above the anterior margin of the acetabulum, and here the middle of the conjoined diapophyses of the second and third sacral vertebræ was applied when in place. In front of this point, the ilium is produced in a straight line, in a stout, flattened form, with obtuse end. Posterior to it, its inner face is concave, to receive the second transverse rest of the sacrum, and the superior margin is produced horizontally toward the median line like the corresponding bone in a bird. The posterior part of the bone is the widest, for it is expanded into a thin plate and produced to a considerable length. From one of the margins, (my sketch made on the ground represents it as the upper,) a cylindric rod is produced still farther backward. The base of the ischium is co-ossified with the ilium, and is separated from the iliac portion of the acetabulum. There is no facet nor suture for the pubis at the front of the acetabulum. The ribs are compressed. There are no bones certainly referable to the limbs. The form of the ilia distinguishes this genus from those known heretofore. It is also highly probable that it differs from some other genera, in which the ilium is not known, *e. g.*, *Thespesius*, in the smaller and differently formed tail.

AGATHAUMAS SYLVESTRIS, Cope, Proceed. American Philos. Soc., 1872, 482.

The last nine dorsal vertebræ have rather short centra, the most posterior the shortest. They are higher than wide; the sides are concave; the inferior face somewhat flattened. The neural arch is keeled behind from the canal to between the posterior zygapophyses, and a similar keel extends from the base of the neural spine to between the anterior zygapophyses. The neural spine is elevated, broad, and compressed; the diapophysis is convex above and concave along the two inferior faces, most so on the posterior. The articular face of the first sacral vertebra is wider than deep. The eight sacral vertebræ are flattened below in all except the first by a plane, which is separated from the sides by a longitudinal angle. The neural spines of the anterior five sacral vertebræ are mere tuberosities. A large sutural surface for attachment of a transverse process is seen in the posterior third of the eighth sacral vertebra, which descends nearly as low as the plane of the inferior surface. On the tenth sacral, there is no such process, but its neural arch and that of the ninth support transverse processes. These are more like those of the dorsals in having three strong basal supporting ribs, the anterior and posterior extending for some distance along the arch.

Whether naturally or in consequence of distortion, the plate of the ilium is at a strong angle to the vertical axis of the acetabulum; and at the posterior part of it, the margin of the plate is free on the outside as well as the inside of the femoral articulation.

Measurements.

	M.
Length of nine posterior dorsal vertebræ	.880
Length of nine sacral vertebræ, (36¾ inches)	.930
Length of right ilium, (two pieces, 0.84 + 0.22, 41 inches)	1.060
Length of eighth dorsal from sacrum	.090
Length of base of neurapophysis	.085
Depth of articular face	.153
Width of articular face	.123
Length of second from sacrum	.070
Depth of articular face	.155
Width of articular face	.137
Elevation of neural canal	.045
Width of neural canal	.028
Elevation to face of zygapophysis	.104
Elevation to base of neural spine	.150
Length of diapophysis from lower base	.200
Length from capitular articulation	.125
Antero-posterior width above	.050
Antero-posterior base of neural spine	.075
Antero-posterior width at zygapophysis	.070
Length of neural spine, (fragment)	.208
Width of centrum of first sacral	.160
Depth of centrum of first sacral, (to neurapophysis)	.140
Length of centrum of first sacral	.105
Length of centrum of seventh sacral	.100
Depth of centrum of seventh sacral, (behind)	.080
Width of centrum of seventh sacral, (behind)	.105
Expanse of second sacral transverse support, (22 inches)	.560
Length of ilium anterior to acetabulum	.470
Length of acetabulum	.200
Length of posterior to acetabulum	.390
Width of ilium at anterior extremity	.140
Width of ilium at front of acetabulum	.210
Width of ilium at posterior expansion	.250
Thickness above acetabulum	.060
Width of acetabulum	.100
Width of basis of ischium	.085
Width of shaft of a rib	.062

Other bones not yet determined will be included in the description in the final report.

This species was no doubt equal in dimensions to the largest known terrestrial saurians or mammals.

HADROSAURUS, Leidy.

[Cretaceous Reptiles of the United States, 1865, 76; Proceedings of the Academy of Natural Sciences, Philadelphia, 1856, 218.]

HADROSAURUS OCCIDENTALIS, Cope, Extinct Batrachia, &c., p. 98; *Thespesius occidentalis*, Leidy, Proceedings of the Academy, Philadelphia, 1856, 311; Transactions of the American Philosophical Society, 1860, 151.

From the lowest member of the lignite formation at Grand River, Nebraska.

Referred, by Professor Leidy, to a distinct genus under the name of *Thespesius*, on account of the slightly opisthocœlian character of the large caudal vertebra. Teeth unknown.

Fragments of a large dinosaur from Colorado were found associated with species of tortoises identical with those found in Dakota in the horizon which contains the *H. occidentalis*, (see under head of *Cionodon arctatus*,) and may possibly belong to it. I have no identical parts in the two for comparison.

Char. specif.—The largest fragment of a long bone is probably from the proximal end of the tibia; it includes the curved inner border of the side, and the inner posterior tuberosity, with five inches of the inner head side of the shaft. The superficial layer is marked with numerous closely-placed longitudinal grooves, which are replaced by a few coarser and deeper ones, which interrupt the angle with the articular surface, giving it a lobate margin. There was probably a prominent cnemial crest. Another fragment exhibits one flat plane and a concave posterior face. It comes from near the extremity of the humerus or the femur; it was found near the fragment of the tibia. The sacral vertebra is probably that of an animal not fully grown, as it was not co-ossified with those adjacent. The articular extremities are expanded, and present distinct faces for articulation for the large diapophyses. The one extremity is more expanded and less thickened; the other more thickened and less dilated; on this rests the greater part of the base of the neural arch. Just at the extremity of this base, the large sacral nervous foramen issues, which is continued in a wide groove downward between the transverse expansions. Inferior surface convex. As compared with the fourth sacral vertebra of *Agathaumas sylvestris*, Cope, which it nearly resembles in size, it is to be observed that the anterior extremity is less expanded transversely as compared with the posterior; that the bases of support for the anterior diapophyses are not produced downward so far; that the sides of the centrum are nearly vertical and not sloping obliquely toward the middle line; and that there is no inferior plane separated from the lateral by a longitudinal angle as in *A. sylvestris*. It differs in like manner from the third and second sacral vertebræ, and still more from the first of the latter saurian.

Measurements.

		M.
Length of centrum of fourth sacral vertebra		.092
Transverse diameter	in front	.103
	at middle	.072
	posteriorly	.121
Vertical diameter posteriorly		.092
Diameter of head of tibia antero-posteriorly		.250

CIONODON, Cope.

Bulletin of the United States Geological Survey of the Territories, 1874, 10.*

Remains of species of *Dinosauria* were obtained at two localities in Colorado not many miles apart—the greater number at one of them, from which also all the crocodilian and turtle remains were derived. Those from the other deposit consist of portions of limb-bones apparently of a single individual of gigantic size. The more abundant fragments are referable to three species. A fragment of limb-bone is very similar to portions from the other locality, and associated is a sacral vertebra of appropriate size and characters. All of these were therefore referred

* Where the proof-reader made it *Cinodon*.

provisionally to a single species under the name of *Agathaumas milo*, but are here described under *Hadrosaurus occidentalis*. The remaining specimens fall into two series. In the one, the bones are occupied by a heavy mineral and the surfaces covered by a white layer, which is marked by irregular ridges, as though produced by deposit along the lines of small adherent foreign bodies. In the other set, the bones are lighter, more spongy, and not covered with the white layer; some of them are stained by the sesquioxide of iron. Both present vertebræ and limb-bones, which are related appropriately as to size and structure; that is, the larger limb-bones have the same mineral character as the larger vertebræ, and the smaller as the smaller. These limb-bones represent corresponding parts in the two, and, differing widely, confirm the belief in the existence of two species indicated by the different types of vertebræ. In these fossils, then, I see evidence for the existence of two species of two genera, which I name, the larger *Polyonax mortuarius*, the smaller *Cionodon arctatus*. Both genera present a solid cancellous filling of femora, tibiæ, and other long bones, and hence differ from such genera as *Hadrosaurus*, *Hypsibema*, *Lælaps*, and others. *Cionodon* differs in dentition from all *Dinosauria* where that part of the structure is known, but it remains to compare *Polyonax* with *Troödon* and *Palæoscincus* of Leidy, which are known from the teeth only, while no portions of dentition are preserved with the specimens at my disposal.

Char. gen.—Established primarily on a portion of the right maxillary bone, with numerous teeth in place. The posterior portion exhibits a suture, probably for union with the palatine bone, while the rest of the interior margin is free. It is removed some distance from the tooth-line in consequence of the horizontal expanse of the bone, while the outer face is vertical.

The teeth are rod-like, the upper portion subcylindric in section, with the inner face flattened from apex to base, while the lower half is flattened externally by an abrupt excavation to the middle for the accommodation of the crown of the successional tooth. The inner face of the tooth, from apex to base, is shielded by a plate of enamel, which is somewhat elevated at the margins, and supports a keel in the middle, thus giving rise to two shallow longitudinal troughs. The remainder of the tooth is covered with a layer of some dense substance, possibly cementum, which overlaps the vanishing margins of the enamel. The outer inferior excavation of the shaft presents a median longitudinal groove, to accommodate the keel of the closely-appressed crown of the successional tooth. The apex of the tooth being obtusely wedge-shaped, the functional tooth is pushed downward and transversely toward the inner side of the jaw. The tooth slides downward in a closely-fitting vertical groove of the outer alveolar wall. The inner wall is oblique, its section forming, with that of the outer, a V; it is furrowed with grooves similar and opposite to those of the outer wall, but entirely disconnected from them. The base of the shank of the functional tooth, on being displaced by the successional, slides downward and inward along the groove of the inner side, each lateral movement being accompanied by a corresponding protrusion. At the most, three teeth form a transverse line, namely, one new apex external, one half-worn crown median, and the stump or basis of a shank on the inner. The new crowns are, however, protruded successively in series of three, in the longitudinal direction also. Thus, when an apex is freshly protruded, the shank in front of it is a little more prominent, and the third stands beyond the alveolar border. As each shank increases somewhat in diameter downward in the *C. arctatus*, the section increases in size with protrusion; hence, before the appearance of a new crown outside of it, there are but two new functional teeth in a cross-row. Thus, in the outer longitudinal row, only every third tooth is in functional use at one time; in the middle series, all are in use; while in the inner, every third one is simultaneously thrown out in the form of a minute stump of the shank, if not entirely ground up.

The dorsal vertebræ are opisthocœlian, the anterior more compressed than the posterior; capitular articular faces, if existing, are slightly marked. The zygapophyses are but little prominent beyond the arch. A caudal vertebra is plano-concave, with rather depressed centrum, a little longer than broad. The condyles of the femur have a short arc and chord; the head of the tibia displays a large cnemial crest, but is not emarginate behind.

The type of dentition exhibited by this genus is perhaps the most complex known among reptiles, and is well adapted for the comminution of vegetable food. While the mechanical effect is quite similar to that obtained by the structure of the molars of ruminating mammals, the mode of construction is entirely altered by the materials at hand. Thus, the peculiarly simple form and rapid replacement of the reptilian dentition is, by a system of complication by repetition of parts, made to subserve an end identical with that secured by duplication of the crown of the more specialized molar of the mammal.

Cionodon is evidently allied to *Hadrosaurus*, but displays greater dental complication. In that genus, according to Leidy, the successional crowns appear on the *front* side of the shank of the tooth, not behind, and below the base of the enamel area, so that the tooth is distinguished into crown and shaft. It also follows from this arrangement that the successional tooth does not appear until its predecessor has been worn to the root, in which case there can be only one functional tooth in a transverse direction instead of two or three.

CIONODON ARCTATUS, Cope, Bulletin, *loc. cit.*, 10.

Char. specif.—The enamel-plate of the tooth extends from apex to near the base of the shaft. Its margins are thickened and without seriation, while the surface generally is nearly smooth. The dense layer over the remainder of the tooth is much roughened by a great number of short, serrate, and somewhat irregular longitudinal ridges.

Measurements.

	M.
Width of alveolar groove	.0120
Length of a triad of teeth on alveolus	.0140
Length of an unworn tooth	.0250
Diameter of surface of attrition of a tooth of the middle row, (longitudinal)	.0063
Diameter of surface of attrition of a tooth of the middle row, (transverse)	.0072
Width of maxillary bone	.0350
Depth of maxillary at inner margin	.0140

What I suppose to be the posterior end of the maxillary bone exhibits the grooves to near its apex, as well as a considerable surface of articulation for the malar.

Two dorsal vertebræ are preserved, whose neural arches are co-ossified, with trace of suture remaining. Both articular faces exhibit a transverse fossa for ligamentous or bursary attachment. Round these, on the convex face, there are transverse rugosities, while oblique-ridged lines descend on each side from the floor of the neural canal. The centra are shorter than deep, and subquadrate in a horizontal section. The sides are concave; the anterior are compressed with lenticular vertical section, with angle below. The more posterior is less compressed, and the surface is smooth; in the anterior, it is thrown into weak longitudinal ridges near the edges of the articular extremities. There are large nutritious foramina on the sides. The neurapophyses are excavated vertically on their posterior edges. Neural arch on the anterior dorsal, a broad, vertical oval. A caudal vertebra is rather elongate and depressed; as it has no diapophysis, it is not from the anterior part of the series. There is no prominent lateral angle, but the two inferior angles connecting the chevron-facets are well marked; neurapophysis only measuring half the length of the centrum. The articular faces exhibit the same transverse fossa as is seen in the dorsals; the anterior is plane, the posterior uniformly concave.

Measurements.

	M.
Anterior dorsal, length of centrum	.074
Anterior elevation of articular face	.073
Anterior width of articular face	.070
Anterior vertical diameter of neural canal	.027
Anterior elevation of anterior zygapophyses	.122
Middle dorsal, length of centrum	.068
Middle elevation of articular face	.085
Middle width of articular face	.080
Middle caudal, length of centrum	.062
Middle elevation of articular face, (at canal)	.047
Middle width of articular face	.068
Middle width between inferior angles	.024
Middle width of neural canal	.013

The femur is only represented by the distal end, with the condyles perfectly preserved. The latter form a single trochlear surface, whose borders form arcs of circles. It is slightly hour-glass-shaped, chiefly by excavation of the posterior face, which is, however, shallow; the deep fossæ seen in *Hadrosaurus* and other genera being absent. The area of the articular cartilage is clearly marked out, and the dense surface of the shaft is marked with delicate striæ, which terminate at the edge of the former. One side of the end of the bone is nearly plane, the other is longitudinally excavated; some shallow grooves furrow the angle with the trochlear face. The section of the shaft, three inches from the end, is a wide, transverse parallelogram. This bone looks no little like the distal end of a metapodial bone, but there are various reasons why it is more probably femur or humerus. The form of the tibia especially determines it to be the former element.

The head and distal end of the tibia, with six inches of the shaft, are preserved. The former relates with the end of the femur, resembling it both in size, simplicity of contour, and details of surface. The form is crescentoid, one horn being the cnemial crest, the other posterior and replaced by a short truncation. The inner (convex) face is rendered angular by a median tuberosity, and all round this margin shallow grooves cut the solid angle at irregular distances. The articular face displays the smooth area, and the shaft the delicate striæ, seen in the femur. The distal end is unsymmetrically lenticular in section, one side being more convex; the articular face is rugose, showing a fixed ligamentous articulation for the astragalus. The convex face of the shaft is coarsely striate-grooved near the extremity; on the other side, the intervening ridges are represented by exostoses or rugosities. The flatter side becomes the more convex on the lower part of the shaft.

Measurements.

		M.
Transverse diameter of condyles of femur		.082
Transverse diameter of shaft of femur		.053
Diameter fore and aft	of middle of condyles	.054
	of side of condyles	.069
	of shaft	.038
Diameter of head of tibia	greatest	.102
	fore and aft	.096
	transverse	.060
Diameter of shaft of tibia proximally	transverse	.050
	fore and aft	.045
Diameter of distal end of tibia	transversely	.115
	fore and aft	.060

Remarks.—If the bones above described as pertaining to the hind limb are really such, they are smaller as compared with the dorsal vertebræ than in *Hadrosaurus foulkei*, and indicate an animal the size of a horse.

POLYONAX, Cope.

Char. gen.—A species considerably larger than the last, represented by vertebræ and numerous fragments of limb-bones. The most characteristic of the former are two probably from the posterior dorsal region, which are somewhat distorted by pressure. The more anterior is shorter than the other, and exhibits both articular faces slightly concave, the one more so than the other. They are higher than wide, and the border is scolloped above for the capitular articulation for the rib. There are numerous nutritious foramina, and some ligamentous pits on the articular surfaces. The inferior face is rounded. In the longer vertebra, both faces are more strongly concave, and at each end of the lower side there is an obtuse hypopophysial tuberosity. The sides of the centra of both vertebræ are concave. The neural canals are relatively small, and the neurapophyses co-ossified. A third vertebra without arches is similar in specific gravity, though without the white surface-layer of the others. It is appropriate in size and form to this species, and is peculiar in its flat form, resembling the anterior dorsals of the *Hadrosaurus*. In this respect it is related to the shorter vertebra of the two above described as the latter is to the longer. The surface of the posterior articular face is damaged; it was not concave, and is now slightly convex; the anterior is preserved, and is concave.

POLYONAX MORTUARIUS, Cope.

The articular faces are deeper than wide in the vertebræ; the sides are smooth; the lower faces narrowed and probably keeled.

Measurements.

	M.
Anterior dorsal, length of centrum	.048
Anterior dorsal, elevation to neural canal	.094
Anterior dorsal, width	.094
Median dorsal, length of centrum	.057
Median dorsal, elevation to neural canal	.117
Median dorsal, width	.083
Posterior dorsal, length of centrum	.092
Posterior dorsal, elevation	.104
Posterior dorsal, width	.083
Posterior dorsal, diameter of neural canal	.015

The measurement of the neural canal is made near the base of the neurapophyses, and is probably a little affected by pressure.

The limb-bones embrace portions of tibia, fibula, and some others not yet determined. The portion of tibia is from the base of the cnemial crest, so that one extremity is trilobate, the other transverse oval. The former outline indicates two posterior tuberosities. The bone is solid, and the superficial layer, for three millimeters or less, is so dense and glistening as to resemble cementum. Portions referred to fibulæ have a subcrescentic section, with narrowed width in one direction. Two fragments of shafts of long bones I cannot determine either as belonging to the limbs or pelvis. They belong to opposite sides; each is oval in section, and the diameter regularly contracts to one end. One side is slightly convex in both directions; the other is less convex transversely, and gently convex longitudinally. A peculiarity consists of a central cavity present in both at the fractured large end, which is bordered by a layer of dense bone like the outside.

Measurements.

	M.
Transverse diameter of tibia fragment below cnemial crest	.125
Antero-posterior diameter of tibia fragment at base of crest	.095
Width of fragment of fibula	.073
Thickness of fragment of fibula	.035
Length of fragment of unknown bone	.145
Proximal diameter of unknown bone	.088
Distal diameter of unknown bone	.065

The above measurements indicate a larger animal than the *Cionodon arctatus*, and one not very different in size from the *Lælaps aquilunguis.*

CROCODILIA.

BOTTOSAURUS, Agass.

Cope, Proceed. Amer. Philos. Soc., 1871, 48.

BOTTOSAURUS PERRUGOSUS, sp. nov.

Represented by numerous fragments, with vertebræ and portions of skull which accompanied the dinosaurian and turtle remains from Eastern Colorado, already alluded to.

A portion of the left dentary bone containing alveoli for ten teeth shows that this species is not a gavial. The dental series passes in a curve from the inner to the outer sides of the bones, one or two alveoli behind being probably bounded on the inner side by the splenial only, as in *B. macrorhynchus*, when that bone is in place. The dentary is compressed at this point; in front it is depressed. There is a slight difference in the sizes of the alveoli, but not such as is usual in Tertiary crocodiles. The external face of the bone exhibits deep pits in longitudinal lines. The angle of the mandible is depressed; the cotylus of articulation is partially concealed on the outer side by the elevation of the surangular, whose upper border is parallel with the inferior margin of the ramus for two inches to where it is broken off. The outer face of this region is marked by irregular coarse ridges more or less inosculating, separated by deep pits. The lower posterior half of the angular bone is smooth.

A posterior dorsal or lumbar vertebra has a depressed cordate articular cup. The zygapophyses are large and widely spread, and strengthened by obtuse ridges running from the base of the neural spine to the posterior margin of the anterior and the posterior outer angle of the posterior. One pit at basis of neural spine in front; two before. Ball prominent; sides of centrum concave.

Measurements.

	M.
Length of fragment of ramus	.100
Width in front	.034
Depth behind	.032
Length of eight alveoli	.069
Diameter of largest alveolus	.012
Diameter of smallest	.007
Width of base of angle of ramus	.048
Depth at surangular	.034
Length of centrum of vertebra	.045
Width of articular cup	.031
Vertical diameter of cup	.025
Vertical diameter of neural arch	.011
Expanse of anterior zygapophyses	.056

The specimen is adult, and indicates an animal about the size of the alligator of the Southern States. Its reference to the present genus is provisional only.

TESTUDINATA.

TRIONYX, Geoffr.

TRIONYX VAGANS, sp. nov.; *Trionyx? foveatus*, Leidy; Proceed. Acad. Nat. Sci. Philadelphia, 1856, 312.

Represented by a number of fragments of costal bones and perhaps of sternals also. The former are rather light or thin for their width, and are marked with a honey-comb pattern of sculpture, in which the ridges are thin and much narrower than the intervening pits. They incline to longitudinal confluence at and near the lateral sutures. Several areæ are not infrequently confluent in a transverse direction near the middle of the bone.

Measurements.

	M.
Width of costal bone	.0370
Thickness of costal bone	.0045
Four and five areæ in $0^{m}.010$.	

This species differs from the *T. foveatus*, Leidy, in the much narrower interareolar ridges, and larger areæ, and in their longitudinal confluence at the margins, characters exhibited by numerous specimens.

Lignite Cretaceous of Colorado; near the mouth of the Big Horn River, Montana; Long Lake, Nebraska; found at the last two localities by Dr. Hayden.

PLASTOMENUS, Cope.

Annual Report U. S. Geol. Survey, 1872, 617.

PLASTOMENUS (?) PUNCTULATUS, sp. nov.

Established on a costal bone found in association with the preceding species, and referred to the genus *Plastomenus* provisionally, and with a probability that it will be found not to pertain to it when fully known. That genus has so far only been found in the Eocene formation. The bone is rather thin and sufficiently curved to indicate a convex carapace of moderate thickness. The surface is marked with closely-packed shallow pits without material variation of form on the proximal half of the bone. The result is an obsolete sculpture quite similar to that seen in some species of the genus to which it is at present referred.

Measurements.

	M.
Width of costal bone	.0230
Thickness of costal bone	.0033

Number of pits in $0^{m}.010$, 6.

Lignite Cretaceous of Colorado; also several fragments from Long Lake, Nebraska, from Dr. Hayden.

PLASTOMENUS (?) INSIGNIS, sp. nov.

Represented by a portion of the right hyposternal bone of a tortoise about the size of the last species, and from the same locality. The specimen resembles in its sculpture such species as the *Plastomenus trionychoides*, and in structural character the species of *Anostira*, but it is scarcely probable that it belongs to either genus. It is flat, and has a narrow, straight, inguinal margin at right angles to the fine suture with the hyosternal. The suture with the postabdomial is partially gomphosial. Surface dense, polished, marked externally with a reticulate sculpture of narrow ridges separating larger and smaller areas wider than themselves. Marginal edge thinner.

Measurements.

	M.
Length of hyposternal fore and aft	.025
Thickness of hyposternal at front	.004

Pits in $0^{m}.010$, 6.

Lignite Cretaceous of Colorado.

ADOCUS, Cope.

Proceedings Academy of Natural Sciences, Philadelphia, 1868, 235; Proceedings American Philosophical Society, 1870, November.

ADOCUS (?) LINEOLATUS, sp. nov.

Established on a number of fragments from different exposures of the lignite beds—primarily on a vertebral and sternal bone from the same locality as the preceding specimen. As the diagnostic portions of this specimen are wanting, it is referred to this genus provisionally, and because the structure and sculpture of the parts resemble most nearly known species of it from the Cretaceous greensand of New Jersey.

The sternal bone is flat, and presents the wide and transverse sutures forming the usual right angle, and of a rather coarse character of a medium serrate keel, with pits on each side for the reception of corresponding ribs. The vertebral bone is rather thick, and is shallowly emarginate in front. The sculpture consists of delicate, obscure, parallel lines, which are more or less interrupted and occasionally joined, so as to inclose faintly-marked areolæ.

Measurements.

	M.
Width of vertebral bone in front	.0135
Greatest of vertebral bone	.0280
Thickness of vertebral bone	.0070
Thickness of sternal bone	.0080

From lignite of Colorado, and mouth of Big Horn River, Montana.

COMPSEMYS, Leidy.

COMPSEMYS VICTUS, Leidy, Proceedings Academy Natural Sciences, Philadelphia, 1856, 312.

Lignite of Long Lake, Nebraska; Cretaceous of Colorado.

APPENDIX.

Descriptions of new mollusks from Cretaceous beds of Colorado, by T. A. Conrad.

I add here some determinations, by T. A. Conrad, of mollusks of Cretaceous age obtained near Denver and in the South Park.

HELICOCERAS, d'Orb.

H. VESPERTINUS.—Sinistral, gradually tapering; ribs prominent, often placed irregularly as regards distance from each other, gradually thickening toward the back, which has two rows of tubercles; back flattened on the large part of the shell, and gradually rounding on the smaller.

Locality.—Seven miles south-southeast of Fairplay.

In the small specimen of rock containing this fossil are two specimens of the same and two of *Ptychoceras.*

ANCHURA, Conrad.

A. BELLA.—Subfusiform; spire elevated; volutions convex, with oblique, subacute, curved, longitudinal ribs, crossed by regular, fine striæ; suture deeply impressed; last volution with two distant, angular, revolving ridges, the upper one largest and extending to the end of the projecting lip; above this angle, the ribs are less prominent and distinct than on the spine, and disappear at the lower revolving angle; lip upturned toward the extremity and acute at the end; lower margin entire; beak short, narrow, acute.

MEEKIA, Gabb.

M. BULLATA.—Subglobose, inequilateral; anterior side short, compressed, acute at the end; summits very prominent; umbo inflated. This smooth little species is proportionally much shorter and the umbones more inflated than in *M. sella*, Gabb. The anterior side is shorter and more acute.

Locality.—Trout Creek, near Fairplay.

PTYCHOCERAS, d'Orb.

P. ARATUS.—Larger branch having prominent, slightly oblique, subundulated, compressed ribs, subacute on the margin; body slightly swelling on the back toward the base, where the ribs become fine and close; smaller branch ribbed obliquely in a downward direction.

Locality.—Trout Creek, near Fairplay.

There are two rows of very small tubercles on the flattened back of this species.

HAPLOSCAPHIDÆ.

The genus *Haploscapha*, described in a former volume of these reports, is not, as I thought at the time, a member of the family *Rudistæ*, but probably belongs to no recognized family. I have every reason to believe that *Inoceramus involutus*, Sowerby, is a species of this or a nearly allied genus. It has the singular character of being very thin on the disk and gradually thickening to the margin, in which it agrees with the American shells, and also in the character of the dorsal margin, which appears to be rolled over. This rolling-over, however, does not exhibit the hinge-character, which has no resemblance whatever to that of *Inoceramus*, and the ridged surface at the top of the hinge is on the outside of the valve, as represented in Sowerby's figure, Table 583, Fig. 2. The typical specimen of one valve of the genus has a broad or thick tooth near the anterior margin, and a thick, rounded ridge forming the rest of the hinge. These singular shells were developed in the Upper Chalk of England and America, and, like the *Rudistæ*, came suddenly and disappeared forever with the last deposit of chalk.

H. CAPAX.—Left valve inflated, subrotund, incurved toward the ventral margin; undulations or concentric ridges profound, distant, extending to the posterior hinge-margin, though becoming almost obsolete very near the margin; interstices regularly and strongly striated. Length and height equal, five inches. Found by Dr. Leconte near Denver. *Inoceramus*, Fig. 2, Frémont's expedition represents, I think, this species.

CHAPTER III.

THE EOCENE PERIOD.

A few species from beds of this period were obtained in Wyoming and Colorado, of which the following are new to science.

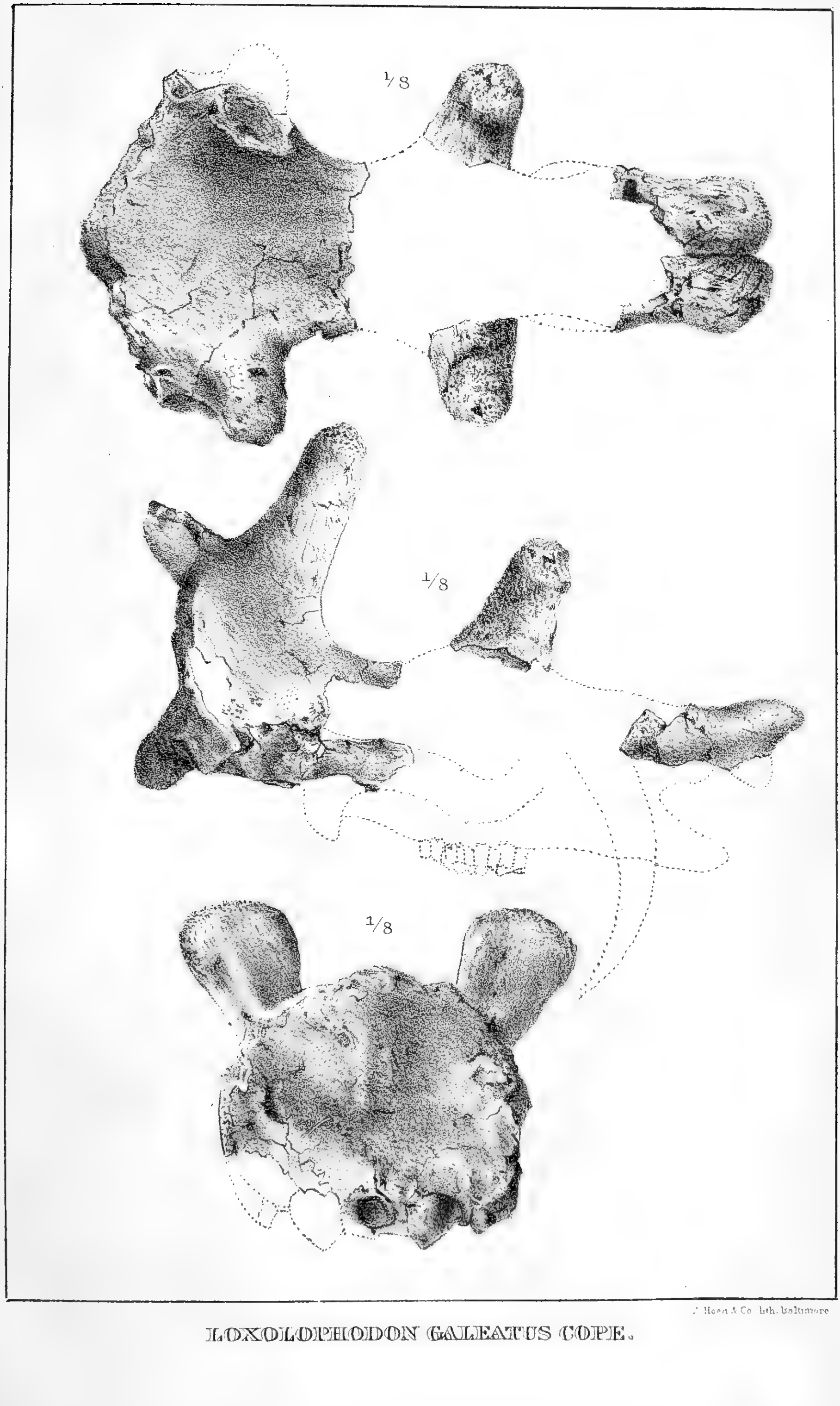
MAMMALIA.

EOBASILEUS, Cope.

EOBASILEUS GALEATUS, sp. nov.

Represented by the greater portion of a cranium of an individual of the size of the *Loxolophodon cornutus*. It possesses a greatly-elevated occipital crest, whose superior border presents a median angle upward. A short distance in front of it, and connected by a very stout, lateral ridge, there arises, on each side, a large, erect horn-core. The base is very massive, subquadrate in section, and flattened in front. Posteriorly, it presents a very shallow groove, which is bounded on the outside by a low ridge. The shaft expands gradually, and is proportionally flattened from behind forward. The posterior face is flat; the anterior gently convex. The extremity is transverse-convex, and pitted for cartilaginous or corneous attachment. These horns stand on the parietal bones. The frontals extend to their bases, and send a laminar expansion backward to the margins of the lateral and posterior crests, covering the parietal in the fundus of the basin, which the former inclose.*

* Marsh originally stated that these horn-cores in *Uintatherium mirabile* stand on the frontal; but later, that it was doubtful whether the frontal supported horns.



J. Hoen & Co. lith. Baltimore

LOXOLOPHODON GALEATUS COPE.

The median horns are very stout, and are connected with the posterior by an acute supratemporal ridge. Their inner face is composed to near the apex of the nasal bones. Where they terminate, the apex contracts, and is composed of a cylindric production from the maxillary. The section of these cores at the middle is subquadrangular, and longitudinally oval at the base.

The extremity of the nasal bones is small and contracted, and is extensively overhung by the cornice-like, flat cores above them. Thus the end of the snout has a bilobate outline when viewed from above.

The occipital face is concave in vertical section and presents a V-shaped depression, with the angle downward, and a low ridge on the middle line to the transverse superior border.

Measurements.

	M.
Width of the foramen magnum and occipital condyles	0.2100
Elevation of occiput, (8 inches)	.2500
Width of basin between lateral crests	.3250
Height of posterior horn-core, (7 inches)	.2300
Width, base of posterior horn-core antero-posteriorly	.1300
Width, base of posterior horn-core transversely	.0900
Width at summit	.1230
Height of median horn-core	.1750
Diameter of base antero-posteriorly	.1060
Diameter of base transversely	.0800
Diameter of summit	.0650
Projection of nasal cornices beyond apex	.0630
Length of posterior molar, crown	.0450
Width of posterior molar, crown	.0550

This species is equal in size to the largest known from the Bridger formation. It differs from *E.* (*Loxolophodon*) *cornutus* in the posteriorly-truncate base of the posterior horn-cores, the quadrate instead of triangular section, and the stoutness of the median cores, and extent of their inner face covered by the nasal bones. It more nearly resembles the *E. pressicornis*, Cope, and may possibly prove to represent an old male of that animal. There is, however, a considerable disparity in their sizes; the horns differ in the greater stoutness, having twice the diameter, with little greater height. They differ also in form, in the abrupt contraction just below the apex. The cornice-like cores of the nasal bones represent the tubercles of the *E. pressicornis*. The posterior horns differ in many ways from those of the *E. furcatus*, and are alone sufficient to indicate a different species.

From the bad lands of South Bitter Creek.

ACHÆNODON, Cope.

Paleontological Bulletin, No. 17, p. 2.

ACHÆNODON INSOLENS, gen. et sp. nov.

Char. gen.—Dentition of mandible, In., 3; C., 1; P. m., 3 (?4); M., 3; forming an uninterrupted series throughout. Molars consisting of two pairs of obtuse tubercles, those of each pair fused transversely by a lower yoke; last molar with a large posterior fifth tubercle; last premolar enlarged, and with a posterior heel; penultimate with a simple conic crown and two roots. It is uncertain whether one or two teeth intervene between this one and the canine. The alveoli are round, and look as through designed for two single-rooted premolars.

This genus presents many points of resemblance to *Elotherium*, but the continuous dental series is characteristic of many genera of the Eocene. In the only known species, there are no osseous tuberosities on the rami. The symphyseal suture is persistent.

Char. specif.—Last premolar with longer basis than first molar; its posterior heel tubercularly plicate. The crown of the penultimate premolar is a slightly-compressed cone with elongate base, but little shorter than that of the first molar. Molars with smooth enamel; an anterior cingulum on the second and third; a small posterior median tubercle on the second molar; and a short cingulum, from the base of the posterior cone forward, on the third. Canines very large, suberect; enamel smooth. Ramus of mandible very stout.

Measurements.

	M.
Length of molar series	0.180
Diameter of canine tooth	.033
Length of premolars	.093
Length of premolars No. 3	.035
Length of molar No. 1	.024
Length of molar No. 2	.027
Width of molar No. 2	.022
Length of molar No. 3	.041
Width of molar No. 3	.024
Depth of ramus at molar No. 2	.073

This species betrays more of suilline character than any yet discovered in the Bridger series; but that it has any such affinity has yet to be shown. It was about as large as a fully-grown cow.

PHENACODUS, Cope.

Paleontological Bulletin, No. 17, p. 3.

PHENACODUS PRIMÆVUS, Cope.

Char. gen., as expressed by a posterior superior molar tooth. Crown transverse, a little narrower and more strongly convex at the inner than the outer extremity. It supports five rather low and obtuse tubercles, two exterior and three on the inner side. Outer tubercles well inside the outer margin of the crown; the one subtriangular in section; the other more nearly conical; the two connected by a low ridge, which incloses a concavity with the outer margin of the crown. Three inner tubercles, arranged on the segment of a circle, subequal; the lateral of one side connected with the exterior tubercle of the opposite side by a low ridge, which incloses a basin with the inner tubercles.

Char. specif.—Median of the three inner tubercles stouter than the others. No noticeable basal cingulum. Two compressed roots, with axes at right angles to each other, and very large pulp-cavities and thin walls.

Measurements.

	M.
Width of crown	0.0140
Length of crown	.0093
Elevation of outer cones above shoulder	.0050
Width between apices of outer cones	.0060
Width between apices of median cones	.0050

This tooth more nearly resembles the last tubercular molar of a canine carnivore than any other with which I can compare it, though it presents some differences. It would represent an animal rather larger than a wolf.

OROTHERIUM, Marsh.

Amer. Journ. Sci. Arts, 1872, p. 217.

OROTHERIUM INDEX, sp. nov.

Represented by both mandibular ramis, with many of the molars in good preservation. These number P. m., 3; M., 3. The last premolar is somewhat like the first molar, but has but one posterior tubercle, and adds a cingular projection in front of the anterior pair. The first premolar has two roots; the second is compressed and with a broad heel behind. In the molars, the anterior tubercles are connected by a cross-ridge; the posterior are a little more distinct from each other. The inner anterior tubercle is obtuse, but not bifid, and its base is connected with the apex of the posterior outer by a diagonal ridge. There is a small median posterior tubercle on the M. 2, and a large heel on the last molar. It supports a conic tubercle, which is connected by sharp ridges with the tubercles preceding it. There is a cingulum on the outer face of the true molars, which does not extend on the base of the tubercle of the posterior pair.

Measurements.

	M.
Length of molar series	0.0350
Length of first premolar	.0032
Length of third premolar	.0055
Width of third premolar	.0040
Length of second molar	.0065
Width of second molar	.0045
Length of last molar	.0098
Depth of ramus at first premolar	.0021
Depth of ramus at second molar	.0023

PISCES.

RHINEASTES, Cope.

Hayden's Annual Report, 1872, p. 638.

RHINEASTES PECTINATUS, Cope, Bullet. U. S. Geol. Surv., No. 2, 1874, p. 49.

This catfish is represented by a single specimen, which includes only the inferior view of the head and body anterior to the ventral fins. These exhibit characters similar in many respects to those of *Amiurus*, Raf., but the interoperculum, the only lateral cranial bone visible, displays the dermo-ossified or sculptured surface of the Eocene genus, to which I now refer it. Other characters are those of the same genus. Thus, the teeth are brush-like, and there is an inferior limb of the post-temporal bone, reaching the basi-occipital. The modified vertebral mass is deeply grooved below, and gives off the enlarged diapophysis that extends outward and forward to the upper extremity of the clavicle. The patches of teeth on the premaxillary are separated by a slight notch at the middle of the front margin The teeth are minute. The four basihyals and the elongate anterior axial hyal are distinct; also, the ceratohyal with its interlocking median suture. The number of branchiostegal radii is not determinable; three large ones are visible. The mutual sutures of the clavicles and coracoids are interlocking, and their inferior surface displays grooves extending from the notches. The pectoral spine is rather small, and bears a row of recurved hooks on its posterior face; there are none on the anterior face.

The head is broad, short, and rounded in front, which, with the uncinate character of the serration of the pectoral spine, reminds one of the existing genus *Noturus*. As compared with the five species of *Rhineastes* described from the Bridger Eocene, the present species is distinguished by the small size and uncini of the pectoral spine.

Measurements.

	M.
Length of head to clavicle, (below)	0.018
Width of head, (below)	.036
Width of scapular arch, (below)	.011
Expanse modified diapophyses	.020
Length of modified vertebræ	.0115
Length of pectoral spine	.021

From the Tertiary shale of the South Park, Colorado.

AMYZON, Cope.

Hayden's Annual Report, 1872, p. 642.

AMYZON COMMUNE, Cope, Bullet. U. S. Geol. Survey, No. 2, 1874, p. 50.

In describing this species, the following additions to our knowledge of the generic characters may be made. There is an open fronto-parietal fontanelle; the premaxillary forms the entire superior arch of the mouth; the pharyngeal bones are expanded behind; there are 12–13 rays of the ventral fin; there is a lateral line of pores, which divides the scales it pierces to the margin.

The greatest depth of the body is just anterior to the dorsal fin, and enters the length 2.66 times to the base of the caudal fin, or a little more than three times, including the caudal fin. The length of the head enters the former distance a little over 3.25 times. The general form is thus stout and the head short; the front is gently convex and the mouth terminal. There are fifteen or sixteen rows of scales between the bases of the dorsal and ventral fins. They are marked by close concentric lines, which are interrupted by the radii, of which eight to fifteen cross them on the exposed surface, forming an elegant pattern. At the center of the scale, the interrupted lines inclose an areolation. The extended pectoral fin reaches the ventral, or nearly so; the latter originates beneath the anterior rays of the dorsal, or in some specimens a litttle behind that point. They do not reach the anal when appressed. The anal is rather short and has long anterior radii. The dorsal is elevated in front; the first ray is a little nearer the basis of the caudal fin than the end of the muzzle. Its median and posterior rays are much shortened; the latter are continued to near the base of the anal fin. Radii, D., 33; P., 14; V., 13; A., 12. The caudal is strongly emarginate, and displays equal lobes.

Measurements.

	M.
Length of a large specimen, (10.25 inches)	0.250
Length of a medium specimen	.182
Depth at occiput	.043
Depth at dorsal fin	.057
Depth at caudal peduncle	.023
Length of head, axial	.044
Length to D. 1, axial	.075
Length to end of dorsal, axial	.131
Length to basis of caudal fin	.146
Length of basis of anal fin	.023

There are thirty-eight or thirty-nine vertebræ, of which nine are anterior to the first interneural spine, and fourteen between that point and the first caudal vertebra.

A very large number of specimens was obtained by Dr. Hayden and myself from the Tertiary shales of the Middle and South Parks, Colorado. They display but insignificant variations in all respects, and furnish a good basis of determination. They all differ from the *A. mentale*, Cope, (Proceed. Amer. Philos. Soc., 1872, p. 481,) in the larger numbers of vertebræ and dorsal and anal fin radii, and greater prolongation of the dorsal fin. It is, however, nearly allied to the species of the Osino shales. The only fish found associated with this one is the small nematognath just described. The predominance of these types and exclusion of the brackish-water genera *Asineops*, *Erismatopterus*, and *Clupea*, so abundant in the shales of the Green River epoch, indicate a more lacustrine, and hence, perhaps, though not necessarily, later deposit.

CLUPEA, Linn.

CLUPEA THETA, Cope, Bullet. U. S. Geol. Surv., No. 2, 1874, p. 51.

Represented by a specimen from the Green River shales, near the mouth of Labarge Creek, in the upper valley of Green River. It is a larger species than the *C. pusilla*, Leidy, which is also found at the same locality, and has a much longer anal fin. Its radii number twenty-six, possibly a few more, as the end appears to have been injured. The dorsal fin is short; the last ray in advance of the line of the first of the anal. The body is deep. Number of vertebræ from the first interneural spine to the last interhæmal, twenty-nine. Depth at first dorsal ray, 0.0485; depth at last anal ray, 0.0170; length of twenty-nine vertebræ, 0.0780.

CHAPTER IV.

THE MIOCENE PERIOD.

The fauna of the White River epoch is well known to be entirely distinct from that which preceded it, which is preserved in the beds of the Bridger formation; no species or genus of mammal is common to the two, and but a proportion of the families. This difference is similar to that which distinguishes the Lower Eocene from the Miocene fauna of Europe. The parallelism of the Wyoming fauna with that of the Eocene of France and Switzerland is very full, although not without exceptions. Both are characterized by the absence of equine perissodactyles and ruminant artiodactyles, of *Elephantidæ*, *Rhinoceridæ*, and extreme poverty in feline and musteline, or the higher carnivora. Both are characterized by the presence of lemurs and generalized quadrumana, and by the great predominance of *Perissodactyla* allied to the tapirs. Parallel genera of the respective groups may be thus exhibited:

	WYOMING.	FRANCE.
Carnivora,	*Mesonyx.*	*Hyænodon.*
Quadrumana,	*Anaptomorphus.*	*Adapis.*
Perissodactyla,	*Palæosyops.*	*Palæotherium.*
	Hyrachyus.	*Lophiodon.*
	Hyopsodus.	*Hyracotherium.*
Artiodactyla,	*Achænodon.*	*Anthracotherium.*

The important differences are the presence of *Artiodactyla* with selenodont molar teeth in the French Eocene; I allude to the *Anoplotheriidæ* and *Hyopotamidæ*, which are entirely wanting in the Wyoming beds. On the part of the latter, the presence of the *Eobasiliidæ*, *Bathmodontidæ*, and *Anchippodontidæ* constitute a marked peculiarity. On the whole, the evidence is in favor of ascribing the priority of age to the Wyoming Eocene.

The appearance of selenodont artiodactyles, including great numbers of *Tragulidæ*, with horses and rhinoceroses in the White River beds, clearly mark the advent of the Miocene, while the presence of *Hyopotamus* and *Elotherium* indicate a nearer relation to the Lower than to the Upper Miocene of Europe. The family of *Oreodontidæ* is the peculiar feature which distinguishes the American from the European beds, while the latter contain numerous viverrine carnivora not known from America. The Loup Fork beds, from the greater proportion of existing genera which they contain, display a resemblance to the European Pliocene; but they differ strikingly in the greater number of horses and camels which they contain. The smaller percentage of existing genera in the Loup Fork beds, with the persistence of an oreodont, (*Merychyus*,) indicates that these also should be placed anterior to the Pliocene of France.

The species enumerated in the following pages are distributed in their orders as follows. I add a list of the species enumerated by Dr. Leidy, as occurring in the White River beds of Dakota and Nebraska, with the number common to them and the Colorado beds. I add also a column indicating the number not yet identified out of Colorado.

	Species above enumerated.	Species of Dakota, &c.	Species common to the two.	Species only known from Colorado.
Insectivora	11	2	0	11
Rodentia	10	5	4	6
Perissodactyla	16	6	4	11
Artiodactyla	10	20	4	6
Carnivora	10	8	3	7
Quadrumana	1	(?) 1	0	1
Testudinata	5	1	1	4
Lacertilia	8	0	0	8
Ophidia	5	0	0	5
Total	75	43	16	59

The difference between the Dakota and Colorado faunas is more apparent than real. The presence of numerous small reptiles and insectivorous and rodent mammals in the latter is chiefly due to local advantages for preservation and subsequent discovery. This is indicated partly by the fact that the more abundant rodents of Colorado are those which have been already discovered in Dakota. Other differences are not so readily accounted for. Thus, the poverty in species of *Oreodontidæ* in the midst of most abundant individual remains is a peculiarity of the Colorado formation, while the *Tragulidæ* of the latter are more abundant in both individuals and species than in the Dakota fauna. While there is but one species in the latter, there are five species of four genera in Colorado. The *Poëbrotherium*, rather rare in Dakota, is quite abundant in Colorado. On the other hand, no trace of the *Titanotherium* of the former has yet been announced from the latter locality, and it is probable, indeed, as remarked by Professor Marsh, that that genus is characteristic of another horizon of the Tertiary from the one under consideration. If, as I believe, the Colorado Miocene is the true White River epoch, then the *Titanotherium* is derived from another.* Comparatively few traces of the *Symborodons* have yet been brought from Dakota, but this may be due to the fragility of these fossils and local causes. The differences in the carnivora are not strikingly great; the only genus not in some degree representative in the two faunas being the *Bunœlurus* of the present paper.

The most important result obtained by the expedition of 1873 was the discovery of an abundant fauna of *Lacertilia* and *Ophidia* and of the smaller mammalia of the insectivorous and rodent orders. A genus of supposed *Quadrumana* was discovered, and an elucidation of the structure of the genus of gigantic, horned perissodactyles, which I called *Symborodon*, was rendered possible by the large amount of material obtained. While the pre-eminently horned type of the present fauna is the order of *Ruminantia*, and it has been found that those of the Eocene period were an aberrant type of proboscidians, those of the Miocene are now shown to be perissodactyles.

The predecessors or ancestors of the hog, *Babirussa*, and similar existing animals, are being gradually brought to light by modern paleontological studies. One of those nearest the domesticated form has been found in the Miocene of France, and is referred to the genus *Palæochœrus*. It is also related to the peccaries, which appear to have existed during the same early period in North America in considerable abundance. Their existence in South America at the present time is one of many indications that that region has not advanced in respect to its fauna as rapidly as our own and the old continents. Another Miocene genus of hogs is the *Elotherium*, which has left remains in France and in North America. The common species of the Nebraska beds is the *E. mortonii* of Leidy, which was as large as a pig. Its front teeth are much developed at the expense of the hinder ones; and it had bony tuberosities on the under jaw in the positions now supporting wattles in the hog. I discovered during the past season much the largest species of *Elotherium* yet known. The skull was longer than that of the Indian rhinoceros, and the tuberosities of the lower jaw were greatly developed. The front pair formed divergent branches on the lower front of the chin, so that it appeared to bear a horn on each side, which the animal, doubtless, found useful in rooting in the earth. The species was semi-aquatic in its habits, like the *Hippopotamus* and *Dinotherium;* but while these are furnished with extraordinary developments of the lower incisor-teeth for tearing up their food, the *Elotherium ramosum* is the only animal known which possessed horns in the same position and for the same purpose.

A still older type of hogs—which may claim to be the predecessor in structure as well as in time of all known genera—is the *Achænodon*, Cope, from the Eocene of Wyoming, described a few pages back. The *A. insolens* was a powerful beast, larger than a boar, with a compara-

* I formerly supposed, following Dr. Leidy, that *Titanotherium* is characteristic of the horizon of *Oreodon*, &c., and therefore quoted Professor Marsh as assigning a different age to the Colorado beds. On re-examination of his remarks, (Amer. Journ. Sci. Arts, 1870, p. 292,) while they bear this interpretation, I believe that he did not intend to make any direct assertion to this effect.

tively short head, and with the uninterrupted series of teeth which belongs to all the oldest forms of the mammals and to the higher quadrumana.

The early relations of the camels is a question, heretofore very obscure, which has been greatly elucidated by the researches in Colorado during the present season. These ruminants differ from all of their order of quadrupeds in having one incisor-tooth in the upper jaw on each side, and in a remarkable structure of the neck-vertebræ. In the latter, the artery that conveys blood to the brain in part occupies the vertebral canal with the nervous cord. In other ruminants, as in most mammalia, it is carried by the lateral process of the vertebræ in a tube at their bases.

Camels and llamas have a limited number of premolar teeth of the permanent series, and a larger number in the milk-series; the excess not being replaced when shed. They have, at a very early stage of development, indications of a full series of upper incisors, which are early absorbed. The extinct camels (*Procamelus*) of the latest of our Western Tertiary formations, supposed to be the Pliocene, have been shown by Leidy to retain, in their permanent dentition, the full number present in the milk-series, thus resembling the younger stage of the modern camels and llamas rather than the adult. I have also found that these early camels possessed a full development of the character seen in the fœtus of various ruminants. In this respect, the *Procamelus* resembled their still earlier predecessors. It is also evident that the change from *Procamelus* to *Camelus* may be explained by a process of retardation of the growth of the teeth.

The ruminants called *Tragulidæ* are now confined to the warm regions of Asia and Africa, but they were formerly widely distributed over the earth, especially during the Miocene period. They embraced then, as they do now, some of the smallest and most elegant of the cloven-footed *Ungulata*. In France, three genera have been discovered, which embrace numerous species. The most numerously-represented genus is the *Amphitragulus*. In North America, four genera have been found in corresponding formations, representing five species. Two of them belong to *Hypertragulus;* while *Hypisodus* includes the smallest of the known species, the *H. minimus*, Cope, which was not heavier than a cat-squirrel. In these musks, the first premolar teeth have a peculiar position, being more or less approximated to the incisor-teeth. The *Leptomeryx evansii*, Leidy, is a species of medium size, which has the permanent premolar teeth of the same form as the milk-premolars; while in *Hypertragulus*, the permanent premolars take on quite a different form, thus making a step in advance not attained by the former. It has been ascertained by me that *Poëbrotherium* has the peculiar neck-vertebræ that belong to the camels, and also similar resemblances in the forefoot, differing in both respects from *Tragulidæ*. Like the camels, it has only two toes, while *Tragulidæ* have four; but then it is like the latter in having these toes entirely separate, as in a hog, and not united into the common bone of ruminants. The conclusion is that *Poëbrotherium* is the prototype of the camels, and that it is near the common ancestor from which *Tragulidæ* seem to have branched off. This ancestor undoubtedly was nearly related to certain fossil ungulates found in the Eocene of France.

INSECTIVORA.

Numerous species of this order were discovered during the exploration of the Colorado Miocene. Two species only had been previously known in the formation, namely, the *Leptictis haydenii* and *Ictops dako-*

tensis of Leidy, from the bad lands of Dakota, obtained by Dr. Hayden in 1866. These species are allied to both the hedgehogs and the tenrecs of Madagascar, and represent the larger forms of the order. A third species of the same group was found by the writer, viz, the *Isacis caniculus.* But the greater number of species discovered are of smaller size, and belong to families of which no representatives had been previously known in the American Miocene. *Herpetotherium*, Cope, embracing the greatest number of species and individuals, is possibly a member of the *Talpidæ*, and presents affinities to the European genus *Talpa*, or the true moles. *Domnina*, Cope, and probably *Embassis*, Cope, present affinities to the *Soricidæ*, so far as known. As elsewhere, the species are most frequently represented by rami of the mandible, often with beautifully-preserved dentition; but portions of crania are occasionally found. Those of the latter in my possession are referable to three species. One of them fortunately supports both mandibular rami, and furnishes the entire dentition of the *Herpetotherium fugax*, the superior incisors only being wanting. Another consists of a very elongate and compressed muzzle, with which a cranium with base of muzzle may be associated. They are described provisionally under the head of *Domnina*.

The generic types differ as follows:

* Inferior molars (except rarely the posterior) similarly composed:

Herpetotherium, Cope. Dentition: I., $\frac{?}{4}$; C., $\frac{1}{1}$; P. m., $\frac{3}{3}$; M., $\frac{4}{4}$. Last inferior molars nearly similar to the others, which have the posterior pair of tubercles and the anterior one distinct; inferior canine large, followed immediately by premolars.

Embassis, Cope. Inferior molars without anterior cone; the anterior lobe elevated, triangular in section; posterior tubercles conic; last molar similar.

Domnina, Cope. Inferior molars three, with the outer posterior tubercle a crescent, like the outer anterior; the inner posterior a cone; anterior forming a sectorial edge with outer; last molar smaller, consisting of one crescent and a heel; molars increasing in size anteriorly with anterior cone.

** Inferior molars dissimilar, tubercular, and sectorial:

Isacis, Cope. Last three molars with cross-crests; the one preceding with an anterior conic cusp and two median ones, with a broad heel, which supports a cusp.

The total number of the species of *Insectivora* obtained by the expedition of 1873 is as follows, all of them being at the time new to science:

Herpetotherium, Cope	5
Embassis, Cope	2
Domnina, Cope	3
Isacis, Cope	1
	11

HERPETOTHERIUM, Cope.

Paleontological Bulletin, No. 16, 1873, p. 1.—Synopsis of New Vertebrata from the Tertiary of Colorado, p. 4.

This genus is more nearly allied to the existing genus *Talpa* of the Palearctic region than to any existing North American form, so far as dental characters are conclusive. The number of molar teeth is greater; thus $\frac{3\,4}{3\,4}$ in the extinct to $\frac{2\,2}{2\,2}$ in the recent genus.* If the inferior cani-

* The dental formula given for this genus (Synopsis New Vertebrata, &c., p. 4) embraces the figures, incisors $\frac{3}{4}$. This is a typographical error for $\frac{?}{4}$. I did not have opportunity of reading the proofs.

niform tooth be regarded with F. Cuvier as a premolar, the numbers of the latter teeth must be read in these genera $\frac{3}{4}$ and $\frac{4}{4}$ respectively. Since it is situated in advance of the foramen mentale and closes in front of the superior canine, it is probably not a premolar, but a true canine, and the number of inferior incisors is correctly stated as four on each side. In the typical species, *H. fugax*, the superior molars are composed of two external triangles, and an internal cingulum-like cresent, near the base of the crown; last molar with only one external triangle; premolars compressed, simple; canines large, simple, subvertical; inferior incisors slender.

The homologies of the cusps of the upper molars appear to be that the apices of the external triangles represent a median series of cusps, while the longitudinal ridge forming their bases represents the cusps of the external row. When in an unworn state, their apices are probably more distinct. At present, in the typical specimen, the ridge is not less elevated than the apices of the triangles. This genus differs from the *Talpidæ* and resembles the *Isacidæ* in the fact that the cusps of the premolars are homologous with the external one of the true molars, and not with those of the median series, as in the former family. But it agrees with the *Talpidæ* in the presence of two triangles and a well-developed internal lobe. All of the teeth, and especially the canines, are more robust than in *Talpa* and *Scalops*.

The known species differ as follows:

I. Anterior cusp of molars well separated; several molars with three cusps on the heel:
  Size, medium .... *H. tricuspis.*
  Size, very small .... *H. huntii.*

II. Anterior cusp well separated; heel (except of the last) with two cusps:
  Heel of M. 4 narrow; middle cusps moderate:
    Very small .... *H. stevensonii.*
    Large .... *H. fugax.*
  Heel of M. 4 narrow; middle cusps elevated much above heel:
    Medium .... *H. scalare.*

HERPETOTHERIUM TRICUSPIS, Cope., Synopsis New Vertebrata Col., 1873, (October 16,) p. 5.

Represented by portions of five mandibular rami. Posterior tubercle low, on the inner side, visible in all the molars. A hiatus between the first and second premolars; foramina below P. m. 1 and M. 1; canine well developed.

Measurements.

	M.
Length of dental series from canine, omitting M. 4	0.0110
Length of first true molar	.0020
Elevation of first true molar	.0018
Depth of ramus at third true molar	.0027

HERPETOTHERIUM HUNTII, Cope, Synopsis, loc. cit., p. 5.

The least species of the genus, represented by portions of three mandibular rami with all of the molar teeth.

All the cusps low, the median unequal, the anterior and posterior divergent, the latter concealed by the former when in place, although well developed. Foramina below P. m. 2 and M. 1.

Measurements.

	M.
Length of dental series, omitting canine and P. m. 1	0.0072
Length of first true molar	.0013
Elevation of first true molar	.0010
Length of third true molar	.0013
Depth of ramus at third true molar	.0019

Dedicated to my friend Prof. T. Sterry Hunt, of Boston.

HERPETOTHERIUM STEVENSONII, Cope, Synopsis, loc. cit., p. 6.

A very small species. Median cusps of molars unequal; the external much elevated, and separated by a deep notch from the anterior. Heel of M. 4 contracted.

Measurements.

	M.
Length of last two molars	0.0029
Length of third true molar	.0015
Elevation of third true molar	.0012
Depth of ramus at third true molar	.0020

Abundant. Dedicated to my friend James Stevenson, of the United States Geological Survey, the discoverer of the deposit from which the fossils here described were procured.

HERPETOTHERIUM FUGAX, Cope, Paleontological Bulletin, No. 16, p. 1; Synopsis New Vert. Colorado, p. 6.

Cranium wide; interorbital region flat; muzzle narrowed, but still wide and plane above. Mandibular rami long and slender; mental foramina below the first premolar and the first molar. The *foramen infraorbitale anterius* is situated above the third premolar. There is a short diastema behind the first premolar in both jaws. There are rudimental basal tubercles fore and aft on the second superior premolar. The superior canine issues a short distance behind the maxillo-premaxillary suture. In the inferior molars, all of the five cusps are distinct to the base, except the median pair, which are connected by a deeply-notched yoke. Enamel smooth; no cingula. The nasal bones are expanded behind and their posterior suture is medially emarginate.

Measurements.

	M.
Width of cranium at front orbit	0.0160
Width of muzzle at canines	.0050
Length of bases of crowns of four true molars of upper jaw	.0070
Length of bases of five inferior molars	.0100
Length of basis of crown of last molar	.0020
Length of basis of crown of penultimate molar	.0020
Height of crown of penultimate molar	.0017
Depth of jaw at penultimate molar	.0036

Established on jaws of many individuals and a nearly complete cranium. These indicate a species of about the size of our common *Scalops aquaticus.*

HERPETOTHERIUM SCALARE, Cope, Synopsis, Vert. Col., 1873, p. 7.

Readily distinguished by the increased disparity in the elevations of the anterior and posterior portions of the molar teeth, resembling in this respect the *Embassis alternans.* It is a considerably larger species than the latter, and exhibits a distinct anterior cusp, of moderate elevation, which is separated from the median external by a deep notch. It is entirely on the inner side, and sends a cingulum to the external base of the outer median. Fourth molar largest, heel narrowed, with three tubercles.

Measurements.

	M.
Length of last three molars	.0060
Length of second true molar	.0020
Elevation of second true molar	.0022

EMBASSIS, Cope.

Synopsis New Vertebrata Colorado, 1873, p. 4.

This genus was instituted to receive a single species supposed to be allied to those of the preceding genus. Its prominent character consists in the development of the anterior three cusps at the expense of the posterior two; the former forming a trihedral mass, to which the latter form but a basal appendage. In the typical species, the last inferior molar exhibits the same reduction in size seen in *Domnina*, and, as I find that a second species agrees with it in all important respects, characters derived from it induce me to refer *Embassis* to a nearer relation with that genus than I have heretofore indicated. This I formerly described as *Herpetotherium marginale*, but it evidently pertains to a distinct genus, characterized by the presence of only three true molars of the inferior series. These present the general characters of those of *Embassis alternans*, and, like it, differ from those of *Domnina gradata* in having the outer posterior cusp a cone instead of a crescent. The last premolar is composed of two conic cusps, the inner the smaller, and separated from the outer by a deep notch. The other premolars are wanting in the specimen; but the characters observed indicate affinity with the *Soricidæ* rather than the *Talpidæ*, and probably a smaller number of teeth than in *Herpetotherium*.

EMBASSIS ALTERNANS, Cope, Synopsis, Vert. Colorado, 1873, p. 7.

Heel of molars with two low tubercles; the last tooth smaller than the penultimate. An antero-external cingulum.

Measurements.

	M.
Length of two last molars	0.0038
Length of third molar	.0020
Elevation of third molar	.0018

EMBASSIS MARGINALIS, Cope. *Herpetotherium marginale*, Cope, *loc. cit.*, 1873, p. 6.

Anterior cusp close-pressed to the median pair, and united with them above the base, forming a triquetrous mass elevated above the heel. The cusps of the heel two, more than usually elevated, and acute. A cingulum descending from the anterior and posterior cusps to the base of the median on the outer side. Only two cusps on the heel of the last molar. Cusps of the last premolar acute, smooth, and recurved.

This species is about as large as the *Domnina gradata*, but differs from it in many respects besides those already noted. The first true molar, though larger than the third, is not so much so as in the *D. gradata;* the anterior crescents are less open, the heel more contracted, &c.

Measurements.

	M.
Length of last three molars	0.0052
Length of third true molar	.0024
Elevation of third true molar	.0018
Depth of ramus at third true molar	.0023

Two specimens.

DOMNINA, Cope.

Paleontological Bulletin, No. 16, (August 20, 1873,) p. 1.—Synopsis Vertebrata Colorado p. 4, (?); *Miothen*, Cope, *loc. cit.*, pp. 4–8.

Three true molars, the last reduced in size; first molar large, with the *foramen mentale posterius* below it, and a small alveolus for the root of a premolar in front of it. In front of this a considerable alveolus-like cavity rises toward the border, but is interrupted by fracture. These characters are derived from the specimen of *D. gradata*. In *D. crassigenis*, the last molar is still more reduced. In none of the species is the premolar series preserved.

Portions of two crania already mentioned are described here provisionally and without final reference. The form is narrower across the frontal region than in *Herpetotherium fugax* and plane above. The muzzle is abruptly contracted at the base, and maintains a narrow, compressed form to the end; the nasal bones are convex in section, and narrow to their posterior extremity. There are three premaxillary teeth on each side, the anterior of which is enlarged and directed downward and a little forward; base of crown an antero-posterior oval; of last, round. The numbers of molars and premolars is probably 3–3; but the alveoli of the last true molars are obscured, so as to leave some slight question as to the presence or absence of a fourth. The first "premolar" is in the position of the canine of *Herpetotherium*, and probably represents that tooth, as there is no caniniform tooth in the present species. It is two-rooted, compressed, and with triangular profile. It is both preceded and followed by a short diastema. The other premolars are two-rooted.

Measurements.

	M.
Length of premolar series of No. 1	0.0054
Length to M. 1 of No. 1	.0090
Width at P. m. 2 of No. 1	.0027

DOMNINA GRADATA, Cope, *loc. cit.*, p. 1.

Crowns of the molars composed of two rows of alternating tubercles, with an odd one in front. The inner tubercles are much the more elevated, and form the apices of V's, of which the inner commence the limbs.

Three rows of acute tubercles on the inner, two on the outer side of each dental crown, the last pair of the last crown fused into a heel; the middle outer and anterior inner forming together a notched, sectorial yoke. A low cingulum on outer, none on inner basis of tooth-crown; enamel smooth.

Measurements.

	M.
Length of basis of three molars	0.0055
Length of basis of first molar	.0023
Length of basis of last molar	.0015
Depth of ramus at first molar	.0026
Width of first molar	.0015

As compared with the *Herpetotherium fugax*, this species has a shallower mandibular bone and a larger anterior true molar. The sectorial character of the oblique yoke connecting the anterior inner and outer tubercles and the crescentic character of the posterior outer are not nearly so well marked in the *H. fugax*.

One specimen.

DOMNINA CRASSIGENIS, Cope. *Miothen crassigenis*, Synopsis New Vertebrata Colorado, p. 8.

This species is less robust than the last, and the last molar still more reduced. The cusps of the latter, though not well pronounced in the specimens, are homologous with those in *D. gradata*.

Represented by two imperfect mandibular rami, with the posterior molars preserved. Last molar longitudinal and diamoned-shaped, half the size of the penultimate. The latter composed of two exterior crescents; the cusps of the inner side worn down in both specimens, if they have existed. Ramus of the mandible deep.

Measurements.

	M.
Length of last two molars	0.0022
Length of third molar	.0018
Depth of ramus at third molar	.0030

DOMNINA GRACILIS, Cope. *Miothen gracile*, Cope, Synopsis Vert. Col., 1873, p. 8.

This species is quite distinct from those that precede, and may, in future, require the use of the generic name I formerly applied to it. It is represented by a portion of a mandibular ramus, which is of slender proportions. The posterior external cusps have the crescentic form characteristic of this genus.

Last molar nearly as large as penultimate, with a low cusp at each extremity and an emarginate cross-crest at the middle. Penultimate molar with three inner cusps and two outer crescents. Ramus of mandible slender.

Measurements.

	M.
Length of last two molars	0.0025
Length of penultimate molar	.0012
Elevation of penultimate molar	.0009
Depth of ramus at penultimate molar	.0021

ISACIS, Cope.

Paleontological Bulletin, (August, 1873,) No. 16, p. 3.—Bulletin U. S. Geol. Survey Terrs., No. 1, 1874, p. 23.

This genus embraces at present but a single species, which is known from numerous specimens discovered by the writer in the Miocene formation of Colorado. From these it appears that *Isacis* is closely allied to the *Leptictis* and *Ictops* of Leidy, occupying a position between them in the system. In *Leptictis* the last premolar is sectorial in form, consisting of a single compressed longitudinal crest, without internal tuberosity or cusp. In *Ictops*, the last premolar exhibits a structure similar to that of the first true molar, viz, two exterior cusps, and well developed third on their inner side, thus giving a horizontal section of the tooth a subtriangular form. In *Isacis*, the last premolar possesses a single acute cusp, as in *Leptictis*, with an internal cusp or heel, homologous with that in *Ictops*. Such peculiarities are generally regarded as tangible definitions of generic groups, and are such in this case, although they separate species which have considerable resemblance in some other respects as far as known.

The *molars* of the superior series have two exterior compressed conic cusps and a stout subtriangular internal one. Behind the latter is a strong cingulum, supporting a rudimental cusp behind and within the principal one. Inferiorly, there are three tubercular molars, of which the two anterior are composed of two elevated cross-crests, which form partial V's, opening to the inner side. The sectorial supports three anterior conic tubercles, the inner and outer equal, and a heel with a conic tubercle on the outer side. The number and character of the teeth in front of this one are unknown.

Portions of the *cranium* preserved present general characters of *Leptictis*. There is a strong postglenoid process giving support to a thin zygomatic process. Behind the base of the latter, the squamosal is pierced by three large foramina, the inferior bounded by a ridge above and one below. The mastoid and paramastoid processes are rudimental, and the occiput is transverse and bounded by a well-marked inion. The petrous bone is large, and there is space for a large bulla, but its existence is uncertain. There is a longitudinal crest directed forward and inward in advance of the postglenoid process, which is probably in line with the external pterygoid ala.

The *cervical vertebræ* are short and transverse, and have well-developed lateral arterial foramina and diapophyses. The centra are depressed to a considerable degree, and are without hypapophyses. The neural arches are narrow, and without spines. The atlas is expanded, and has a very short diapophysis. The axis has a solid obtuse *processus odontoideus*. The dorsal vertebræ are smaller than the cervical in transverse diameter of the centrum, which somewhat exceeds the length; the articular faces are nearly plane. The intervertebral foramina are quite large, and the narrow neurapophysis is almost entirely occupied by the basis of the diapophyses. These are well developed, obliquely truncate below at the end, and grooved on the under side of the shaft. The neural spines are elevated, narrow, and acute in front. The ribs are flat, and the capitular and articular faces are well developed.

The *præsternum* is shaped somewhat like the sternum of a bird. It has a prominent inferior longitudinal keel, which disappears posteriorly, leaving a vertically oval face of articulation for the second sternal segment. The superior face is slightly concave, and the only lateral articular faces are those for the attachment of clavicles, and are of considerable size. The borders of the bone are but little contracted behind them. The scapula is elongate, and has an elevated crest, descending abruptly near the glenoid cavity. The latter is an elongate oval, the border at one end more produced than at the other, and terminating in a short hooked coracoid.

The *humerus* has a protuberant head and shaft, and condyles much flattened. The head is nearly 180° in arc, is posteriorly directed, and of compressed form. On the inner side is a depressed tuberosity for the pectoralis muscle, while opposite to it the large deltoid crest rises as high as the head parallel to it. Distally, the condyles are continuous, nearly concave, and supplemented by a huge inner and a smaller outer tuberosity. There is no supracondyloid foramen, but a strong arterial foramen.

The cast of almost the entire *brain* is preserved, and, as the parietal bones are wanting, the proportions are clearly traceable. The olfactory lobes are wanting, but were clearly attached at the extremity of the hemispheres. The superior face of the hemispheres and cerebellum together have a subquadrate outline, a little wider than long. The cerebellum is completely exposed behind the hemispheres, and is strongly angulate at its upper posterior border to fit the inion. The vermis is nearly as wide as each lateral lobe. The surface of the hemispheres is smooth, and the sylvian fissure distinctly indicated.

In determining the affinities of this and the two allied genera already named, it is first necessary to ascertain the homologies of the cusps of the molar teeth. *Insectivora* and some genera of *Marsupialia* are characterized by the presence of three longitudinal series of tubercles on the molar teeth. With the exception of the posterior molars of some *Carnivora*, the arrangement usual among *Mammalia* is in two longitudinal series, with frequently but two in each row. In most *Insectivora*, the cusp or cusps of the median series are the most prominent, and those of the outer series sometimes entirely wanting. Hence, Mivart* homologizes the middle pair with those of the external series of the other *Mammalia*, the inner with the internal, and the outer are regarded as representing cusps of a basal cingulum. Now, in the *Isacidæ*, (including *Leptictis* and *Ictops*,) the external cusps very are largely developed; there is one well-developed median and a rudimental internal cusp. Are the external cusps only cingular, or homologous with those that occupy the same position in other *Mammalia*; and what are their relations to the corresponding ones of the premolars?

In the true molars of the opossum and tubercular molars of the dog, there are three rows of tubercles. In both, it is evident that the two of the outer series correspond with the outer tubercles of the teeth which precede them in the jaw, and in which the inner tubercles are reduced in size and number. This is notably clear in comparison with the sectorial molar of the dog. It might, however, be asserted that the single outer tubercle of the last premolar in *Isacis* (and *Leptictis*) is homologous with that of the middle series of the true molars instead of the outer, and some color is given to this view from the internal position of the last premolar in *Leptictis*, so that its outer cusps range with the median of the true molars. This opinion is, however, readily corrected by a consideration of the arrangement in *Ictops dakotensis*,† where the last premolar exhibits both the median and internal cusps, so that the homology of the outer pair with those of the true molars is assured.

In *Didelphys*, in passing to the anterior molar, where the three series of cusps are not well defined, we observe that it is the middle tubercles are the ones which disappear, the internal remaining. In the same manner, in tracing the series of forms from the horse to the tapir, we find the cusps of the middle series disappear, leaving the internal and external to represent those of the original quadritubercular molar. In *Ictops* and probably *Isacis*, the median cusp is preserved at the interval of the last premolar. The case is quite different in *Talpa* and *Scalops*, where it is evident that, as we advance along the dental series forward, the cusps of the outer row disappear, and the external ones remaining represent those of the middle series of the true molars. As already indicated, the arrangement in *Herpetotherium* is as in *Isacis*, and the premolars have, therefore, an entirely distinct structure from that observed in the *Talpidæ*.

From the above considerations, it appears that the external, often minute, cusps of the teeth of *Insectivora* are the homologues of those of

* See his valuable Memoir on Osteology of Insectivora, Journ. Anatomy and Physiology, vol. ii, p. 138.

† See Leidy's Extinct Fauna of Dakota and Nebraska, p. 351, Pl. xxvi, Fig. 29.

true external series, and do not represent merely a cingulum. Comparisons of the molars of the extinct and recent forms are thus facilitated.

In *Chrysochloris* and *Centetes*, according to Mivart, the external cusps are wanting. In the genera in which they are present, as *Tupaia*, *Talpa*, *Sorex*, &c., there are two of the middle series, as in *Herpetotherium*, and these add a strong internal lobe also. In *Erinaceus*, they are quadrituberculate; but which pair represents the median, I am not yet sure. The closest approximation is made by the genera *Potamogale* and *Solenodon*, the former African, the latter West Indian. In these, the external cusps are present; there is but one well-developed median, and in the latter the internal is quite reduced. The molars of *Isacis* thus resemble most closely those of *Solenodon*, (Brandt,) but the external cusps are more developed than in that genus. If, as is probable, the superior molars of *Erinaceus* possess only the outer and median pairs of tubercles, a resemblance between the two may be traced; the existing genus differing from *Isacis* in its two median cusps. The single one of *Isacis* is connected with the external ones by oblique ridges, as in *Erinaceus;* and on one of these is a rudimental tubercle, representing the second median cusp.

In the lower series, the form of the true molars is not unlike that of several diverse recent genera. It is quite unique in its large four or five cusped last premolar, which has some resemblance to a modified sectorial. The nearest approach to it which I can discover among recent genera is the Madagascar *Galeopithecus*.

In respect to the remainder of the skeleton, numerous characters distinguish it from the *Centetidæ* (which includes *Solenodon*) and the *Potamogalidæ*. Both of these lack the zygoma, which is present in *Isacidæ*, and have the nasals co-ossified, while they are distinct in these Tertiary forms; *Potamogale* further lacks the clavicle. The presence of the zygoma without postorbital processes is a point of resemblance to *Erinaceus*, but the strongly-keeled presternum and absence of cervical neural spines are found elsewhere in the *Talpidæ*. In the presence of the humeral arterial foramen, it again differs from *Erinaceus* and resembles other forms of the order.'

Thus the affinities of *Isacis* are quite complex, and abundantly indicate its position and that of the two allied genera to be in a family distinct from any now in existence.

ISACIS CANICULUS, Cope, *loc. citat.*

This species is represented by portions of the skeletons of six individuals. All of these lack the anterior teeth of both jaws, while one includes mandibular teeth with vertebræ, ribs, humerus, scapula, presternum, a large part of the cranium, &c.

The basi-occipital is three-keeled below, and the petrous bone with a longitudinal concavity below. The edges of the outer lobes of the first superior molar are acute. There is no external cingulum, but the diagonal crest from the median cusp passes to the posterior base of the posterior outer. There is a short but strong cingulum on the posterior base of the median lobe, which terminates in a small internal cusp. The rudimental anterior middle cusp is on the anterior diagonal ridge, which does not reach the base of the outer anterior cusp. The outer cusp of the last premolar is elongate and compressed; the inner cusp is small, acute, and opposite the posterior margin of the outer; enamel smooth. The anterior of the two prisms composing the inferior true molars is more elevated than the posterior. The crests of each form a V with the obtuse apex outward, and the anterior limb is shorter than the posterior. The last molar is a little smaller, and is produced behind by the addition of a small median lobe. In the last premolar, the conic cusps are well separated, and the inner one of the heel is insignificant. This tooth appears to have been the last one protruded; its temporary predecessor is distinguished by the obtuseness of the cusps, especially of the anterior one. Mandibular ramus deep, compressed, without inferior hook as far as opposite the basis of the coronoid process.

Measurements.

	M.
Length of sectorial and two tuberculars	0.0210
Length of sectorial alone	.0045
Width of sectorial	.0020
Width of first tubercular	.0030
Length of first tubercular	.0032
Depth of jaw at first tubercular	.0060

Size of a skunk.

RODENTIA.

Species of this order are numerous in the Tertiary of Colorado, and the individuals were more abundant than those of any other type of mammalia. Hundreds of specimens of some of the species were found, which range from the size of a marmot to even less than the domestic mouse. The relationships of these are as follows:

Muridæ:	
Eumys, Leidy	1
Sciuridæ:	
Sciurus, Linn	1
Gymnoptychus, Cope	2
Incertæ sedis:	
Heliscomys, Cope	1
Ischyromys, Leidy	1
Leporidæ:	
Palæolagus, Leidy	4
	10

EUMYS, Leidy.

Mus (*Eumys*), Leidy.

The single species embraced in this genus is nearly allied in dental and the known portions of its cranial characters to those of the existing genus *Mus*. The only distinctive feature which I can discover is that the supraorbital ridges rise from the lachrymal bones, and unite, forming a median keel between the orbits as in the *Fiber*. Whether it is found in any of the numerous existing species of *Mus*, I cannot state; but the frontis plane and the superciliary ridges are well separated in *Mus decumanus*. The *foramen infraorbitale anterius* is much as in *Mus decumanus*, being large and continued into a fissure below. The dentition is also similar, including the composition of the molars. These support two rows of obtuse tubercles, the number increasing with the size of the teeth from behind forward. Formula: I., $\frac{1}{1}$; C., $\frac{0}{0}$; M., $\frac{3}{3}$.

EUMYS ELEGANS, Leidy, Ext. Fauna Dakota and Nebraska, p. 342, Pl. xxvi, Figs. 12–13.

This species is exceedingly abundant in the Colorado Miocene, and many specimens were obtained. These display considerable variation in size and robustness; some, perhaps males, having the muzzles stouter in proportion to the length than others; some more decurved than others.

With molar teeth as large as those of the Norway rat, the muzzle is not more than two-thirds as long, so that the species was in general proportions smaller and more robust.

HELISCOMYS, Cope.

Synopsis New Vert. Colorado, 1873, p. 3.

Char. gen.—Inferior molars four; the crowns supporting four isolated cones in pairs. This genus is only known from mandibular rami. These resemble in their dental structure some of the *Muridæ*, but the number of molars is more, as in *Sciuridæ*. In *Myops*, Leidy, of the Bridger Eocene, the dental cusps are connected by cross-yokes.

HELISCOMYS VETUS, Cope, *loc. cit.*, p. 4.

Char. specif.—First molar with only three cones; all the molars except the first with a broad contiguous cingulum on the external side. Ramus rather stout; incisor-teeth very slender, elongate, slightly compressed, with parallel sides and convex anterior face.

Measurements.

	M.
Length of molar series	0.0030
Length of third molar	.0008
Elevation of third molar	.0005
Depth of ramus at third molar	.0023
Length of ramus to end of molars	.0010

The least mammal of the fauna to which it pertains.

SCIURUS, Linn.

SCIURUS RELICTUS, Cope. *Paramys relictus*, Cope, Synopsis New Vert. Colorado, 1873, p. 3.

This species is established on two left mandibular rami, with all the teeth complete. It was referred to the genus *Paramys*, because I found no difference between the corresponding parts in the respective species; but as the characters of the latter are chiefly observable in the maxillary teeth, the reference was not final. As it does not differ in any degree from corresponding parts of the existing squirrels, I place it for the present in the same genus with them, as the safer course.

The teeth increase regularly in size from the front backward. The transverse crests are marginal, and terminate in cusps at the inner extremity, which are separated by a lower acute median cusp. A longitudinal crest connects the crests just within their outer extremities; it exhibits a loop directed outward. A low ridge passes from the posterior outer buttress, just in front of the posterior margin, in the last two molars. Anterior cusps of first molar contiguous.

Measurements.

	M.
Length of ramus to end of M. 4	0.0120
Length of molars	.0088
Length of third molar	.0015
Width of third molar	.0018
Depth of ramus at third molar	.0050
Width of incisor	.0015

Size that of the chickaree, (*Sciurus hudsonius.*)

GYMNOPTYCHUS, Cope.

Paleontological Bulletin, No. 16, p. 6.

This genus is allied to the squirrels, differing as to cranial characters in the structure of the molar teeth. These exhibit in the superior series two crescents on the inner side, connected by transverse yokes with two cusps on the outer; in the lower jaw the crescents are on the outer, and the cusps on the inner side. The yokes are separated by deep valleys without cementum, which do not wear out so readily as in *Sciurus* and marmots. It differs from both these genera in its two well-defined crescents in both dental series. It agrees with them in the position of the *foramen infraorbitale anterius*, which is small, inferior, and situated in advance of the dental series. There are four molars, which do not differ materially in structure in both jaws. Two species are known, a larger and a smaller.

GYMNOPTYCHUS TRILOPHUS, Cope, Pal. Bulletin, No. 16, p. 6. *G. nasutus*, Cope, *loc. cit.*

Inferior molars with two cross-crests and two cingula from the external cones; each posterior crest of a pair terminating in an interior cone. The inner apices of the crescents unite and give origin to a short median cross-crest. First molar narrower; the anterior part of a ranium probably belongs to the same species. The first molar has a subround crown, with four tubercles; the second is constructed like the corresponding inferior. Muzzle much compressed; nasal bones flat, extending to beyond above incisors.

Measurements.

No. 1.

	M.
Length of interior three molars	0.0045
Length of first molar	.0015
Diameter of inferior incisor	.0008
Depth of ramus at second molar	.0036
Length of diastema above	.0080
Width of a pre-orbital region	.0073
Width of end of muzzle	.0030

No. 2.

Length of four molars	0.0070
Length of second molar	.0017
Width of second molar	.0015
Depth of ramus at second molar	.0035
Width of lower incisor	.0010

GYMNOPTYCHUS MINUTUS, Cope, Pal. Bull., No. 16, p. 6.

A very small species. Middle pair of molars with the anterior and posterior cross-crests bifurcate, and a short median cross-crest; only three cross-crests on the fourth, and four tubercles on the first. Ramus deep.

Measurements.

	M.
Length of inferior molars	0.0040
Length of second molar	.0010
Width of second molar	.0010
Transverse diameter of incisor	.0008
Depth of ramus at second molar	.0030

Scarcely larger than the house-mouse.

ISCHYROMYS, Leidy.

Proceed. Acad. Nat. Sci. Philad., 1856, p. 89.—Extinct Fauna Dakota and Nebraska. 335.—*Colotaxis*, Cope, Paleontological Bulletin, No. 15, p. 1.

Char. gen.—The essential features are, dentition, I., $\frac{1}{1}$; C., $\frac{0}{0}$; M., $\frac{5}{4}$; the molars with two crescents on the inner side above, each of which gives rise to a cross-ridge to the outer margin. In the mandibular series the crests and crescents have a reversed relation. No cementum.

Dr. Leidy remarks that this genus belongs to the family of the *Sciuridæ.* This is indicated by the dental characters; but in some other respects there is a greater divergence from the squirrels and marmots than is the case with the preceding genus, *Gymnoptychus.* Thus, there is a large *foramen infraorbitale anterius*, which occupies the elevated position at the origin of the zygomatic arch seen in the *Fiber*, the porcupines, and cavies. There is no superciliary ridge nor postorbital process as in most *Sciuridæ*, but the front is contracted between the orbits in the same manner as, but to a less degree than, in *Fiber*, and the Eocene *Pseudotomus*, Cope. Both the last-named and *Ischyromys* present many points of resemblance to Pomel's tribe of *Protomyidæ*, but differ from any of the genera he has included in it.

ICHSYROMYS TYPUS, Leidy, *loc. cit.* *Colotaxis cristatus*, Cope, Pal. Bull., No. 15, p. 1. *Gymnoptychus chrysodon*, Cope, *loc. cit.*, No. 16, p. 5.

First upper molar a simple cone. Incisors quite compressed. First inferior molar a broad oblong; the cusps opposite, the anterior close together. The two posterior cross-crests do not form a V; the anterior being interrupted at the cusp. There is a delicate tubercle between the outer cusps of the three last molars. The incisor is compressed; the anterior and outer faces being separated by an angle.

Measurements.

	M.
Length of molars	0.0140
Length of penultimate molar	.0033
Width of penultimate molar	.0035
Width of first molar	.0030
Length of first molar	.0035
Depth of jaw at penultimate molar	.0090
Depth of incisor-tooth	.0040
Width of incisor-tooth	.0020

The skull is broad and stout but not depressed; muzzle broad above, short; front moderately contracted; no postorbital processes.

This species varies considerably in the form of the premolar teeth, and I believe the above names refer to varieties, not to species.

PALÆOLAGUS, Leidy.

Proceed. Acad. Nat. Sci. Philad., 1856, p. 89.—Extinct Mamm. Dakota and Nebraska, p. 331.

As observed by Leidy, this genus presents the same number of teeth as in the existing rabbits, viz, I., $\frac{2}{1}$; C., $\frac{0}{0}$; M., $\frac{6}{5}$; and that the difference consists in the fact that the first molar possesses two columns, while in *Lepus* there are three. Having collected a great number of remains of this genus, I am able to show that it is only in the immature state of the first molar that it exhibits a double column, and that in the fully adult animal it consists of a single column with a groove on its external face. The dentition undergoes other still more important changes with progressing age, so as to present the appearance of difference of species at different periods. These are explained under the head of the *P. haydenii*, the most abundantly represented in the collections. It may be mentioned here that in neither *P. haydenii* nor *P. turgidus* is there any evidence that more than two anterior molars are preceded by deciduous teeth, while the latter are present in many specimens.

PALÆOLAGUS AGAPETILLUS, Cope, Paleontological Bulletin, No. 15, p. 1.

Established on a mandibular ramus with the first and last permanent molars just protruding. Size the least in the genus, not exceeding the *P. haydenii* in the milk-dentition, but more robust and with larger incisor-tooth. Form of the ramus wedge-shaped, contracted, and convex on the outer side forward. Molars all composed of two columns, the anterior the more elevated, the fore portion surrounded by its distinct enamel sheath, with a narrow intervening band of cementum. Posterior molar much reduced in size; posterior column of molars with a median posterior rib, which forms a loop in section. Anterior column much more elevated than posterior. The section of the slender incisor is nearly a right-angled spherical triangle.

Measurements.

	M.
Length of molar series	0.0100
Length of penultimate molar	.0020
Depth at penultimate molar	.0070
Depth at first molar	.0050
Transverse thickness at first molar	.0037

PALÆOLAGUS HAYDENII, Leidy.

The earliest dentition of this species known to me is the presence of the two deciduous molars, the first and second in position, before the appearance of any of the permanent series. Each of these has two roots, and the crown is composed of three lobes. In the first, the first lobe is a simple cusp; the two following are divided into two cusps each; the second is similar, excepting that the simple cusp is at the posterior end of the tooth. The grooves separating the lobes descend into the alveolus on the outer side, but stop above it on the inner. The measurements at this stage are—

Measurements.

	M.
Length of two milk-molars	0.0050
Depth of ramus at No. 2	.0042
Depth of ramus at diastema	.0032

In the next stage, the third permanent molar is projected, and has, like the second deciduous, a posterior simple column, whose section forms an odd cusp or lobe. The fourth true molar then follows, also with an odd fifth lobe behind. This lobed form of the molars is so different from that of the adult as to have led me to describe it as indicating peculiar species under the name of *Tricium avunculus* and *T. annæ*.

In the next stage, the fifth small molar appears in view, and the second permanent molar lifts its milk-predecessor out of the way. In a very short time, the posterior, or odd, columns entirely disappear, sinking into the shaft, and the permanent molars assume the form characteristic of the species. The last stage prior to maturity sees the first milk-molar shed, and the younger portion of the first permanent molar protruded.

There is the merest trace of a posterior lobe at this time, and that speedily disappears. The anterior lobe is subconical, and is entirely surrounded with enamel. By attrition, the two lobes are speedily joined by an isthmus, and for a time the tooth presents an S-shaped section, which was supposed to be characteristic of the genus. Further protrusion brings to the surface the bottom of the groove of the inner side of the shaft, so that its section remains in adult age something like a B.

Ths measurements of a medium-sized adult are—

Measurements.

	M.
Length of inferior molar series	0.012
Length from M. 1 to end of incisor	.012
Length of diastema	.008
Length of crown of M. 1	.0029
Elevation of crown of M. 1 above alveolus	.0035
Depth at M. 1	.0070
Depth at M. 5	.0085
Inferior diameter of ramus below M. 1	.0040

Several hundreds of specimens of this species were observed.

PALÆOLAGUS TURGIDUS, Cope, Pal. Bull., No. 16, p. 4. *Tricium paniense*, Cope, *loc. cit.*, p. 5.

The largest species of the genus. Molars with two simple columns, the first and fifth grooved on the outer side only; the interior grooves of the others weaker. A porous enlargement on the inner inferior part of the ramus just behind the symphysis. Diastema obtuse.

Measurements.

	M.
Length of molars	0.016
Length of three median molars	.010
Depth of ramus at central molars	.011
Width of central tooth	.0035

The deciduous molars present much the same character as in *P. haydenii*, except that there is scarcely a trace of the odd posterior tubercle on the second. The posterior root of the latter extends to the bottom of the alveolus. The grooves of crown do not descend to the alveolus on either side. Measurements of such a specimen are—

Measurements.

	M.
Length of two anterior molars	0.0068
Length of first molar	.0032
Width of first molar	.0021
Depth of ramus at first molar	.0085
Depth of ramus at diastema	.0061

PALÆOLAGUS TRIPLEX, Cope, Paleontological Bulletin, No. 16, p. 4.

This species rests on characters which I have observed to be transitional in the *P. haydenii*, and I have attended to the possibility of the individual which has furnished them being a similarly immature *P. turgidus*. In a considerable number of specimens of the latter, no approach to the present one is exhibited; the latter is a fully-grown animal, and its characters would remain after considerable attrition of the teeth has been reached; size of the last; first and last molars deeply grooved on both sides, as well as all the rest; first molar with a trifolium-lobate crown. Median three molars with a narrow posterior column, as in *P. agapetillus*. Punctate patch on inner face of ramus extensive.

Measurements.

	M.
Length of molar series	.016
Length of median three molars	.010
Width of median molar	.003
Depth of ramus at median molar	.011

This species and the last are rather larger than the prairie-marmot, (*Cynomys ludvicianus.*)

PERISSODACTYLA.

SYMBORODON, Cope.

Paleontological Bulletin, No. 15, p. 2, (August 20, 1873.)—Synopsis Vertebrata Colorado, 1873, p. 14.—Proceed. Amer. Assoc. Adv. Sci., 1873, p. 109.

A genus embracing species, so far as known, of large size, allied to *Titanotherium*, Leidy, and belonging to the same family. Its affinities are indicated by the following description:

Dental formula: I., $\frac{2}{0}$; C., $\frac{1}{1}$; P. m. $\frac{4}{3}$; M., $\frac{3}{3}$. Teeth reduced in size anteriorly; no diastema behind the canine. Molars consisting of two external and confluent crescents, and one or two internal cones. In the larger premolars, there are two, sometimes confluent, cones; in the molars, the posterior cone is sometimes much reduced, especially on the third, while on the second and third a small third one is sometimes added in front. The mandibular teeth are constructed like those of *Palæotherium*, *i. e.*, of two crescents with the horns directed inward, the middle two united, and the third molar with a third posterior one. The superior incisors are very small and with obtuse crowns, and are separated by a median interval; the inferior canines are separated by a short edentulous space, with thin alveolar margin openly emarginate.

The *cranium* is remarkably elongate in proportion to its width, excepting in those species where the zygomas are so expanded as to modify the proportions. The top of the skull is flat or convex in transverse direction, and the well-separated temporal fossæ are overhung by the angular or produced borders. The temporal fossæ are well produced posteriorly, in some species remarkably so, and, with the supraoccipital border or horizontal crest, inclose a deep occipital fossa. The inferior border of the fossa is continued to the zygoma. The zygomatic fossa is rather narrow, but the squamosal process is sometimes horizontally expanded to a great mass. There are no postorbital processes, and in all the species the orbits are small. The *foramen infraorbitale* is very large, and is a simple perforation of the thin wall bounding the orbit in front. A narrow column separates it from the orbit exteriorly, and a stouter one from the external nasal meatus. The latter is large and very little incised behind the premaxillary border. Hence the fore portion of the nasal bones is very short. The lateral walls, anterior to the orbits, are directed somewhat anteriorly, so that, viewed from the front, there is a considerable border on each side of the nasal meatus, bounded by a lateral vertical angle, and pierced below by the *foramen infraorbitale.* The borders of the nasal bones are thickened, and often ridged below. The premaxillaries are small and fragile.

The *maxillaries* rise above the level of the orbit in a solid support for a stout horn-core, which is principally composed of a production of the nasal bone. The distance to which these supporting elements rise differs in the species. The horn-cores are a striking feature of the genus, and vary in shape and proportions in the species. In one, they are rudimental; in others, short and stout; in another, long, slender, and curved. The nature of their investing membrane remains unknown, but the extremities in several of them (*S. acer*, *S. bucco*) are so rugose with coarse exostoses as to suggest strongly a cartilaginous or corneous appendage or continuation representing the deciduous horn of the deer. The nasal bones are co-ossified in most of the species, and present various forms in the different species. In all the specimens, the sutures on the upper face of the skull are obliterated, so that it is difficult to determine the true structure. The orbits being far anterior and but little behind the line of the bases of the horn-cores, it is evident that the frontal bones are produced well forward. The nasals are, however, produced broadly between the anterior portions of the frontals.

The *basioccipital* and basisphenoid are narrowed and bounded by a large confluent *foramen lacerum anterius et posterius*. The petrous bone is small and deeply set. There is a transverse paramastoid process, and a very large transverse postglenoid process. The mastoid process is thickened and recurved so as to be nearly in contact with the postglenoid, and to inclose the external auricular meatus. The side-walls of the posterior nasal meatus are prolonged, and form an abrupt obtuse angle posteriorly where the border rises to the basisphenoid. The pyramidal process of the palatine, the pterygoid, and the pterygoid ala of the sphenoid, which compose each, are closely co-ossified. The external side of this plate is deeply longitudinally grooved, which terminates posteriorly in a foramen, the spheno-orbital. The posterior base of the plate is longitudinally perforated, and in line with this short tube is a large foramen opposite the glenoid cavity. The *foramen ovale* is probably confluent with the *f. lacerum anterius* as in *Eobasileus* and *Rhinocerus*. The palate is incised to the front of the last molar. In outline, it is quite narrow when compared with the large molars; the diameters of the two being about equal.

The *mandible* is small when compared with the cranium, and contracts rapidly forward. The condyle is large and transverse, and the coronoid process small, narrow, and close to the condyle. The angular region is strongly convex both backward and downward. The inferior margin of the ramus is without tuberosities, and the symphysis co-ossified, shallow, and oblique.

The *cranial chamber* is elongate, and is divided into three departments for corresponding segments of the brain. The posterior is elongate-oval, for the reception of the cerebellum. It is separated from the median division by a thin tentorium, whose union with the superior walls indicates that the cerebral hemispheres did not overhang the cerebellum. The anterior border of the hemispheres is indicated by a thickened, arch-like contraction of the lateral and superior cranial walls within, and is situated much behind the orbits, as in perissodactyles and some carnivora. This chamber is divided longitudinally by a thin falx, and each posterior lobe is again divided vertically by a thin osseous septum, thus accommodating two convolutions. The external of these is supported underneath by a thin septum from the outer wall. The falx divides or forks at its anterior extremity into two vertical laminæ, which continue parallel to each other to the inner bases of the nasal horns. They are here continuous with the external wall, forming the posterior boundary of the anterior narial opening. They form the lateral walls of the long nasal fossa, and inclose a large chamber on each side with the lateral cranial walls. This sinus appears to be separated by a thin osseous septum from the brain-case proper; the septum extending from above obliquely forward and downward, altogether behind the arch-like projection of the frontal bone above described. As it is not perforated, it gave no exit for the olfactory nerves. I cannot detect the proper boundary separating the hemispheres from the olfactory lobes, as their usual position, both in front of and behind the frontal arch, is included in the large sinus above described. The nasal fossa is divided by the usual septum, and each half communicates with the large fossæ above mentioned by a large longitudinal oval foramen. In one specimen of *Symborodon acer*, in which this lateral septum is almost entirely preserved, there is no indication of attachment of turbinal bones, but the surface is smooth. On these and the median septum, the olfactory nerve was, no doubt, distributed. The olfactory lobes were contracted in dimensions, and the large lateral sinuses in front of them are doubtless the frontal sinuses of the mammalian skull. Their length is double that of the brain-case, and they extend far posterior to the orbits and above and behind the olfactory lobes. They do not appear to have been divided by septa, excepting a small one springing from the outer wall near the posterior fourth in *S. acer*, and near the same place from the inner wall in *S. trigonoceras*. This huge cavity was doubtless an air-chamber, which gave a lightness to the skull not otherwise attainable consistently with its great length, and which has rendered the use of the nasal horns entirely practicable. They explain the elongation of the skull in the Eocene genera *Eobasileus* and *Uintatherium*, and prove that the sinus at the base of the horns of the middle pair is the frontal sinus and not the alveolus of the canine tooth, as supposed by Marsh.

The cervical vertebræ in all the species are concavo-convex, and much deeper than long; they are longer than in *Eobasileus*. The odontoid process is a solid cone; the coracoid process is a tubercle; there is no acromion; and the spine of the scapula rises gradually from its base. The ilium is strongly pedunculate.

In *S. bucco*, the femur has a third trochanter, and is relatively longer than in *Rhinocerus*. There is a fossa for the round ligament, and the condyles are expanded. The fibula is enlarged distally, and is distinct. The phalanges, including the ungueal, are very short. The carpals interlock; and the ulna is much reduced, giving the carpal articulation to the radius.

The *S. acer* is the smallest species described, and has the longest horns. Its astragalus resembles that of *Rhinocerus*, having a deeply-grooved trochlea and well-defined head and neck. The cuboid facet is rather larger than in that genus, but is considerably smaller than the navicular, and extends with an acuminate outline behind it, as in *Eobasileus;* otherwise it has no resemblance to that element in that genus. The metatarsals have much the form of those of *Rhinocerus*.

The palate is deeply incised, as in *Rhinocerus*, and other cranial peculiarities resemble those of that genus. In no case are any traces of inferior incisors present in the numerous under-jaws at my disposal.

In estimating the ordinal affinities of the genus, the greater number at once assign it to the *Perissodactyla*. The teeth,* the incised palate, the distribution of the cranial foramina, including the perforation of the pterygoid, the postglenoid and paramastoid processes, are all characters

* See the Structure and Homologies of Molar Teeth of Mammalia, by E. D. Cope, Journ. Acad. Sci., Philad., 1874.

of that order. The scapular and pelvic arches have the same significance in the gradually-descending spine of the former and pedunculate ilium of the latter. The limbs testify to the same effect, and in the third trochanter of the femur, (small, it is true,) the digitigrade hindfoot, with attendant modifications of the structure of the calcaneum and astragalus. Its only indications of other affinity are a few toward the *Eobasileidæ*, seen in the enlarged cuboid facet of the astragalus, the elongate femur with reduced third trochanter, and the paired horns on the anterior part of the cranium. They present no special marks of affinity to the artiodactyles, and show that the paired horns of the *Eobasileidæ* have no significance in the same direction, as has been supposed by a recent writer on this group.

As compared with the *Rhinoceridæ*, the principal distinctions are to be observed in the feet, in which the median pair of toes are less unequal in proportions. The cranium is still more abbreviated in front and the orbits more anterior, while the bilateral arrangement of horns belongs exclusively to the extinct. The structure of the molar teeth is distinct, but not widely so, and represents a more primitive type, and one approximating the bunodont forms of *Proboscidia* and *Artiodactyla*, and lower types. The same type of detention is displayed by *Palæsyops*, Leidy, of the American Eocene; *Chalicotherium*,* Kaup, of the Miocene of Europe and Asia; and *Titanotherium*, Leidy, of the American Miocene. It is with the latter genus that comparisons must now be made.

Titanotherium proutii, Leidy, is a large species, originally described by Dr. Hiram Prout in the American Journal of Science and Arts † as a *Palæotherium*. It was based on specimens brought by Dr. Prout from the Missouri. Subsequently, Messrs. Owen, Norwood, and Evans named it *Palæotherium? Proutii*;‡ they had procured other material, but based their name on Prout's descriptions. In the same year, Dr. Leidy proposed for it the generic name *Titanotherium*,§ without generic description or diagnosis. In his work on The Ancient Fauna of Nebraska,‖ Dr. Leidy gave a full specific description of the material which had been obtained up to that time, and it is on this and the figures accompanying that our knowledge of *Titanotherium* as a genus reposes. In the Journal of the Philadelphia Academy,¶ 1869, Dr. Leidy had described additional remains, chiefly cranial, some of which belong to different species, and perhaps some of it to those of the present allied genus.

Doctor Leidy gives the dental formula of *Titanotherium*, as I., 2; C., 1; P. m., 4; M., 3, for the maxillary series, and adds:** "Fragments of lower jaws exhibit the same number of molar and canine teeth, and probably there existed also the same number of incisors as in the upper jaw." In the museum of the Academy of Natural Sciences, one of Dr. Prout's original specimens, as indicated by the label and the one first figured by Dr. Leidy, is preserved, but it furnishes no evidence as to the number of premolars. Associated with it in the collection is a mandibular symphysis,†† marked as being one of Dr. Owen's original specimens. These two are peculiar in their iron-rust color, so different from that always characterizing the fossils of the White River epoch

* Professor Gill has created a family, *Chalicotheriidæ*, for this genus.
† II, 288, fig. 1, 1846; III, 248, figures, 1847.
‡ Proceed. Acad. Nat. Sciences, 1850, 66.
§ Proceed. Acad. Nat. Sciences, 1850, 122.
‖ Smithsonian Contrib. to Knowledge, vol. VI.
¶ Extinct Fauna Dakota and Nebraska, 1869, p. 206.
** Page 207.
†† Described by Leidy in his Fauna Dakota and Nebraska, p. 214.

both in Dakota and Colorado, and it is a point worth investigating whether they were really derived from beds of that horizon. The superior size and the color and mineral character of these specimens refer them as probably parts of the same species at least. The symphysis contains the alveoli for, and basal portions of roots of, one premolar, (with two roots,) one canine, and two incisors, on each side. The incisors were evidently well developed, and indicate in the clearest manner that *Titanotherium* and *Symborodon* are distinct genera. With a considerable number of mandibles at my disposal, I have failed to find any trace of inferior incisors in the latter genus; and if they were present at any time, it must have been only during early youth, and as a part of the deciduous dentition.

Prof. O. C. Marsh has recently* described, under the name of *Brontotherium*, a species allied to *Titanotherium proutii*, in which the mandibular dentition is stated to be I., 2; C., 1; P. m., 3; M., 3. If the mandibular fragment described by Professor Leidy as presenting four premolars belongs truly to the *T. proutii*, then the form described by Professor Marsh will occupy a position between it and *Symborodon*. Finally, Dr. Leidy described the horned snout of a species of this group under the name of *Megacerops coloradensis*.† The specimen differs in various respects from any species observed by me in Northern Colorado. It was derived from a locality remote from that which contains the *Symboroda*, from a bed of coarse sandstone entirely different in mineral characters from the argillo-calcareous beds from which the fossils described in this report were obtained. In the absence of knowledge as to the dental characters of this animal, and the consequent uncertainty as to which of the three genera above named it belongs to, I leave it for the present.

Six well-defined species of the genus are known to the writer, which vary in dimensions from that of the Indian rhinoceros to nearly the size of the elephant. They may be readily recognized by the following characters; the most important of which is the basal cingulum of the premolars:

A. Horn above the preorbital region:
- I. Premolars without inner basal cingulum:
  - *a.* Nasal surface continuous with front:
    - Horn-cores large, compressed; zygomata enormously expanded; cranium depressed.—*S. bucco.*
    - Horn-cores large; zygomata not expanded; cranium rather elevated; nasals very short.—*S. altirostris.*
    - Horn-cores mere tubercles; nasals not shortened.—*S. heloceras.*
- II. Premolars unknown; nasal plane sloping downward from a roof-shaped angle with the frontals:
  - Horn-cores very elongate, subcylindric, curved, partly composed of maxillary bones at base.—*F. acer.*
- III. Premolars with a strong internal basal cingulum:
  - Horn-cores short, very stout, and subtriangular in section; nasal bones more elongate.—*S. trigonoceras.*
  - Horn-cores small, compressed, followed by a tuberosity on the frontal bone.—*S. hypoceras.*

AA. Horn-cores above the orbit:
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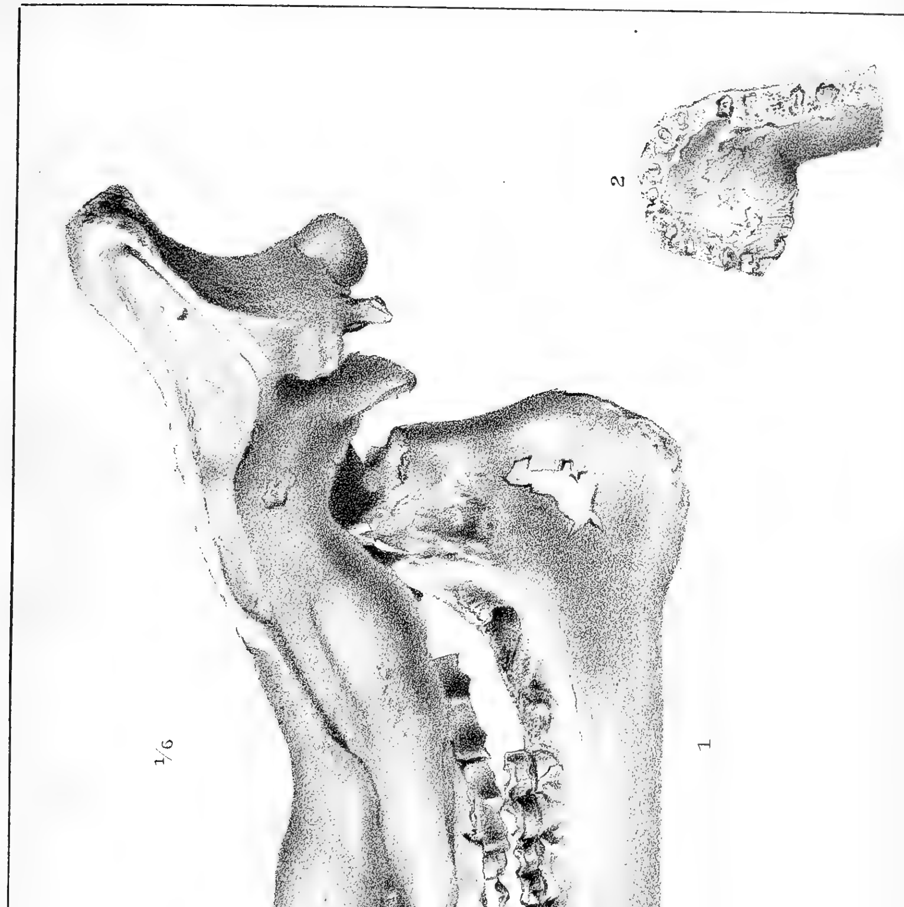
* Amer. Journ. Sci. Arts, 1873, p. 486.
† Report (4to) on Geol. Survey Territories, p. 239, pl. I, figs. 2, 3, and II, fig. 2.



A. Hoen & Co. lith. Baltimore

1 SYMBORODON BUCCO COPE. 2 TITANOTHERIUM PROUTII LEIDY.

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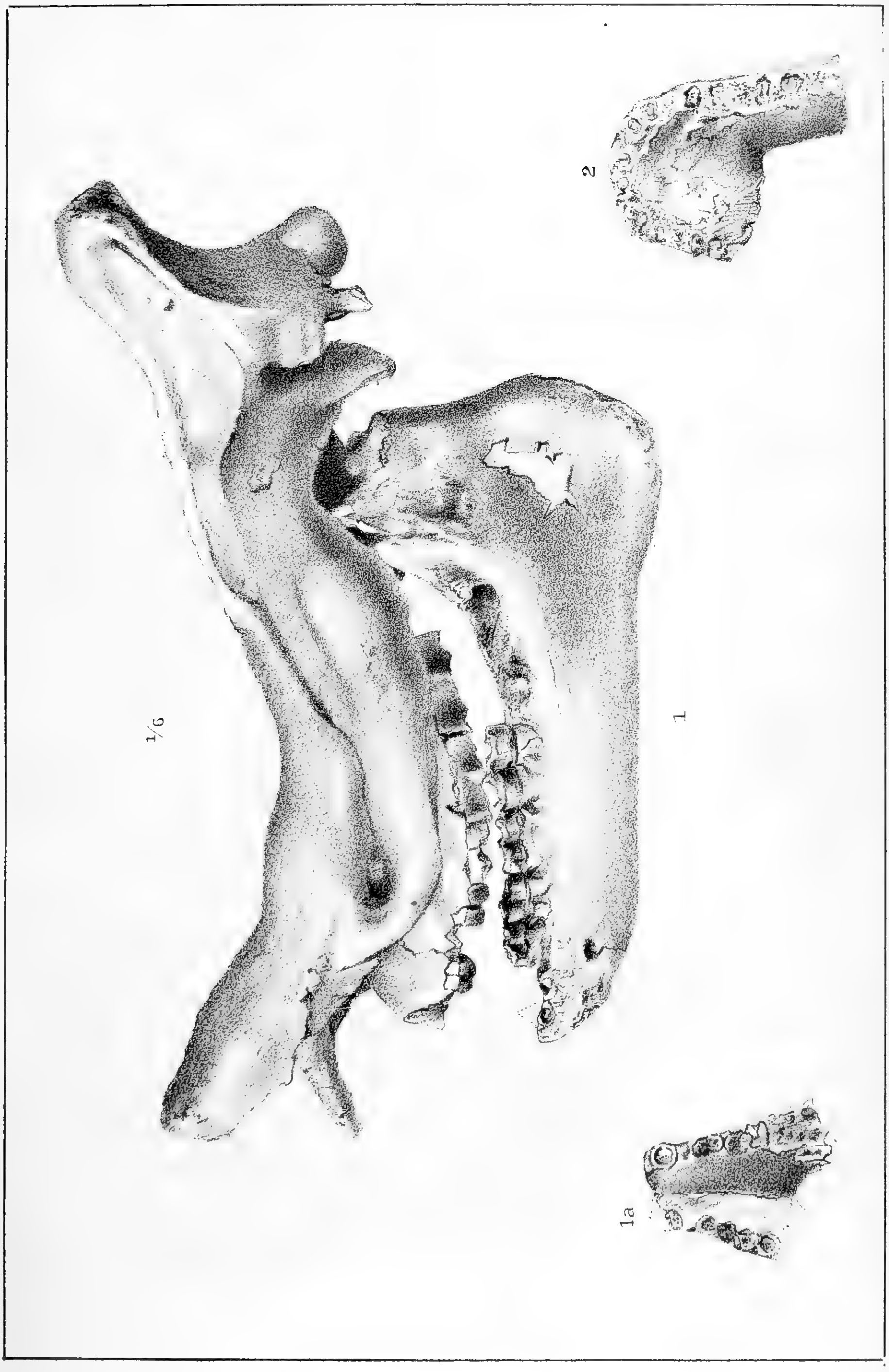

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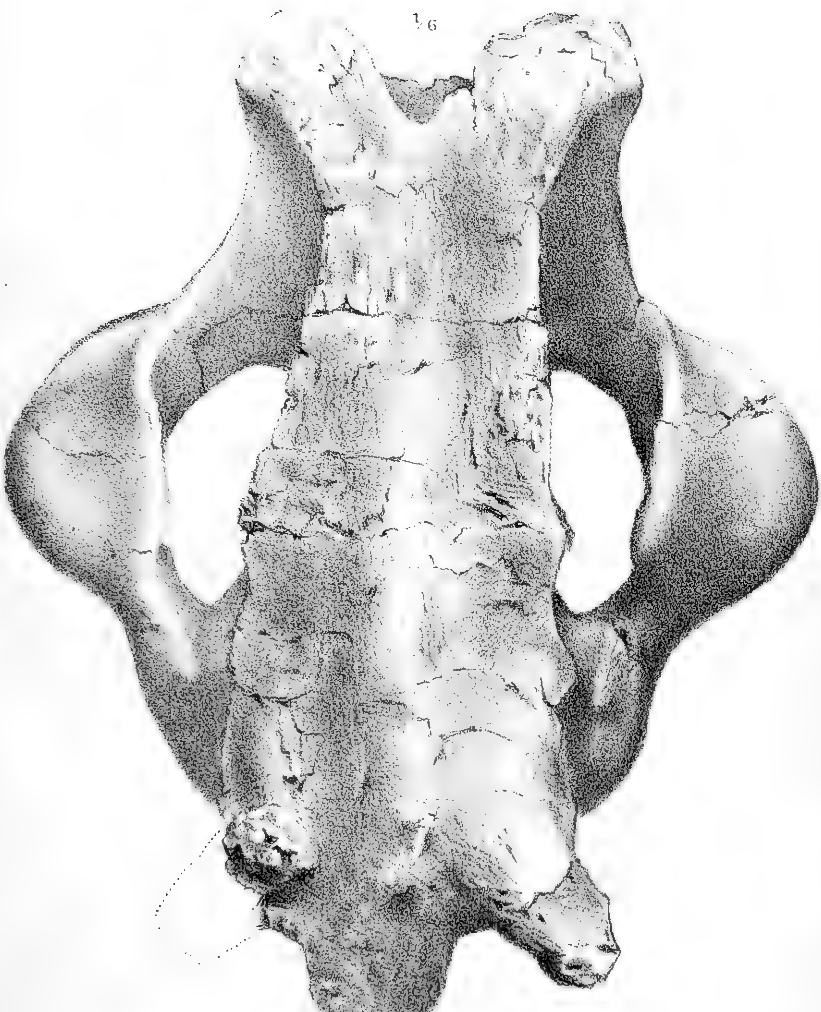
1 SYMBORODON BUCCO COPE. 2 TITANOTHERIUM PROUTII LEIDY.



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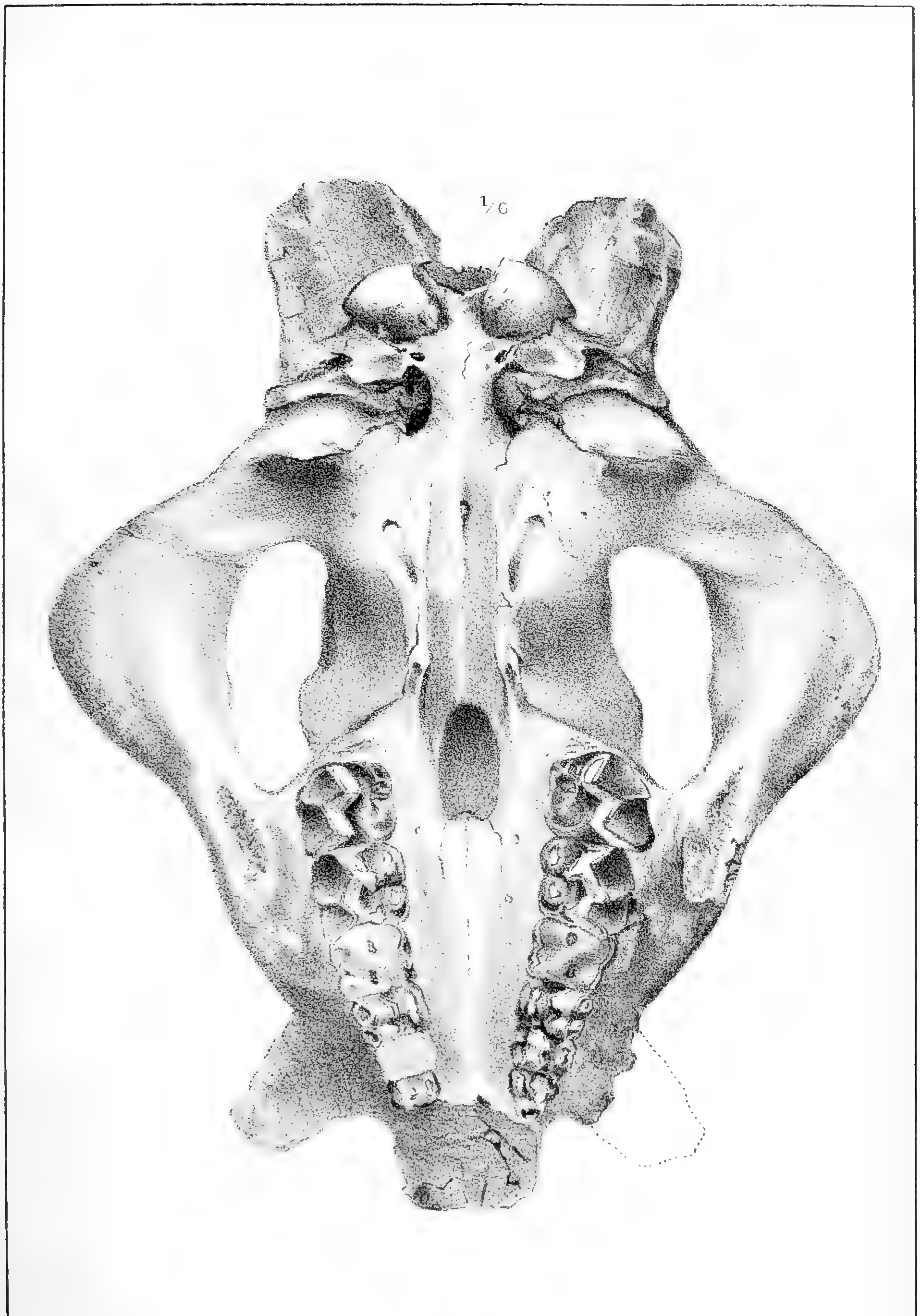

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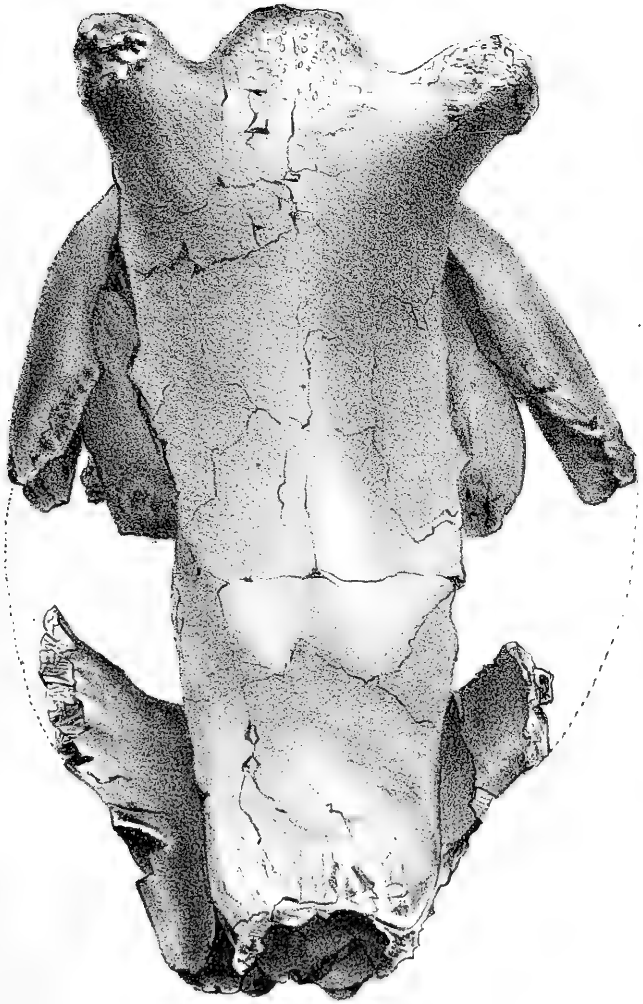
SYMBORODON ALTIROSTRIS COPE.



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SYMBORODON ALTIROSTRIS COPE.

SYMBORODON ACER COPE.

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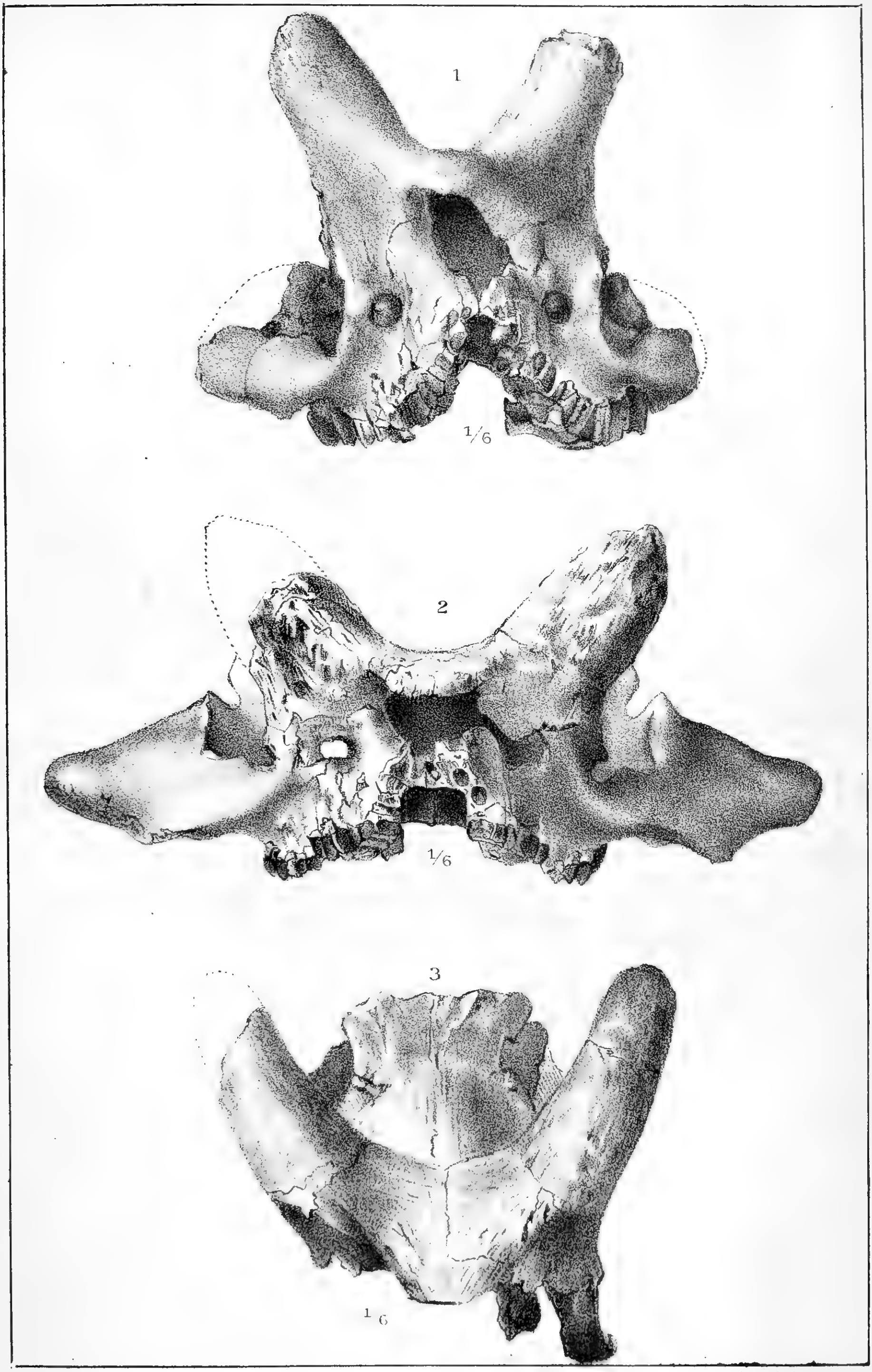

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1 SYMBORODON ALTIROSTRIS. 2 SYMBORODON BUCCO.
3. SYMBORODON ACER.

It is probable that both sexes of these species are horned. This is the case with all of the crania which I obtained in which the nasal region is not wanting, and doubtless many of these are females. The only one which I obtained with reduced horns is one of the largest size, (*S. heloceras*,) and does not probably represent the only female of the collection.

The general appearance of these species when living must have combined features of the rhinoceros and elephant in almost equal proportions. The length of the femur indicates that the first joint of the leg was free from the abdominal integument, and that some of the species stood higher on the legs than the rhinoceros. There is indication of a trunk, probably a short one, since the neck is not so remarkably shortened as to render this organ absolutely necessary. The indications are: the massive borders of the nasal meatus separated laterally from the face by a vertical, obtuse angle; the great stoutness and shortness of the free end of the nasals, which much resemble the same region in the elephant; and the reduction of the premaxillary region and its teeth. It is altogether probable that it had no great length, resembling, perhaps, that of the tapir. These views are in accordance with those already expressed by Professor Marsh in his description of *Brontotherium ingens*.* Professor Leidy had previously inferred a short proboscis for the *Megaceratops coloradoenesis*. As compared with the *Eobasileidæ* of the Eocene, their appearance must have been less exceptional. The proboscidian foot, with short neck, reproduced the elephant; while the narrow head, with the posteriorly placed horns, and the very elongate muzzle, gave these a more suilline expression than the symborodons. The powerful horns, admirably situated for effective use, did not avail to secure their survival beyond the Miocene period more surely than did the laniary tusks of the *Eobasileidæ* in conquering for them a place in the ages that succeeded the Eocene. As the most powerful of the *Ungulata* of the Miocene, they were the legitimate successors of the *Eobasileidæ*, of the Eocene, as these were of the great land-saurians of the Cretaceous. A few mastodons and elephants contested with them the supremacy of the Miocene, and held it without rivals in the Pliocene; but why the less formidable rhinoceros should have continued with them, while the *Symborodons* disappeared, is a problem whose solution cannot yet be conceived.

The material on which the above determinations and deductions are based is abundant. The expedition obtained portions of fifty individuals, probably referable to this genus, and twenty-five complete or fragmentary crania. Those certainly determined belong to the species in the following proportion: *S. bucco*, 3; *S. torvus*, 2; *S. altirostris*, 2; *S. acer*, 3; *S. heloceras*, 1; *S. trigonoceras*, 6; *S. ophryas*, 1. Crania of *S. bucco* and *S. acer* were obtained with mandibles associated; the other species were not; nevertheless, it is probable that some of the various mandibles found separately pertain to the most abundant, *S. trigonoceras*.

SYMBORODON BUCCO, Cope, Synop. New Vert. Col., 1873, 10.

The largest species of the genus approaching nearly the living elephant in size. Represented by an imperfect cranium; by a cranium almost perfect, including, very probably, both mandibular rami, with entire dentition; a fragmentary skeleton, including parts of cranium, teeth, and vertebræ. The crania are very depressed in form, and exhibit a peculiarity in the horizontal expansion of the malar bones, and the still greater enlargement of the zygomatic processes of the squamosal.

*Amer. Journ. Sci. Arts, 1874, p. .

These form two horizontal bony masses of remarkable size, with the exterior border convex in both the vertical and horizontal planes. The nasal bones are flat and truncate wedge-shaped. The horns are situated above the face in front of the orbit, and are expanded in one plane, so as to be much flattened. Their length is moderate, and their direction outward and forward. There are slight angulations of the frontal and zygomatic margins, which form slight contractions of the zygomatic orbital fossa, one behind the orbit, the other marking the anterior four-tenths of the zygomatic fossa. The orbits are small and horizontally oval, and the temporal fossæ contracted. The latter are greatly extended posteriorly, and are bounded by an ear-shaped prolongation of the exterior occipital angular ridge to beyond the line of the foramen magnum. The plane of the vertex and front is wide and uninterrupted by tuberosities, but forms a gently concave continuum. The dentition is $\frac{2}{0}$, $\frac{1}{1}$, $\frac{4}{3}$, $\frac{3}{3}$. The anterior teeth are all small, the posterior large. There is no internal cingulum on the molars, which are smooth and with low internal cones.

Measurements.

	M.
Length of cranium, (33 inches)	0.840
Width of cranium, (25 inches)	.636
Length of nasal bones to bases of horns	.107
Length of orbit	.115
Width of nasals	.152
Width above orbits	.255
Width, least, between temporal fossæ	.170
Width of mass of zygomatic squamosal	.140
Width between temporal fossæ behind	.331

This large quadruped was considerably larger than the *S. acer*, Cope; but the horns are shorter, and of an entirely different form. Its orbits are remarkably small, and during life the eyes were directed more or less obliquely upward. The broad, flat, wedge-shaped head is not unlike that of snapping-tortoise (*Chelydra*) in its physiognomy.

I append here a description of the mandible, on which the species *Symborodon torvus* was established. I am not able at present to refer it to its proper cranium, but hope soon to have that opportunity. It nearly resembles that of *Symborodon bucco*. Dentition; I., (?) 0; C., 1; P. m., 3; M., 3; the canines slightly separated from each other, but not from the first premolar; crowns of the premolars with L-shaped crescents, as in *Rhinocerus;* of the molars with completed crescents; the last molar with third posterior crescent; symphysis mandibuli co-ossified; crowns of canines not projecting, conic. Symphysis oblique; ramus rather shallow. Last molar with three columnar ribs on the outer side, four on the inner, produced by the continuance inward of the ridges from the anterior and posterior outer cusps. Enamel nearly smooth; a cingulum round inner basis of crown of canine.

Measurements.

	M.
Length of mandibular ramus	0.520
Length of symphysis	.144
Length of series of molars	.320
Length of series of true molars	.215
Length of last molar	.088
Length of penultimate molar	.072

SYMBORODON ALTIROSTRIS, Cope, Synop. New Vert. Col., 1873, 12.

A large species represented especially by a nearly perfect cranium, and probably by several others, some of which are nearly perfect. The muzzle is shorter than in any other, and the orbit more anterior. The premaxillary and nasal bones are shortened; the latter broad, obtuse, and massive, and standing on a plane above that of the front. The vertex and front do not form a continuous concavity, as in other species, but are divided equally by a tuberosity on each side; posterior to these the vertex is flat and rather wide, while the front anterior to them is roof-shaped. The temporal fossæ do not project so far behind the occipital union as in some species, and the squamosal bone is not remarkably expanded laterally. There is a small postorbital angle. The front rises much to the basis of the horns. Each of these stands above the orbit and face at the base, and one-third of each over orbit; face and nasal bones above the latter. They are straight, with approximated bases, and but moderately divergent. They are subcylindrical at base, and compressed inward and forward at the narrow apex. The maxillary rises on the base, forming a squamosal suture on the anterior and lateral aspect, opposite the nasal meatus, and below the nasal bones.

The first premolar and two incisors are very insignificant; canines with short, stout crown. The premolars have no inner cingulum, but two smooth cones. The molars have only two inner cones, which converge toward the crescents. The latter do not give origin to any transverse crests.

Measurements.

	M.
Length of cranium, (25½ inches)	0.649
Length of crowns of teeth from canine	.444
Length of true molars	.240
Length of last molar	.083
Width of last molar	.084
Width of first premolar	.035
Length of first premolar	.026
Length of orbit	.090
Least width of parietal plane	.235
Length of nasals from horns	.045
Width of nasals at horns	.152
Length of horn-core above orbit, (9 inches)	.229
Length of horn-core above nasal bones	.140

This is one of the most formidably-armed species, and must have presented a most *outré* appearance in life, owing to the extreme shortness and elevation of the muzzle and anterior position of the orbit. The general form of the cranium reminds one of a pack-saddle without the hind cross-trees.

I owe the discovery of the beautiful cranium, which represents the species, to the acuteness of my assistant, William G. Shedd.

SYMBORODON HELOCERAS, Cope, Proceed. Amer. Assoc. Adv. Sci., 1873, 109; Synop. New Vert. Col., 1873, p. 14. *Megaceratops heloceras*, Cope, Pal. Bull. No. 15, p. 4.

Free portion of nasal bones as broad as long. Horn-cores mere tuberosities, with one flat outer, and one very convex, face presenting in the other directions; summit contracted, truncate, oval in outline. A distinct superciliary ridge. The upper surface of the cranium rather narrow, gently concave longitudinally. Molar teeth with smooth enamel; the crescents not displaying the T-shaped branches seen in *S. ophryas*. Zygomas deep, flat, not expanded.

Measurements.

	M.
Length from posterior rim of temporal fossa to middle of osseous eyebrow	0.472
Least width of parietal plane	.104
Superciliary width	.260
Elevation of horn-core	.050
Length of free nasal bones	.010
Width of free nasal bones at base	.010

SYMBORODON ACER, Cope, Proceed. Amer. Assoc. Adv. Sci., 1873, 109; Synop. New Vert. Col., 13. *Megaceratops acer*, Cope, Pal. Bul., 1873, No. 15, 4.

Another huge mammal, second only to the preceding in size, but more formidably armed, was its contemporary. It is represented in my collection chiefly by the entire upper portion of a cranium; the greater part of a skeleton, with upper part of cranium and lower jaw with teeth; and by portions of skeleton, with horns, of a third. Top of head concave longitudinally, somewhat convex between the orbits, and flat, forming a narrow plane between the temporal fossæ; latter produced backward. Orbit not inclosed behind; an overhanging superciliary ridge. Nasals exceedingly short and massive, abruptly decurved, each supporting a large acute horn-core, which is connected with its fellow by a ridge at the base, and diverges widely from it, with an outward and forward curve to the acutely-compressed apex. Each horn-core composed externally of the ascending portion of the maxillary bone as high as some distance above the base of the nasals. Nasals abruptly contracting to a stout subangular apex. Zygomatic arch deep.

Mandibular ramus massive, and in every respect stouter than in *S. bucco*, and similarly without incisor-teeth.

Measurements.

No. 1.

	M.
Length of cranium, (35 inches)	0.895
Length from posterior rim of temporal fossa to middle of superciliary ridge	.345
Width of front between eyebrows	.210
Length of horn-core on inner side, (10 inches)	.254

No. 2.

Length of first and second molars	.135
Width of second inferior molar	.040
Depth of ramus at second inferior molar	.123

This was a truly formidable beast, exhibiting a position of the horns strangely the reverse of that seen during the present period. Its size exceeded that of the Indian rhinoceros.

SYMBORODON TRIGONOCERAS, Cope, Synop. New Vert. Col., 1873, 13. *Brontotherium trigonoceras*, Marsh, Amer. Nat., 1874, p. .

A species similar in size to the last, but presenting peculiarities not shared by any other species of the genus. The first of these is the strong basal cingulum on the inner side of the premolars, which is continued in a less prominent form between the bases of the cones of the molars. The bases of the cones of the premolars are strongly plicate. The horns rise from a basis which is anterior to the orbit, and are short and very stout. They are triquetrous, with the faces interior, posterior, and latero-anterior, and are directed outward and upward. Their extremities are coarsely rugose and subtriangular, sending an apex toward the middle line, and decurved convex outwardly. The vertex and front are a continuous gentle concave plane, which is narrowed behind and widened in front to support the bases of the horns. A postorbital process. Orbit well developed, not remarkably anterior; nasals elongate, transversely plane, decurved, slightly emarginate at end. Premaxillary prominent, with distinct spine, and extending as far as the line of the end of the nasals. Squamosals not expanded. First premolar small; canine narrow.

Measurements.

	M.
Total length of cranium, (27 inches)	0.686
Total width, including zygomas	.433
Width between temporal fossæ at inion	.102
Width in front	.247
Width of orbit	.102
Length of horn above orbit	.122
Length of horn above nasals	.045

The horns of this species, though stout, are less formidable as weapons than those of some of the others.

At one locality teeth and a few other fragments of a very large individual were discovered, and a few feet distant a series of cervical and dorsal vertebræ of appropriate size. A little further off, in an opposite direction, a portion of the skeleton of a *S. bucco* was found, with the characteristically expanded zygomatic masses. It is not unlikely, however, that the vertebræ really belong to the *S. trigonoceras*. They indicate an animal of huge proportions, and present a marked feature in the enormous length of the neural spines of the dorsals. These are compressed at the end and enlarged at the summit, indicating that the animal supported a hump, somewhat as in the bison.

Measurements.

	M.
Length of crown of fourth upper premolar	0.050
Width of crown of fourth upper premolar	.065
Length of cervical vertebræ, (to base of ball)	.060
Depth of articular face behind	.114
Width of articular face behind	.110
Diameter of cervical canal	.024
Diameter of vertebral canal	.065
Length of centrum of dorsal to ball	.065
Depth of articular face behind	.108
Width of articular face behind	.111
Depth of base of diapophysis	.070

A peculiarity of the dorsal vertebræ consists in the presence of two tuberosities at the base of the articular convexity, resembling the articular facets for chevron-bones, but at the opposite end of the centrum.

Beside the above, six more or less complete crania were found, and two others without horns and otherwise mutilated, so as to render it uncertain whether they do not belong to the *S. ophryas*. These exhibit some range in size; one of them presents the following—

Measurements.

	M.
Total length of skull, (30 inches)	0.762
Length to orbit	.172
Length to posterior base of horn	.280
Width at zygomas, (17 inches)	.432
Height of horn above orbit	.127
Length of free part of nasal bones	.127
Width of base of nasal bones	.133
Width of horn on antero-exterior face	.120
Width between temporal fossæ posteriorly	.260
Width between apices of horns, (17 inches)	.432

Professor Marsh described* a species allied to or identical with this one, under the name of *Brontotherium ingens*. It was based on a cranium which has so great a resemblance to those of *S. trigonoceras* that I have regarded it as pertaining to it,† and written Professor Marsh's name as a synonym, as it was published several months later than mine. Subsequently,‡ Professor Marsh pointed out a number of characters which he finds in my description as justifying him in retaining the species as distinct. He states that it is "nearly or quite twice as large in bulk. The horn-cores also are very differently placed; the nasals are more elongated, and not emarginate at their extremities; the premaxillaries are not prominent. The squamosals are greatly expanded, and there is no postorbital process." Commencing at the last of these definitions, I would remark that (1) the postorbital process is a rudiment in one of the crania, and is entirely wanting in a larger one; (2) the squamosal processes of the zygomata are not more expanded than might be looked for in the adult male of *S. trigonoceras*, and would not be regarded as remarkable in this respect by one who has seen the larger expansions of the *S. bucco*; (3) there is no difference in the premaxillaries, which are more prominent than such species as *S. altirostris*; (4) "The nasals are more elongate and not emarginate at their extremities;" Professor Marsh's figure represents the nasals quite elongate as compared with other species, and exactly as in some of my specimens; the emargination is slight and is not always present in *S. trigonoceras*; (5) there is no difference in the form and position of the horn-cores; (6) the superior size: I have no crania so large as that described by Professor Marsh, which he states to be $0^m.915$ long and $0^m.558$ wide through the zygomas, with horn-cores 20 inches apart at the apices. My largest measures $0^m.762$, $0^m.432$, and 17 inches, respectively. The specimen from which vertebræ and a premolar tooth were described above approaches nearer in dimensions; thus, the fourth premolar measures—

	S. trigonoceras.	*S. ingens.*
Length of crown	0.050	0.053
Width of crown	.065	.069

While still under the impression that the species are the same, I defer final conclusion until all of my material is in suitable condition for study

SYMBORODON OPHRYAS, Cope; *Miobasileus ophryas*, Cope, Pal. Bull., No. 15, 3; Proc., Amer. Assoc. Adv. Sci., 1873, 108.

Established on a cranium with nearly complete dentition, but without mandibular ramus. Head elongate, concave in profile from the interorbital region to the supraoccipital crest. This is transverse and concave, the posterior borders of the temporal fossæ extending behind it. These fossæ leave a narrow, flat vertex between them. Zygomatic arch stout and rather deep; a strong postglenoid process. Nasal bones very massive; their free portion elongate, hornless. A massive horn-core rising from above each orbit; no superciliary angle or ridge. Orbit not inclosed behind. Of molar teeth only P. m. 3–4, M. 1–2–3, preserved; the M. with two, the P. m. with one inner cone and two outer continuous crescents. The latter send inwards to one side of the cones a transverse ridge. Incisors and canines unknown. The malar bone is flat and proportionally deep below the orbit. Front concave transversely just behind between the horns. Latter massive and a little compressed. Nasal bones convex longitudinally and transversely, slightly rugose. Trans-

*Amer. Journ. Sci. Arts, 1874, Jan., p. 85.
† Bulletin of U. S. Geological Survey of Terrs., No. 2, p. 28.
‡ American Naturalist, Feb., 1874, p. 84.

verse ridges of teeth with transverse expansions at their inner extremity, being thus T-shaped.

Measurements.

	M.
Length from apex of nasals to occipital condyles, (axial, 26.5 inches)	0.664
Length from occipital condyle to fundus of palate	.376
Length from occipital condyles to end of palatine lamina pterygoidea	.270
Length of four last molars	.242
Length of three last molars	.195
Length of last molar	.068
Width of palate at narial notch	.116

The dental characters of this species ally it to the *S. trigonoceras*, but the form as well as the position of the horns is quite different. Instead of being triangular, a section of the base of these is elliptic. Extremity conical.

SYMBORODON HYPOCERAS, Cope; *Miobasileus hypoceras*, Cope, MS.

This species reposes on a fragmentary cranium only, which embraces nasal, maxillary, frontal, malar bones, &c., both zygomata, premolar and parts of molar teeth, &c. These fragments were taken out of the matrix by the writer, and were found in juxtaposition. They represent parts of the same skull, and, as no other was found in the same bank, are probably without admixture.

The first characteristic of this species is the elongate form of the face anterior to the orbit as compared with other species. The column which separates the orbit from the infraorbital foramen is flat and has a wide external face, instead of being a cylindric column as in *S. acer*, *altirostris*, *bucco*, and *ophryas*. In *S. trigonoceras* it is wider, but, instead of being flat, presents a strong vertical ridge of the lachrymal bone. The infraorbital canal is hence longer than in those species, the more as it does not communicate with the orbit at as anterior a position. Between this point and the preorbital border, the orbit is strongly concave. From the infraorbital canal to the narial orifice, the face is flat, and the border of the meatus is thin, somewhat as in *Rhinocerus*, but includes a narrow prolongation of the large sinus common to this genus. The premaxillary bone does not appear to enter into it. It is evident from the weakness of this support that there could have been no horn of great size or strength above it, and the character of the horn-core preserved is consistent with this view. This consists of the extremital part, thus not exhibiting the basal sinuses. Its section is a compressed oval, narrowed in front; its profile with parallel outlines and a little recurved and not very rugose. Its size as compared with the rest of the skull is the smallest in the genus, and not more than half the proportions of the *S. altirostris*.

A bone of the upper cranial walls was found in place above the second and third premolars, but presents some puzzling peculiarities of form. It is either the posterior part of the nasals or anterior portion of the frontals, and a short decurved border is either that of the nasal meatus or of the orbit. The left maxillary and lachrymal bones are the ones preserved, and the present bone probably belongs to the same side, which agrees with a mark I placed upon it when I exposed it, indicating the anterior and posterior extremities. There can therefore be little doubt that the element is the frontal. The reason for this investigation is the fact that it supports on its anterior extremity a large osseous tuberosity, which consists of a mass of bone co-ossified with the upper surface, as in the horn of the giraffe. It is broken off at the antero-external sutural line of the bone, so that it probably extended over the adjacent margin of the maxillary. It resembles in form the short-horn cores of *Symborodon heloceras*, but is not as in that species an autogenous part of the bone, and its base is therefore not excavated by the anterior part of the frontal sinuses. Thus it is probable that this species possessed two pairs of osseous processes or cores on each side, the one on the nasal, the other on the frontal bone. The absence of interior sinus shows that the latter is not homologous with the horn-core of the typical species of *Symborodon*, while the structure of the post-narial walls (composed of both nasal and maxillary) is clear as to the presence of those sinuses. The horn-core first described is probably from the left side as indicated by its shape. Their existence is also to be inferred from a fragment which resembles the base of the usual horn-core of the other species, especially *S. trigonoceras*. From the preceding it may be derived that this species possesses either two pairs of horn-cores, of which the posterior are on the frontal bone, or that it possesses a single pair on the frontal bone only. As the former is much the most probable supposition, I hesitate to separate this species as a genus distinct from the *Miobasileus ophryas*, which it resembles in many respects.

A portion of the margin of the frontal bone supports an angular projection, doubtless postorbital. The malar bone has an extensive surface of attachment with the maxillary. Its anterior portion bounding the orbit below is a narrow prominent rib, as in *S. trigonoceras*, and different from that of *S. ophryas*. The zygomata are strong, but not expanded; they resemble those of *S. trigonoceras*; but, while shorter than in a specimen of the latter, the squamosal process is deeper. A portion of the nasal bone shows that they were short and light.

There are teeth or alveoli representing four premolars and three true molars as well as a canine. In a right premolar, No. 2, there is a strong basal cingulum, from which coarse plicæ extend inward. The inner cones are confluent into a curved ridge, which is connected by a lower ridge with the outer crescents. The latter are entirely confluent. The canine has a short recurved obtusely conic crown, with a strong cingulum round its posterior base, as in other species of the genus.

Measurements.

	M.
Length from front of orbit to glenoid fossa, (axial)	0.365
Depth of malar below orbit	.020
Depth of squamosal process	.082
Length of molars and last three premolars	.293
Length of last three premolars	.110
Length from nasal meatus to orbit	.103
Length of crown of second premolar	.029
Width of crown of second premolar	.038
Height of crown of canine	
Diameter of crown at base	
Depth of frontal tuberosity	.038
Diameter of frontal tuberosity	.075
Diameter of horn-core, transverse	.038
Diameter of horn-core, longitudinal	.049

Although the specimen from which this species is described is as large as the smaller of the *S. trigonoceras*, it does not belong to an old animal, as the cranial sutures are distinct. It makes one more addition to our knowledge of these curious forms, whose abundance during the Miocene period reminds one of the antelopes of the present period in Africa. It is so distinct from the typical species of *Symborodon* as to render it not unlikely that it will be proper to call it *Miobasileus hypoceras*.

HYRACODON, Leidy.

HYRACODON NEBRASCENSIS, Leidy, Ext. Fauna Dak. and Neb., p. 232.

Abundant in Colorado as in Dakota. During maturity, the first inferior premolar is shed, while that of the upper jaw is retained, leaving the formula $\frac{3}{4}$, $\frac{4}{4}$.

HYRACODON ARCIDENS, Cope, Paleont. Bull., No. 15, 2.

Established primarily on a specimen which includes the left maxillary and premaxillary bones with the teeth as far posteriorly as the fifth molar. Some of these were not fully protruded, and the third premolar of the deciduous dentition was attached, the removal of which displayed the crown of the permanent tooth. The species is about the size of the *H. nebrascensis*, and differs in the form of the inner lobes of the molars and of the first premolar. All the molars have the outer longitudinal and inner transverse crests, the posterior short, the anterior much curved backward round it, and thus forming the inner boundary of the tooth-wall. The first premolar is shorter than the others, and has a short anterior lobe. The milk-molars show more nearly transverse crests as in *Rhinocerus*, but the first premolar had the anterior lobe. Canine and first incisor short, conic; second incisor with an outer lobe; median incisor transverse; enamel smooth.

Measurements.

	M.
Length of four superior molars	0.072
Length of diastema	.006
Length of canine and incisors	.020
Length of first premolar	.014
Width of first premolar	.012
Length of third premolar	.021
Width of third premolar	.022
Height of third premolar	.025

ACERATHERIUM, Kaup.

At least three species of this genus have left remains in the White River beds of Colorado, for the third, which I formerly referred to the preceding genus, may find a more appropriate place here. They are distinguished as follows:

I. Crowns of premolars 2–3–4 broader than long:
 Smaller: symphysis mandibuli much shortened and contracted.—*A. mite*.
 Larger: symphysis elongate, with large incisors.—*A. occidentale*.
II. Crowns of premolars 2–3 as long as or longer than wide:
 Size of *A. occidentale;* P. m., 2, subcuneiform.—*A. quadriplicatum*.

ACERATHERIUM MITE, Cope.

This species is intermediate between the *A. occidentale* and *Hyracodon nebrascensis*, not only in size, but in its short concave diastema, and short, contracted symphyseal region. There are two large external incisors, which are not only absolutely but relatively much smaller than in the *A. occidentale.* If any median incisors exist, they must be small, as the narrow fracture-surface below the original alveolar border exhibits no trace of alveoli. The mandibular teeth are rather elongate, the first having two roots. The ramus has not the incurvature to the diastema seen in *H. nebrascensis*, and is relatively not so deep, and more robust below the last molar than in that species.

Associated with this mandibular ramus, I found the large part of the skeleton of the same animal and the superior molar dentition of two individuals of the same size. The teeth resemble those of the *A. occidentale*, but, besides the smaller size, exhibit differences in the structure of the premolars. The first is about as broad as long; has a strong anterior basal cingulum, and both of the transverse crests strongly curved backward at their inner extremities. The second is transverse, and the transverse crests are simple and distinct distally. The third premolar has its inner anterior angle produced at the base of the crown. The transverse crests form a continuous circuit inwardly, and it is the posterior which curves forward and joins the anterior a short distance external to the inner termination of the latter. In the fourth premolar, the transverse crests are entirely distinct, and the anterior is the longer, causing, as in the third, the protuberance of the inner anterior angle of the shoulder of the crown. Both are bounded at the base by a cingulum, which extends round the posterior base to the outer crest. The posterior transverse crest sends forward a process toward (in one specimen joining) the anterior at one-third the length from its end. The transverse crests of the true molars are simple, and the anterior cross-crest the thickest; no cingula on the inner bases.

Measurements.

	M.
Length of inferior molar series	0.172
Length of premolars only	.080
Length of first premolar	.015
Length from first premolar to end of symphysis	.040
Length of symphysis	.048
Width of symphysis at diastema	.040
Depth of ramus at last molar	.050
Thickness of ramus at last molar	.030
Diameter of inferior incisor	.010
Length of series of superior molars	.153
Length of series of superior premolars	.073
Length of first premolar	.013
Length of fourth premolar	.022
Width of fourth premolar	.032
Length of penultimate molar	.037
Width of penultimate molar	.038

The other series of molars presents similar dimensions, and a few slight variations in structure.

The remainder of the skeleton pertains to one or the other of these individuals. The axis strongly keeled below; the anterior articular surfaces are widely expanded, and the posterior is concave and oblique. Its neural carina is elongate and elevated behind. The dorsal and lumbar vertebræ are slightly opisthocœlian. The glenoïd cavity of the scapula is a broad oval, and the coracoid is quite prominent, but obtuse. The internal condylar tuberosity is strong, the external almost wanting; the internal distal crest is very strong. The supracondylar fossæ are very deep. The radius is a stout bone, and attached to the slender ulna by coarse sutural surface, which is very narrow along the middle of the shaft. The femur is stout, and its large trochanter is recurved anteriorly as well as posteriorly so that both faces are concave. There is an elongate crest in place of the little trochanter. The trochlear groove is angular, and bounds a pit just above its proximal end; the condyles are subequal.

The crest of the tibia is deeply grooved, and the spine divided by a wide gutter. The external face is concave proximally, and turns to the front distally. The inner proximal face unites on the last third of the length, to become the internal face. The distal posterior face narrows upward, and runs out below the inner facet of the head. The astragalus has the hour-glass face quite open. The inner tuberosity of the head extends within the line of the trochlea a half-inch. The cuboid facet is oblique and parallel to the outer margin of the head, and constitutes one-fourth the width of the latter.

Measurements.

	M.
Length of radius	0.198
Diameter of its carpal face	.041
Width of humerus, distally	.058
Depth of outer condyle of humerus, distally	.048
Long diameter of glenoid face of scapula	.042
Short diameter of glenoid face of scapula	.038
Length of femur, (over all)	.295
Proximal width of femur, (over all)	.100
Diameter of head, (antero-posterior)	.042
Least transverse diameter of shaft	.035
Transverse diameter of condyles	.060
Antero-posterior diameter at condyles	.084
Length of tibia	.230
Diameter of head, antero-posterior	.580
Diameter of head distally, antero-posterior	.036
Diameter of head distally, transverse	060
Diameter of head of astragalus, transverse	048

This rhinoceros was about the size of a mule.

ACERATHERIUM OCCIDENTALE, Leidy, Ext. Fauna Dak. and Neb., p. 228, Plate xxii.

Several specimens from different localities.

ACERATHERIUM QUADRIPLICATUM, Cope, *Hyracodon quadriplicatus*. Cope, Pal. Bull., No. 15, p. 1.

This species is similar to the last in bulk, with greater proportional elongation of the teeth of the premolar series, at least. It is represented by two individuals, one possessing the permanent, the other the temporary dentition, at least in part.

The former presents only the second and third premolar teeth with an alveolus of the first. The third premolar has four roots and strong basal cingula fore and aft only. The transverse crests are simple and separate. A strong but short crest originates from the outer marginal crest between them, and being in near proximity to the anterior and transverse, it nearly isolates a triangular valley with it. There is a low tubercle between the bases of the inner extremities of the transverse crests. The second premolar is three-rooted only, and is narrowed anteriorly. Its two inner cross-crests are widely separated, and the intervening branch is rudimental. The anterior prolongation of the external crest is longer than the posterior.

The second specimen consists of molars in both maxillary bones, viz: the four premolars, probably deciduous. They differ in appearance from those above described, but not in essential details.

The transverse crests are little curved, and the outer elevated crest uninterrupted. A short elevated fold proceeds from the latter, dividing the head of the transverse valley. A compressed conic tubercle stands between the inner extremities of the crests. The first premolar has two transverse crests and an anterior tubercle. The posterior crest is strongly curved backward at its inner end. A strong cingulum surrounds the base of the crown except on the outer side.

Measurements.

	M.
Length of three anterior molars	0.090
Length of third molar	.030
Width of third molar	.033
Length of first molar	.026
Width of first molar	.019

ANCHITHERIUM, Kaup.

Three species of this genus left their remains in considerable abundance in the Miocene of Colorado. One of these is the *A. bairdii*, Leidy; a second is similar to, and a third smaller than, that well-known animal. They are chiefly known from molar teeth, but greater or less portions of the entire skeleton are frequently found. The following are some of the characters by which the teeth may be recognized:

I. Anterior median tubercle not separated from inner, obsolete on the second premolar:
  A median ridge on each outer lobe, and basal tubercle between the inner.—*A. bairdii.*

II. Anterior median tubercle well separated from inner:
  Second premolar with anterior median tubercle distinct at both ends; no inner basal lobe.—*A. cuneatum.*
  No inner basal lobes; crescents with concave outer faces.—*A. exoletum.*

These are the only species of horses known to occur in the Colorado Miocene.

ANCHITHERIUM BAIRDII, Leidy, Ext. Fauna Dak. and Neb., p. 303, Pl. xx.

Not uncommon.

ANCHITHERIUM EXOLETUM, Cope, *spec. nov.*

Established on a portion of the right maxillary bone, which contains the last premolar and first premolar in perfect preservation and part of the third premolar. These teeth differ from the corresponding teeth in *A. bairdii* in many respects, resembling in the constitution of their outer lobes some of the symborodonts. The outer faces of these are uniformly concave to near the shoulder, leaving a very narrow basal ridge and no longitudinal median ridges. The intercrescentic ridge is incurved and not straight. The anterior middle tubercle is separated from the inner by a deep fissure and grooves to the base; the median is, on the other hand, continuous with the posterior inner. The posterior median is very small. The anterior and posterior basal ridges are small, and there is no trace of basal tubercle between the two medians. Enamel smooth.

The size of this animal was probably that of the *A. bairdii*, but the molar teeth have the antero-posterior diameter greater in proportion to the transverse than in that species. The *foramen infraorbitale exterius* is over the front of the fourth premolar; it is above the front of the third in *A. bairdii.*

Measurements.

	M.
Length of fourth and fifth molars	0.0275
Length of fourth molar	.0140
Width of fourth molar	.0125
Elevation of fourth molar	.0080
Length from front of malar to *foramen infraorbitale anterius*	.0140

This species differs from the *A. agreste*, Leidy, in size about as the *A. bairdii.* The former is only known from mandibular teeth.

ANCHITHERIUM CUNEATUM, Cope, Paleont. Bull., No. 16, p. 7, (August 20, 1873,) specimen No. 1.

The smallest species of the genus represented by both maxillary bones of one individual; several loose molars and a maxillary bone with teeth of others. In the first-named specimen, the second premolar has the elongate form of the corresponding deciduous molar of *A. bairdii*, but I am not sure whether it is the deciduous or permanent one in the present case, as the series only includes the fifth molar. The middle anterior tubercle is directed forward, inclosing an angular fossa with the inner. The latter is separated from the posterior by a basal tubercle, but there is none on the third premolar. The posterior median tubercle is well developed. The outer faces of the outer lobes are concave; sometimes with a faint median ridge.

The fore and aft cingula are well developed, and the basal parts of the posterior transverse ridges are connected with the posterior median tubercles.

Measurements.

	M.
Length of M. 2 and 3 of No. 1	0.0260
Length of M. 1 of No. 1	.0130
Width of M. 1 of No. 1	.0110

The specimen measured as No. 2 in the original description does not belong to the species.

Another specimen contains what are without doubt the permanent third, fourth, and fifth molars. These resemble the corresponding ones of the specimen just described, differing only in being a little smaller. Besides the small size, they differ from those of *A. bairdii* in the entire absence of the inner basal tubercles, and in the rapid reduction in size of the molars from the fifth forwards. The anterior median lobe is very distinct, and the posterior median small.

Measurements.

	M.
Length of third, fourth, and fifth molars	0.0350
Length of third molar	.011
Width of third molar	.011
Width of fifth molar	.014
Length of fifth molar	.013

Since the description of this species was published, Professor Marsh has described an *Anchitherium* of about the same size, from the Miocene of Nebraska, under the name of *A. celer.** It will be desirable to institute comparisons between these to settle the question of their distinctness or identity.

* Amer. Journ. Sci. Arts, 1874, p. 251.

ANCHITHERIUM AGRESTE, Leidy, Report U. S. Geol. Surv. Terrs., (4to,) I, p. 251, Pl. vii.

A portion of the left mandibular ramus, with the last two true molars remaining, indicates a larger species than any of the preceding, and not materially different from that described by Leidy as above.

ARTIODACTYLA.

OREODON, Leidy.

Remains of species of this genus are exceedingly abundant in the Miocene of Colorado, but represent but two species, which are identical with those already known from Dakota and Nebraska.

OREODON CULBERTSONII, Leidy, Ext. Fauna Dak., &c., p. 86.

OREODON GRACILIS, Leidy, Ext. Fauna Dak., &c., p. 94.

About one specimen in ten of the genus belongs to this species.

POËBROTHERIUM, Leidy.

Extinct Fauna Dakota, &c., p. 141.

This genus differs from *Amphitragulus*, Pom., in the association of the first inferior premolar with the canine and incisors rather than with the remaining premolars. Dental formula I., $\frac{?}{3}$; C., $\frac{1}{1}$; P. m., $\frac{4}{4}$; M., $\frac{3}{3}$; the diastema between the first and second premolars only; canine more or less approximated to the first incisor. The arrangement in the anterior part of the upper jaw has not yet been described. There is a diastema behind the first premolar, and one in front of it. The canine is a weak, simple-crowned tooth, and is immediately preceded by a large, canine-like, exterior incisor. The existence of other superior incisors cannot be demonstrated in my specimens.

As already known from the descriptions of Leidy, the otic bullæ are enormously expanded. Their walls are either occupied with an extensive diploë, or lined with a cancellous layer, which gives a reticulate net-work or section. The osteology of this genus presents a number of interesting features. The cranium only has been described by Professor Leidy. The following observations are based on portions of several skeletons, which include the maxillary, mandibular, and other cranial bones, which I extricated from the matrix myself. The dentition agrees with that figured and described by Leidy.

The *atlas* is rather broader than long, with thin diaparapophyses, pierced by the usual foramen at the middle of the base, and produced well backward at the outer margin. The articular facets of the axis are continuous below the *foramen dentale*. The neural arch is regularly convex and without keel on its posterior .4; but the anterior .6 consists of a flat facet descending obliquely to the neural canal, with a median keel and prominent lateral angle descending to the base of the diapophysis in front. The third and fourth cervical vertebræ are enlarged and quite elongate, and present the usual peculiarity of the *Camelidæ* in the position of the canal for the vertebral artery. It perforates a part of the base of the neurapophysis, and not that of the diapophysis. The latter is a decurved lamina, extending the entire length of the centrum, and sending a strong angular ridge from the posterior outer angle to the anterior zygapophysis. The zygapophyses are connected by a strong longitudinal angular ridge. The neural spine is a prominent keel of no great elevation. The hypapophysis is an acute keel, low in front, but produced downward and backward to a rugose, obtuse extremity. The centra are slightly opisthocœlian; the articular surfaces so moderately interlocked as to constitute a form intermediate between that of the camel's and of the *Macrauchenia*. An anterior dorsal vertebra is more strongly opisthocœlian, resembling that of the llama. The diapophysis has a reniform tubercular surface, which looks downward; from its posterior-inferior angle, a strong, fold-like ridge originates, and is continued as the posterior margin of the neural arch. Below the capitular facet, a short ridge originates, which incloses a median fossa, with its fellow on the anterior half of the centrum. A lumbar exhibits a strongly-depressed centrum, and the absence of an epiphysis from it and from the dorsal described indicate the immaturity of the individual.

The *humerus* is a little expanded distally, and is truncate from the trochlear margin on the inner side. The posterior portion of this face is produced into a strong tuberosity, of which a trace may be observed in the llama, which prevents the extension of the fore-arm beyond an angle of 180°. The inner trochlear face has the greater sweep and less width, and is uninterrupted; the outer is wider, and is divided into two nearly coincident planes. There is a supracondylar, but no arterial foramen, as in *Oreodon*.

The fore-arm is long and slender, and the *ulna* co-ossified its entire length, except a foramen near its distal end. The medullary cavities of the two bones are separated for the proximal half of their length. A shallow groove distinguishes the ulna proximally, and at the middle of the shaft the latter forms an acute edge. Distally, the combined bones present three planes, two lateral and a median. The lunar facet is most impressed; the scaphoid and cuneiform are equally prominent.

The *carpus* consists of eight bones, the entire mammalian number, all entirely distinct. The second series presents the most important peculiarities. The *trapezium* is small and posterior; the *trapezoïdes* has an almost entirely lateral presentation, and is also small, and fits an angle of the magnum; the metacarpal facets of these bones are continuous and uninterrupted. The *magnum* is flat and transverse; the *unciform* is nearly as broad, and less depressed; it presents two inferior articular faces, the lesser interior for the third metacarpal; that for the fifth metacarpal is wanting.

There are two principal and two rudimental *metacarpals*. The third articulates with half of the trapezoïdes, the magnum, and a fourth of the unciform; the fourth with the remainder of the unciform. The second and fifth are very short and wedge-shaped, and closely adherent in shallow fossæ of the third and fifth respectively. The latter are distinct, and present no traces of present or prospective attachment; their opposed faces are only flattened on the proximal three-fourths, and rounded on the remaining fourth. Their articular extremities present no basal ridge, and the median keel is posterior, terminating at the distal center. The basal *phalanges* are short, and with a distal trochlear groove; those of the second series are half as long.

Another specimen displays, in addition to cranium with teeth, vertebræ, &c., the hind limbs. The *astragalus* is that of a true ruminant, but the astragalus and cuboid bones are entirely distinct. The ectocuneiform is a subcubical bone, and is distinct from the inner cuneiform behind it, and which is relatively larger than in the typical *Ruminantia*. The metatarsals are two in number, and are distinct throughout their length, the distal portions being not even flattened for mutual contact. They are very much elongate and resemble those of the fore limb. There is, on the external, a proximal excavation for the rudiment of the fifth metatarsus, like that which contains the fifth metacarpus. Probably there is a similar second, but the indications are lost. The distal end of the fibula is not co-ossified with the tibia.

The above analysis determined some interesting relations of this genus. The cervical vertebræ indicate affinity to the *Camelidæ*, and there is nothing in the remainder of the structure to contradict such relation. The separation of the *os trapezoïdes* is found in the camels, and very few others only among *Ruminantia;* but, in the presence of the *trapezium Poëbrotherium* shows relationships to more ancient types, as *Anoplotheriidæ*, &c. The reduction of the digits to two and the separation of the metacarpals point in the same direction; indeed, the number of carpals and metacarpals is prcisely as in *Xiphodon.* But the mutual relations of these bones are quite different from what exists in that genus, and is rather that of the *Camelidæ* and other ruminants, or what Kowalevsky has called the "adaptive type." This author has seen, in the genus *Gelocus*, Aym., from the Lowest Miocene, or Upper Eocene of France, the oldest ruminant and the probable ancestor of a number of the types of the order; but among these he does not include the *Camelidæ.* The present genus is a more generalized type than *Gelocus;* in its separate trapezoid and distinct metacarpals, it represents an early stage in the developmental history of that genus. It also presents affinity to an earlier type than the *Tragulidæ*, which sometimes have the divided metacarpals, but the trapezoïdes and magnum co-ossified. In fact, *Poëbrotherium*, as direct ancestor of the camels, indicates that the existing *Ruminantia* were derived from three lines represented by the genera *Gelocus* for the typical forms; *Poëbrotherium* for the camles; and *Hyæmoschus* for the *Tragulidæ.* The first of these genera cannot have been derived from the second, on account of the cameloid cervical vertebræ of the latter, and all three must be traced to the source whence were derived, also, the *Anoploheriidæ*, and perhaps the little-known *Dichodontidæ.*

The two distinct metacarpals, separate trapezium and trapezoïdes, cameloid cervical vertebræ, and dentition characterize this type as a peculiar family, which may be called *Poëbrotheriidæ.* The genus from which it takes its name was originally referred by Leidy to the *Camelidæ.* I have been unable to detect any characters by which *Protomeryx hallii*, Leidy, can be placed in a distinct genus from the present one. It rests on a portion of a lower jaw of an individual somewhat larger than the usual size of *P. vilsonii.*

POËBROTHERIUM VILSONII, Leidy, *loc. cit.*, p. 141; Cope, Bull. U. S. Geol. Surv., No. 1, 24.

Several individuals procured. The size was about that of a sheep, but the limbs and neck were much longer. The latter resemble, in their slender proportions, those of the *Xiphodon gracile* of the Paris Eocene, and exceed those of any of their contemporaries in this respect.

Measurements.

	M.
Length of continuous six molars	0.058
Depth of mandible at M. 2	.022
Length of atlas, (on centrum)	.035
Length of third cervical vertebra	.056
Width of centrum behind	.020
Depth of centrum behind	.015

	M.
Depth of centrum behind, with hyapophysis	.020
Expanse of diapophysis of fourth cervical	.034
Expense of zygapophyses of fourth cervical	.038
Length of centrum of first dorsal	.025
Width of centrum of first dorsal	.020
Depth of centrum of first dorsal	.014
Width of humerus cistally	.024
Length of radius	.183
Width, proximally	.018
Width distally, (greatest with ulna)	.023
Length of lunar, (anterior face)	.009
Length of magnum, (anterior face)	.004
Width of carpus distally	.020
Width of III. and IV. metacarpal proximally	.019
Width of III. metacarpal proximally	.011
Width of III. metacarpal distally	.009
Length of III. metacarpal	.131
Length of proximal phalange	.017
Length of phalange of second row	.010
Total length of hind foot, (No. 2)	.243
Length of tarsus	.040
Length of astragulus	.025
Length of metatarsus	.147
Length of unguis	.015

HYPISODUS, Cope.

Synopsis New Vertebrata Colorado, 1873, pp. 5, 7.—Bulletin U. S. Geological Survey, No. 1, p. 26.

With this genus we enter a group of true ruminants which are allied in many respects to genera now living in the warm regions of Africa and Asia, namely, the *Tragulidæ.* The premolar teeth are similarly sectorial in their character, excepting the last in *Hypisodus* and *Leptomeryx*, and the metapodial bones are co-ossified into a common bone late in growth; a deep intervening groove always remaining. The cuboid and navicular tarsal bones are more or less completely co-ossified. The relations of the lateral metapodial bones are not yet determinable.

Dental formula of *Hypisodus*: I., $\frac{?}{3}$; C., $\frac{?}{1}$; P. m., $\frac{?}{4}$; M., $\frac{3}{3}$. In the maxillary bone, two posterior premolars are preserved; the last has a single internal crescent, which extends from the posterior external crescent as an oblique branch inward and forward. In the mandibular series, the six incisors, two canines, and two first premolars form an uninterrupted series of ten subequal teeth, and are followed by a long diastema. There is no diastema behind the first premolar. The number and relations of the teeth (the P. m. superior nos. 1–2 unknown) are much as *Poëbrotherium*, but the molars are more prismatic in form.

HYPISODUS MINIMUS, Cope, Bull. U. S. Geol. Surv., 1874, No. 1, p. 26. *Leptauchenia minima*, Cope, Pal. Bull., No. 16, p. 8; *Hypisodus cingens*, Cope, Synop. New Vert. Col., p. 7.

Represented by numerous remains of a species not larger than a gray squirrel.

The antero-exterior vertical ridge of the molars is more prominent and overlaps the preceding tooth more extensively than in the other species. The posterior-superior molar is narrowed behind, and has a small heel-column. In the mandible, the third premolar is three-lobed, and the first premolar is not separated from the second by a hiatus. The superior molars exhibit no basal shoulder, but have distinct roots. The inferior molars are still more prismatic, and the roots of the last are short; enamel smooth. The valleys of the anterior lower molars disappear with use more readily than in some of the allies. The second inferior premolar is one-rooted.

The symphysis is spatulate, and emarginate distally, very convex below, shallowly concave above. The diastemata are occupied by sharp borders, which are slightly approximated at the posterior part. The teeth are directed anteriorly, and are subequal. The mental foramen is just in front of the bounding angle of the symphysis.

Measurements.

	M.
Length of symphysis	0.0090
Width, (least)	.0035
Width at I. 5	.0042
Width at I. 3	.0046
Length of three molars above, (No. 1)	.0120
Length of last molar	.0050
Width of last molar	.0030
Length of three inferior posterior molars, (No. 2)	.0130
Length of inferior last molar	.0058
Width of inferior last molar	.0025

Probably the least-known species of *Artiodactyle*. This exceedingly small ruminant was very abundant during the period of the oreodons, &c.

HYPERTRAGULUS, Cope.

Bulletin U. S. Geol. Survey, No. 1, 1874, p. 26.

This genus is allied to *Dremotherium*, Geoff., and *Leptomeryx*, Leidy. The diagnosis may be thus compared; that of the first I derive from Pomel:

Hypertragulus, Cope: Molars, 6–6; first superior premolar without internal lobe; inferior premolars differing in form, the first one lobed, situated at a distance from the second, which is not three-lobed.

Dremotherium, Geoff.: Molars, 6–6; first superior premolar without interior lobe; inferior premolars similar, three-lobed, and contiguous.

Leptomeryx, Leidy: Molars, 6–6; first and second superior premolars three-lobed, and with an internal lobe; third with an inner and an outer crescent; inferior premolars similar, three-lobed, and contiguous.

In *Hypertragulus*, the third upper premolar exhibits an internal as well as an external crescent. The canine of the inferior series stands in the middle of a considerable diastema, which is preceded by three incisors.

HYPERTRAGULUS CALCARATUS, Cope, Bull. U. S. Geol. Surv., p. 26; *Leptauchenia calcarata*, Cope, Pal. Bull., No. 16, p. 7.

The second superior premolar is quite short, and its inner lobe small. The last premolar has a strong cingulum on the anterior, and especially on the posterior faces of the last premolar. The superior molars have no rib or column opposite the interval between the crescents; the last molar exhibits four ribs on the outer side. The second (third) inferior premolar is compressed and elevated and much shorter than the third, which is three-lobed. The posterior crescents of the last inferior molar are opposite, and not separated posteriorly by a fissure.

This very abundant species of musk is a little smaller than the *Leptomeryx evansii*.

Measurements.

	M.
Length of five molars	0.0260
Length of three true molars	.0175
Length of last true molar	.0080
Width of last true molar	.0070

This species is smaller than the smallest of the genus yet described.

HYPERTRAGULUS TRICOSTATUS, Cope, Bull. U. S. Geol. Surv., No. 1, 1874, p. 27.

A second species, about the size of the last, is represented by the superior molars of one individual, and perhaps by numerous mandibles which I cannot certainly associate with them. The last premolar has, as in the preceding species, a strong posterior cingulum; but there are only three ribs on the outer side of the third molar, the characteristic heel being absent. The latter also lacks the cingulum, which passes round the inner side of the bases of the crowns in *C. calcaratus*, its representative being the basal tubercle between the inner lobes of that and the other molars.

LEPTOMERYX, Leidy.

LEPTOMERYX EVANSII, Leidy, Ext. Fauna Dak. and Neb., p. 165; *Trimerodus cedrensis*, Cope, Pal. Bull., No. 16, p. 8.

The form of premolars characteristic of *Trimerodus*, as cited, pertains also to this genus. The specific name represents the smaller forms, but I find a considerable range in size in the numerous specimens obtained, and do not at present regard them as belonging to more than one species.

STIBARUS, Cope.

Paleontological Bulletin, No. 16, p. 3.

This genus is known from a portion of a mandibular ramus which supports two premolar teeth, one in an imperfect condition. These teeth are of unusually large size as compared with the depth of the ramus, especially in their antero-posterior diameter. The mental foramen issues opposite the anterior root of the first, which is also preceded by a diastema of uncertain length. The second premolar is sectorial in its form, and entirely symmetrical bilaterally, *i. e.*, its cutting edge is median, and there is no incurvature or ribbing of the inner or outer side, but the sides slope symmetrically to the apices of the three cusps of the crown.

The character of this tooth is quite that of some carnivorous animals, *e. g.*, of some *Canidæ*, but the elongate preceding premolar, diastema, and absence of canine alveolus lead me to the opinion that it is an artiodactyle, with the sectorial premolar teeth of the group just considered. The elongate form of these teeth resembles most that of *Poëbrotherium*, but it differs from this genus, as from the others, in the most decided manner. But one species is known.

STIBARUS OBTUSILOBUS, Cope, *loc. cit.*, p. 3.

This species is rare in Colorado, as but one specimen has come under my observation. It is represented by a portion of a mandibular ramus, which supported the two anterior premolars. The teeth are elongated and compressed, with low crowns and flattened roots; the crown of the third is four-lobed. Third premolar with large anterior lobe and posterior heel. Median lobes obtuse; three last lobes connected by a low edge. Enamel slightly rugose.

Measurements.

	M.
Length of bases of three premolars	0.076
Length of basis of third premolar	.008
Elevation of crown of third premolar	.004
Depth of ramus at third premolar	.007

PELONAX, Cope.

This genus embraces species which are nearly allied to *Elotherium*. It is more hippopotamoid than that genus, in the possession of four digits on all the feet and a rudimentary fifth on the pes. According to Kowalevsky, *Elotherium* possesses but two digits of the fore-foot. The *E. mortonii* and *E. ingens* of Leidy represented the genus during the Miocene period in North America, species which Kowalevsky is disposed to unite with the *E. magnum*, Aym., of Europe.

PELONAX CRASSUS, Marsh. (?) *Elotherium crassum*, Marsh, Amer. Journ. Sci. and Arts, 1873, p. 487.

According to Marsh, the digits in this species are 4–5. Three crania, one nearly complete, represent this species in our collections, so far as I can determine from Marsh's very brief description. The form of the skull is very different from that of the *Elotherium mortonii*. The posterior portion from the orbits is abbreviated and the sagittal crest descends from the protuberant frontal region. The orbits present upward and forward, and the temporal fossa is higher than long; the face and muzzle are long and narrow. The malar portion of the zygoma is considerably deeper than the squamosal portion. The descending process of the zygoma is directed downward and forward, as described by Marsh. There is a small, supernumerary, single-rooted premolar close behind the second in all three crania. The length of one of the skulls is eighteen inches. The measurements of the teeth agree with those given by Marsh.

PELONAX RAMOSUS, Cope; *Elotherium ramosum*, Cope, Bull. U. S. Geol. Surv. Terrs., 1874, No. 1, p. 27.

Established on the greater part of a mandible with teeth, from a cranium, which, when complete, must have measured nearly two feet and a half in length, indicating an animal no smaller than the largest living rhinoceroses. The species is remarkable for the great size of the tuberosities on the under side of the mandibular rami, especially of the anterior pair. The symphysis is narrow and deep in front, and the tuberosities form two branches, whose bases occupy the entire lower part of its infero-anterior face. They are some inches long, and are directed outward and downward. The posterior edge is acute, and the extremity very rugose, as though for the attachment of a horny or cartilaginous cap or apex. The outer face is flat; the inner, convex. The second tuberosity is below the first true molar, and is flat and with apex obtuse in profile, and turned outward. The molar teeth number seven; the first and second of the four premolars have but a single root, and are separated by a short diastema. The tubercles of the molars are low; the crowns of some of the premolars have a cingulum in front and behind. The canines are lost, but their alveoli indicate huge size; the root possesses an open groove on the front of the inner side. The outer incisors are large and close to the canine; the last molar is two-lobed and rather small.

Measurements.

	M.
Length of series of inferior molars	0.370
Long diameter of canine alveolus, (28.5 lines)	.060
Length of true molar series	.140
Length of crown of fourth premolar	.053
Height of crown of fourth premolar, (worn)	.022
Width of symphysis between canines	.090
Length of chin-process, (3.5 inches)	.090
Width of chin-process antero-posteriorly	.080
Length of interval to second tuberosity	.150
Length of basis of second tuberosity	.075
Length of symphysis	.175
Depth of ramus at P. m. 2	.100

The only species with which it is necessary to compare the *Pelonax ramosus* is the *Elotherium imperator*, Leidy, (=*E. superbum*, an older though less appropriate name,) known from a canine and incisor-teeth from California and Oregon. The long diameter of the canine is to that of *E. ramosum* as $5\frac{1}{2}$ to $7\frac{1}{8}$.

CARNIVORA.

HYÆNODON, Laiz. et Par.

HYÆNODON HORRIDUS, Leidy, Ext. Fauna Dak., &c., p. 39: Cope, Bull. U. S. Geol. Surv., No. 1, p. 9.

HYÆNODON CRUCIANS, Leidy, *loc. cit.*, p. 48; Cope, *loc. cit.*, p. 9.

This and the preceding species were found rather rarely, and in about equal proportions.

AMPHICYON, Larl.

AMPHICYON VETUS, Leidy, Ext. Fauna Dak., &c., p. 32.

CANIS, Linn.

CANIS HARTSHORNIANUS, Cope, Synop. New Vert. Col., 1873, p. 9.

Indicated by a portion of the mandibular ramus with the first tubercular molar and alveolus of the second. The species was as large as the *Canis latrans*. The anterior molar preserved has an interrupted cingulum on the outer side, which projects considerably in front, thus interrupting the parallelogramic outline of the crown. The outer anterior tubercle is much the larger, while the inner ones are both obsolete. In *C. gregarius*, Cope, the tubercles are equal, and there is no cingulum. Root of tubercular molar subround in section as in *C. gregarius*.

Measurements.

	M.
Length of bases of M. II and III	.0130
Length of base of crown of M. II	.0090
Width of base of crown of M. II	.0060
Elevation of crown of M. II	.0050

Named for my friend, Dr. Henry Hartshorne, professor of natural sciences in Haverford College.

As compared with the corresponding parts of the *Amphicyon vetus*, the specimen of this species displays the characters of the genus *Canis*. The first tubercular molar is considerably smaller—not much more than half as large, and the second very small, and supported by but one cylindric root. The alveolar portion of the ramus is at the same time as stout as that of the *A. vetus*.

CANIS LIPPINCOTTIANUS, Cope, Synop. Vert. Col., 1873, p. 9.

Among the numerous remains of dogs associated with those of rodents and insectivora, I have observed several portions of mandibular rami with teeth which indicate a species intermediate in size between the *Canis hartshornianus* and the *C. gregarius*. It was therefore not very different from the coyote in size. Selecting one specimen as type, which contains the teeth which correspond to those which represent the species last described, I find the following peculiarities: The root of the last molar is much compressed. There is only a trace of cingulum on the penultimate, and the tubercles of the inner side of the crown are well developed. Dimensions half as large again as in *C. gregarius*, as indicated by many specimens of the latter. In it the anterior lateral tubercles are subequal.

A second specimen from the same locality is a mandibular ramus, with the alveoli of the entire molar series and the last premolar and sectorial perfectly preserved. As compared with a larger number of specimens of *C. gregarius*, the jaw is larger, but is chiefly distinguished by the relatively stouter and broader teeth. The first premolar is one-rooted.

Measurements.

	M.
Length of bases of crowns of M. II and III, (No. 1)	0.0095
Length of base of crown of M. II	.0060
Width of base of crown of M. II	.0035
Elevation of crown of M. II	.0030
Length of bases of five anterior molars, (No. 2)	.0320
Length of bases of four premolars	.0220
Width of sectorial at middle	.0045
Elevation of sectorial at middle	.0070
Depth of ramus at sectorial	.0130
Thickness of ramus at sectorial	.0055

CANIS GREGARIUS, Cope, Pal. Bull., No. 16, p. 3.

About half the size of the red fox, (*Vulpes fulvus*,) or equal to the *V. littoralis*, Baird, but with relatively deeper mandibular ramus than either. The premolars are in contact with each other, and the middle posterior lobe is well developed, except in the first, which is also one-rooted. Sectorial, with stout inner tubercle as high as the anterior lobe; heel rather small. First tubercular with two roots relatively smaller than in the species last described; with two anterior and one posterior tubercle. The second tubercular is very small, and has a single subcompressed or round root. It remains in very few specimens, and in a few has evidently never existed. A premaxillary with part of the maxillary bone displays parts and alveoli of two incisors, one canine, and the first premolar. There is scarcely any diastema, and the canine is compressed oval in section. The exterior incisor is quite large, exceeding by several times the inner one. The premaxillary bone has but little anterior production.

Measurements.

	M.
Length of molar series	0.036
Length of premolar series	.019
Length of fourth premolar	.006
Length of sectorial	.009
Width of sectorial	.004
Height of sectorial	.006
Depth of ramus at sectorial	.010

This species is more abundant than all the other carnivora of the Colorado beds together, and is the only one that bears due proportion to the numbers of rodentia, on which it no doubt depended for food. Slight and unimportant variations may be observed among the numerous specimens.

This species is about the size of the *Amphicyon gracilis*, Leidy, from the White River beds of Dakota, and I suspected at one time that I had found that species in Colorado. Dr. Leidy describes that dog as having a two-rooted second tubercular molar, a character befitting its reference to *Amphicyon*, but very distinct from anything found in *Canis gregarius*. Leidy's figure (7–8, Pl. v) exhibits also an equality in the size of the incisor-alveoli and production of the premaxillary bone not found in the present species.

CANIS OSORUM, Cope, Synop. Vert. Col., 1873, p. 10.

Represented by two mandibular rami of a species of about the size of a weasel. One of these exhibits four premolars, the other a fourth premolar with fangs of a sectorial, and one or two tuberculars. The first premolar is one-rooted and close behind the large canine; the third exhibits no posterior lobe, and the crown is low. The ramus is shallow and stout.

In the second specimen, which is only provisionally referred here, the proportion of the base of the crown of the fourth premolar is identical with that of the first-described specimen. It exhibits a posterior median lobe. The succeeding tooth was a little larger, and the first root following placed transversely in the jaw.

Measurements.

	M.
Length of bases of four premolars, (No. 1)	0.0113
Length of basis of P. m. III	.0030
Elevation of crown of P. m. III	.0020
Length of basis of crown of P. m. IV.	.0040
Depth of ramus of mandible at P. m. IV	.0060
Length of bases of P. m, IV, M. I	.0080
Depth of ramus at first molar	.0060

BUNÆLURUS, Cope.

Synopsis Vertebrata Colorado, 1873, p. 8.

Char. gen.—Molars two, the first sectorial and without inner tubercle; the second small, tubercular. Premolars simple, acute; mandible not widening forward. This is one of the forms which associates the *Felidæ* and *Mustelidæ*. With the tubercular tooth of the latter, the sectorial resembles that of the cats, in the absence of all trace of the inner tubercle, but is again weasel-like in the well-developed heel of the sectorial. The genus is probably without the peculiarities of the *Drepanodons*, &c., *i. e.*, the downward expansion of the mandible, &c. The genus *Ælurogale*, of Delfortrie, is said to present a dental structure not unlike that of *Bunælurus*, but I have not had the opportunity of reading his diagnosis.

BUNÆLURUS LAGOPHAGUS, Cope, *loc. cit.*, 1873, p. 8.

Represented by a portion of a mandibular ramus, which carries the sectorial and tubercular teeth, and another, more perfect, from the right side, which contains the two last premolars as well as the sectorial and tubercular teeth. Thus the number of premolars is uncertain. Those preserved are narrowly acuminate; the basal lobes of No. 3 quite small. The middle lobe of the sectorial is considerably higher than the anterior, and the heel, though short, is well developed. Tubercular small; crown longitudinally extended.

This feline was about the size of a half-grown cat.

Measurements.

	M.
Length of crowns of four molars, (No. 1, immature)	0.0140
Length of two true molars	.0065
Length of sectorial tooth	.0050
Width of sectorial tooth	.0021
Elevation of sectorial tooth	.0045
Depth of ramus at sectorial tooth	.0050
Depth of ramus at sectorial, (No. 2, adult)	.0070

DAPTOPHILUS, Cope.

Paleontological Bulletin, No. 16, p. 2.

General character of dentition as in *Machærodus*, but the mandibular teeth are: C., 1; P. m., 3; M., 1, a premolar tooth being added. Second premolar three-lobed; carnassial tooth with short cutting-heel; tubercular none. Superior canine much compressed, denticulate, not grooved.

DAPTOPHILUS SQUALIDENS, Cope, *loc. cit.*

Established on a specimen in which the permanent sectorial of the lower jaw is protruded, but the temporary sectorial not yet displaced by the permanent last premolar. Second premolar with strong, subequal anterior and posterior basal lobes and two-rooted. Enamel smooth.

Sectorial with two posterior lobes, the lower prominent. Ramus decurved at symphysis. Superior canine in shape, like a tooth of a shark of the genus *Oxyrhina;* flat within, slightly convex without; the front cutting-edge turned inward at the basis; both edges denticulate. The fang of the inferior canine penetrates beyond a point below the first premolar.

Measurements.

	M.
Length of bases of three posterior molar teeth	0.040
Length of basis of second molar tooth	.010
Elevation of basis of crown of second molar tooth	.009
Length of basis of crown of fourth molar tooth	.017
Elevation of basis of crown of fourth molar tooth	.013
Depth of ramus at fourth molar tooth	.015
Depth of ramus at second molar tooth	.018
Length of fragment of upper canine	.025
Width of fragment of upper canine at base	.011

Size of the panther.

Should it be ascertained that this cat developes a tubercular molar, (of which I can now find no trace,) it will be necessary to estimate it as a second species of *Dinictis*. Besides the large basal lobes of the second premolar, the inferior canine has an apparently larger size and more posterior extent of the fang; certainly much greater than in the *Hoplophoneus oreodontis*, which resembles the *Dinictis felina* in this region exteriorly. In accordance with the continuation of the canine alveolus, the inferior border of the jaw is rounded, and though flared on the outer margin for the large superior canine, it is not truncate as in the saber-toothed tigers generally. Coincidentally the superior canine is reduced in size, being relatively shorter than in *D. felina*.

HOPLOPHONEUS, Cope.

Bulletin U. S. Geological Survey Terrs., No. 1, p. 23, 1874.

Char. gen.—Dental formula of mandible, I., 3; C., 1; P. m., 2; M. 2. Superior canine greatly developed; end of mandible expanded and thickened to protect it.

This is simply *Machærodus* with a tubercular molar, as in *Dinictis*. The dental formula is the same as that of *Bunælurus*, but the latter probably has the character of *Felis* in its anterior dentition.

HOPLOPHONEUS OREODONTIS, Cope; *Machærodus oreodontis*, Cope, Synop. New Vert. Col., 1873, p. 9.

Char. specif.—The species was established on a young individual with part of the temporary dentition remaining. A jaw of an adult furnishes additional characters. The first premolar (the third) has two roots and is as large as the second, instead of being smaller, as in *Drepanodon primævus*. The second (fourth) has a prominent anterior basal tubercle, as in the last-named species, but which is, according to Leidy, wanting or very small in *Dinictis felina*. The anterior angle of the mandible is not produced downward so much as in the *Drepandon*, but is more as in *Dinictis felina*, with which the present species agrees nearly in size. The diastema is very short and rises to the base of the large inferior canine. There is a mental foramen below the anterior root of the first premolar, and two vascular foramina on the front face of the ramus, one above the other. In the form of the second premolar, this species resembles *Drepanodon occidentalis*, Leidy; but that species is supposed not to possess the tubercular molars, and is nearly twice the size of the present animal.

Measurements.

	M.
Length of ramus to end of molar series	0.065
Length of molar series	.048
Length of base of first premolar	.014
Length of base of sectorial	.017
Depth of ramus at sectorial	.017
Depth of ramus at diastema	.024
Depth of ramus at symphysis	.024

The second specimen is immature, and presents the following characters. It is represented by an incomplete manibular ramus of the right side, containing two incisors, and the deciduous sectorial, with portions of other teeth. The incisors are very stout, and exhibit slightly-curved conic crowns, with a serrulate cutting-edge on the inner face. The sectorial tooth has the elevated acute anterior lobe, which forms with the median lobe the usual sectorial shear. Posteriorly to the median, there are two acute lobes, the third as high as the anterior, while the fourth nearly reaches the line of the base of the anterior notch. There is no anterior basal lobe. The sectorial was of large size, judging by the alveolus. The first premolar was also large and two-rooted. The alveolus for the inferior canine is flat on the inner side. The increasing anterior depth of the ramus indicates an expansion for the protection of the large superior canine.

From the same locality as the last. About the size of the Canada lynx.

Measurements.

	M.
Length of bases of crowns of premolars I and II	0.0210
Length of bases of crowns of premolar II	.0110
Elevation of crown of premolar II	.0110
Elevation of crown of incisor II	.0055
Diameter of crown of incisor II	.0035
Length of diastema behind canine	.0110

QUADRUMANA.

MENOTHERIUM, Cope.

Bulletin U. S. Geological Survey of Terrs., No. 1, 1874, p. 22.

This new genus is probably quadrumanous, and allied to the lemurs; but as I only possess portions of two mandibular rami with dentition, a more exact determination will be looked for with interest. It is the first indication of the existence of monkeys in the Miocene formation of the United States.

There are at least two premolars and three molars in the inferior series; those anterior being lost in the specimens. The last premolar is somewhat sectorial in form, having a compressed but stout median cusp, a broad heel behind, and a small tubercle in front. The last molar is rather smaller than the others, and with a slight posterior or fifth tubercle. The molars support four tubercles nearly opposite, in pairs, and connected by a diagonal crest, so that when the crown is worn an S-shaped figure results. The two alveoli in front of the last premolar may have contained each a separate tooth, or a single tooth, longer than any of the others. The genus is apparently allied to the *Leptochœrus* of Leidy.

MENOTHERIUM LEMURINUM, Cope, *loc. cit.*, January, 1874.

Char. specif.—The last premolar is longer than any of the molars. There are no cingula on the molars, but the transverse crest from one of the tubercles descends to the side of that opposite to it, along the end of the crown. Enamel smooth. Ramus of the jaw rather elongate.

Measurements.

	M.
Length of bases of six molars	0.0250
Length of bases of true molars	.0120
Length of basis of first true molar	.0040
Width of basis of first true molar	.0032
Length of basis of last premolar	.0052
Width of basis of last premolar	.0030
Depth of ramus at last premolar	.0090

This animal was about as large as the domestic cat.

TESTUDINATA.

TESTUDO, Linn.

Remains of species of this genus are very abundant in the Miocene of Colorado, and present much greater variety of structure than do the tortoises of the White River beds of Dakota. This is most strikingly seen in the forms of the lobes of the plastron, which may be flat and truncate, deeply bifurcate or produced into a wedge-shaped process. I have distinguished four species, as follows:

TESTUDO CULTRATUS, Cope, Pal. Bull., No. 15, p. 6.

This species introduces several from the same formation as the *Peltosaurus*, which agree with the existing genus *Testudo* in their short, stout metapodial and phalangeal bones, and single anal scutum of the carapace.

In the present species, the prominent peculiarity is seen in the form of the lip of the anterior lobe of the plastron, each half of which is an elongate pyramid, its depth and width being equal. The marginal bones were short, stout, and recurved. Length of carapace nearly 18 inches.

TESTUDO LATICUNEUS, Cope, Pal. Bull., No. 15, p. 6.

In this species, the anterior lip of the lobe of the plastron is very prominent and wedge-shaped, and with dentate margin, and is flat and thin. The posterior lobe is subtruncate. The mesosternal bone is hexagonal and broader than long, and is pointed behind. The pygal bone is triangular, and the anal marginal is convex in both sections and abbreviated below. Each marginal bone behind the bridge presents a mucro, where a dermal suture reaches the margin. Anal scutum very wide. All the sutures double lines. Length from 18 inches to 2 feet; width two-thirds the length. Carapace rather flattened.

This is the most abundant species of the formations; several good specimens obtained.

TESTUDO AMPHITHORAX, Cope, Pal. Bull., No. 15, p. 6.

Anterior lobe of plastron broadly truncate, scarcely lipped; posterior lobe openly emarginate. Mesosternum longer than broad, acute in front, very obtuse behind. All the sutures simple. Anal marginal shortened but convex. Form depressed. Length and width as in the last.

TESTUDO LIGONIUS, Cope, Pal. Bull., No. 15, p. 6.

Posterior lobe of plastron produced into two flattened, sharp-edged, wedge-shaped processes, separated by a deep notch, as in *Hadrianus corsonii*. Marginal bones behind very wide, or, considered separately, long and narrow, with a step-like angle and notch where the scutal suture reaches the margin.

The form of the anterior lobe of the plastron is yet uncertain, though fragments found with the type resemble that of *T. laticuneus*. At least three incomplete specimens obtained.

STYLEMYS, Leidy.

STYLEMYS NEBRASCENSIS, Leidy; *Testudo nebrascensis*, Leidy, Report Geol. Surv. Terrs., (4to,) vol. i, p. 339.

LACERTILIA.

PELTOSAURUS, Cope.

Palentol. Bulletin, No. 15, p. 5.

Premaxillary undivided, with spine; a zygomatic postorbital; and parieto-quadrate arches. Teeth pleurodont, with obtuse, compressed crowns, of similar form on all the jaw-bones. Body covered with osseous scuta, which are in places united by suture. Vertebræ depressed, with simple articulations. Median, hexagonal, dermal scuta on the parietal bone. Parietals united.

There are sufficient remains of the typical species of this genus to furnish a basis for an estimation of its affinities, a point of some interest, as this has been seldom if ever done in the case of a terrestrial lizard of the Miocene. The primary group to which it is to be referred is not difficult to determine.*

The frontal and parietal bones are each undivided, and there is no fontanelle in either or their common suture.† There is a large postfrontal, and the usual cranial arches are present, and the quadrato-jugal absent. The frontal possesses strong lateral inferior crests, but whether they underarch the olfactory tube completely the specimen does not show. All the usual elements of the mandibular ramus are present, but the angular is very narrow. The dentary does not extend behind the coronoid on the external face of the jaw. The coronoid is little produced either forward or backward above, but sends a process forward on the inner face of the dentary. The splenial is well developed but becomes very slender anteriorly; it covers the meckelian groove except for a short space distally, where it furrows the inferior aspect of the jaw. The surangular is quite peculiar; it is massive, and lacks the usual deep fossa for the pterygoid muscle, and has a broadly truncate superior margin. It is in the same vertical plane as the dentary, and not oblique or subhorizontal as in most *Gecconidæ*. The dental foramen is small and pierces its inner face. The posterior angle of the ramus is broken off.

The characters of the premaxillary bone, fontanelle, dentition, coronoid, dentary, splenial bones, and Meckelian groove place this genus out of the pale of the acrodont families. The parietals and vertebræ are distinct from anything known among the geccos. There is no resemblance in essentials to the *Amphisbœnia*, so that we must look for its place among the numerous pleurodont families. Here the absence of the knowledge of the periotic bones and sternum somewhat embarrasses us; but other indications are clear. The coincidence of the want of parietal fontanelle with the lateral frontal plates refers us at once to the *Leptoglossa* or *Diploglossa;* a reference confirmed by the simple frontal and strong cranial arches. The massive form of the surangular bone, and reduction of the angular, at once distinguishes *Peltosaurus* from any known family of the tribe *Leptoglossa*, and constitutes a point of near resemblance to the *Gerrhonotidæ*. This appears to be a real affinity, which is further confirmed by the presence of a symmetrical dermal scutellation on the top of the head.

Referring *Peltosaurus*, therefore, provisionally to the *Gerrhonotidæ*, it

* See the author's Osteological Characters of the Scaled Reptiles, in Proceedings Academy Philadelphia, 1864, p. 224.

† What I originally thought was such is a foramen-like sinus in the posterior margin of the parietal.

remains to consider the generic characters. The temporal fossa was not roofed over by true bone, though the border of the postfrontal encroaches on it; and it is rather small. The orbits, on the other hand, are large, and the malar bone forms a segment of a circle. The parietal thins out behind, and its posterior border has a subround excavation. The two median dermal scuta, which left their impressions on the parietal bone, represent the interparietal and postinterparietal plates respectively; the latter especially characteristic of the *Gerrhonotidæ*, and not found in leptogloss or diplogloss families generally; those possessing it being the *Lacertidæ* in the former, and *Anguidæ* in the latter. The most prominent character which distinguishes this genus from *Gerrhonotus* is the existence of the osseous scuta which covered the body. Even the form of these is similar to the corresponding dermal scuta of the existing genus.

PELTOSAURUS GRANULOSUS, Cope, Pal. Bull., No. 15, p. 5.

Indicated by considerable portions of a skeleton, which I excavated from the matrix. Parietal bone broad and flat, frontal little narrowed, gently convex, both with finely granular upper surface. Scuta not keeled, finely granular. Number of teeth on premaxillary bone, 7; teeth on dentary, 10 in $0^{m}.010$. Surfaces of dentary smooth.

Measurements.

	M.
Median width of parietals	0.0140
Median width of frontals	.0080
Length of mandibular ramus to cotylus	.0400
Diameter of vertebral centrum, (transverse)	.0030
Length of vertebral centrum	.0055

Size about that of the American *Heloderma*.

EXOSTINUS, Cope.

Synopsis New Vert. Colorado, p. 16.

Char. gen.—This form of lizard is represented principally by a nearly entire frontal bone. Close to it were found a zygomatic bone and a nearly complete dentary bone with the teeth. The former is in all respects appropriate to the frontal bone, and the size of the dentary bears the usual relation of size to the same. Its dentition is appropriate to the affinities of this genus to *Peltosaurus*, Cope.

The frontal bone is much narrowed between the orbits, as in recent leptogloss *Pleurodonta*, while the olfactory lobes were almost as completely underarched as in the thecagloss-type. The stout, well-developed zygomatic, with malar process, resembles the former group, and the teeth have a similar structure. These are closely placed, truly pleurodont and subcylindric. The crowns are simple, compressed, and with a convex edge. They are similar in form throughout the dentary bone. Cranial bones covered with symmetrical osseous prominences.

These details, so far as they go, resemble those of *Peltosaurus*, and *Exostinus* is doubtless to be referred to the same natural tribe of lizards, the *Diploglossa*. The rugosities of the cranium indicate its greater resemblance to *Heloderma* than to *Gerrhonotus*, but the teeth are much more like those of the former genus than the latter. This genus and *Peltosaurus* constitute our first definite knowledge of the extinct forms of *Diploglossa*.

EXOSTINUS SERRATUS, Cope, *loc. cit.*

Char. specif.—A series of tubercles along each supra-orbital border, longitudinal at the front, quadrate at the back part of the eyebrow. A single series of tubercles separates them. Five tubercles in a transverse row at the posterior margin of the frontal. Two series of flat tubercles on the zygomatic bone. Dentary quite convex on outer face; inner face slightly convex; 8 teeth in $0^m.0050$.

Measurements.

	M.
Length of frontal, (nearly complete)	0.0070
Width of frontal posteriorly	.0034
Width of frontal at post-orbital point	.0045
Width of frontal between orbits	.0018
Length of zygomatic	.0070
Depth of dentary at last tooth	.0030
Length of a mandibular tooth	.0018

About the size of the common eastern scinc, (*Eumeces fasciatus.*)

ACIPRION, Cope.

Synopsis Vert. Colorado, p. 17.

Char. gen.—Represented by a dentary bone, with nearly all of the teeth remaining. A groove, apparently the Meckelian, extends along the inferior border of the distal half of the bone. The teeth are truly pleurodont, closely placed, and cylindric, with compressed crowns. The latter supports a large median and two small lateral cusps, three in all.

ACIPRION FORMOSUM, Cope, *loc. cit.*

Char. specif.—The crowns project well above the alveolar border. External face of dentary smooth, with rather distant foramina. Ten and a half teeth in $0^m.0050$.

Measurements.

	M.
Depth of dentary at middle	0.0022
Length of a median tooth	.0018
Elevation of same above alveolus	.0010

This species is about the size of our *Cnemidophori*. From all the genera oi this group, *Aciprion* differs in the uniform character of the teeth, there being no simple teeth in the front of the series so far as preserved. A jaw-fragment probably represents a second species of this genus.

DIACIUM, Cope.

Synopsis Vert. Colorado, p. 17.

Established on the sacral vertebra of a large lizard, which presents such peculiarities as to indicate that its affinities are remote from those above described.

The diapophysis is subcylindric and elongate. Centrum concave below; neural arch flat above. Articulation without zygosphene or rudiment of it; zygapophyses oblique, the arch deeply excavated between the anterior ones. Obliquity of ball inferiorly.

DIACIUM QUINQUEPEDALE, Cope.

Char. specif.—Two hypapophysial tubercles below the ball. Centra slightly depressed, the cup excavated above and below. An angulation extends backward from each anterior zygapophysis; the neural arch between them flat on the anterior half.

Measurements.

	M.
Length of centrum below	0.0100
Diameter of articular cup, transverse	.0086
Diameter of articular cup, vertical	.0064
Diameter of base of diapophysis	.0044
Width between anterior zygapophyses	.0098
Width of upper plane of neural arch	.0078

This species is as large as any of the existing species of *Varanidæ*.

CREMASTOSAURUS, Cope.

Synopsis Vert. Colorado, 1873, p. 18.

Established on vertebræ which differ from those of *Peltosaurus* in the absence of the sharp ridges which connect the anterior zygapophyses with the posterior in the dorsal vertebræ. They are better developed in the cervical region. The species of this genus which are known are ntermediate in size between those of *Peltosaurus* on the one hand and *Exostinus* and *Aciprion* on the other.

Dorsal vertebræ without zygosphene.

The neural arch is capacious in the cervical region, and each neurapophysis is excavated below the posterior zygapophysis, and sending a ridge downward and backward round the centrum, continuing as a low shoulder on the inferior face. Diapophysis with a single narrow capitular articulation, extending obliquely downward and forward; that of the third vertebra smaller. Axis with an elevated neural arch, with obtuse, inferior carina. Odontoid a crescentic element, with a transverse groove on its anterior face. All the centra with an obtuse but prominent hypapophysial keel.

CREMASTOSAURUS CARINICOLLIS, Cope, *loc. cit.*, p. 18.

Ball of sixth cervical vertebra round. Neural arches broad, each with a low, acute keel for spine, which is elevated on the third, and produced roof-shaped backward and forward on the axis. The costal articulations are not produced below the centrum.

Measurements.

	M.
Length of cervical vertebræ II to VI	0.0140
Length of axis	.0038
Elevation of axis behind	.0047
Diameter of odontoid, (in front)	.0034
Length of c. VI	.0029
Diameter of ball of same	.0011
Total elevation of same	.0030

The dorsal vertebræ, which are appropriately associated with the cervicals, have transversely-oval articular faces, and centra without inferior keel or ridge. The vertebræ are all dorsal, hence the diapophyses have the usual form in the order for costal articulation, and do not project as far inferiorly as the plane of the lower face of the centrum. It does not project beyond the anterior zygapophysis, and the lower half is especially developed as the costal condyle. Neural spine a keel extending from the front of the arch and rising into a short apex above the articular ball. There is a collar round the ball, which is faintly visible on the inferior side.

Measurements.

	M.
Length of centrum	0.0040
Width of cup	.0018
Depth of cup	.0010
Elevation of neural arch anteriorly	.0015
Elevation of neural spine and arch posteriorly	.0043
Total expanse in front	.0047

The dorsals represent several individuals.

CREMASTOSAURUS UNIPEDALIS, Cope; *Diacium unipedale*, Cope, Synop. Vert. Col., p. 18.

Represented by a sacral vertebra of an individual smaller than any of those of the last-described species, and characterized by the unusual protuberance of the articular ball and absence of flattening of the centrum below. Centrum depressed; plane longitudinally convex in transverse section. An annular groove round the ball. Diapophysis elongate, slightly depressed.

Measurements.

	M.
Length of centrum	0.0034
Diameter of cup, transverse	.0020
Diameter of cup, vertical	.0018

PLATYRHACHIS, Cope.

Synopsis Vert. Colorado, p. 19.

Char. gen.—Dorsal vertebræ united by the zygosphene, as well as the usual articulation. Centrum much depressed, flat below. Neural arch depressed, an angle connecting the zygapophyses. Neural spine a keel, projecting beyond the posterior margin in a mucro.

PLATYRHACHIS COLORADOENSIS, Cope, *loc. cit.*, p. 19.

Char. specif.—Ball truncate below its convex face, looking slightly upward. Costal capitular surface semiglobular directly below the anterior zygapophysis. Neural arch concave between zygapophyses.

Measurements.

	M.
Length of three dorsal vertebræ	0.0070
Length of one dorsal vertebra	.0028
Diameter of ball, transverse	.0014
Diameter of ball, vertical	.0006
Elevation of vertebra	.0019
Width between zygapophysis	.0025

The size of this species is similar to that of the two species already described from teeth; but the vertebral articulation is not appropriate to *Exostinus* with existing lights.

OPHIDIA.

NEURODROMICUS, Cope.

Synopsis Vert. Colorado, p. 15.

Char. gen.—Centrum small, with a prominent truncate hypapophysis. Neural arch capacious, the zygantrum wider than the articular cup. Neurapophyses bounding the canal laterally below the zygosphene; its border not angulate behind. Parapophysis projecting acutely below centrum. An elevated neural spine.

NEURODROMICUS DORSALIS, Cope, *loc. cit.*

Char. specif.—Articular surfaces of centrum round; the ball with a slightly upward-looking obliquity. Hypapophysis continued to cup as a prominent carina. A ridge connecting zygapophyses. Neural spine extending its base forward, so as to stand on the entire length of the neural arch.

Measurements.

	M.
Length of centrum	0.0045
Diameter of cup, vertical	.0020
Diameter of cup, transverse	.0021
Elevation of neural spine above centrum	.0055
Elevation of neural spine above neural arch	.0029
Length of hypapophysis below centrum	.0012
Width of hypapophysis	.0011

The zygantrum is capacious, and the whole neural arch open and light. The species was about the size of the black snake, (*Bascanium constrictor.*)

CALAMAGRAS, Cope, *loc. cit.*

Char. gen.—An obtuse hypapophysial keel most prominent posteriorly. No ridge from the zygosphene; that from the parapophysis wanting or rudimental. Neural spine posterior, short, and obtuse. Neural arch not produced posteriorly; zygosphene wider than articular cup. Articular surfaces moderately oblique. A concavity separating the articular surfaces of the diapophysis and parapophysis.

This genus differs from *Boavus*, as described by Marsh, in the absence of ridges and concavity of parapophysis.

CALAMAGRAS MURIVORUS, Cope, *loc. cit.*, p. 15.

Char. specif.—Articular surfaces a broad transverse ellipse. Hypapophysis terminating in an appressed point. No inferior lateral ridge on centrum; a trace of one on the posterior part of neural arch.

Measurements.

	M.
Length of centrum	0.0030
Width of ball	.0017
Depth of ball	.0013
Width between parapophyses	.0023
Depth of entire vertebra	.0040

Represented by six consecutive vertebræ. Size that of the water-snake, (*Tropidonotus sipedon.*)

CALAMAGRAS TRUXALIS, Cope, *loc. cit.*, p. 15.

Smaller. Articular surfaces more oblique. Neither centrum nor arch with ridges; hypopophysis low, without apical point. Parapophysial surface very short vertically.

Measurements.

	M.
Length of centrum	0.0027
Width of ball	.0016
Depth of ball	.0011
Width between parapophyses	.0020
Depth of entire vertebra	.0034

Size of the garter-snake; four vertebræ preserved.

CALAMAGRAS ANGULATUS, Cope, *loc. cit.*, p. 16.

The largest species, distinguished by the presence of a low ridge on the centrum from the parapophysis to the middle of the centrum. Neural spine on the posterior half of the neural arch short, truncate. Hypapophysis short, ending in an obtuse point. Parapophysis larger than in other species, nearly equal to the diapophysis.

Measurements.

	M.
Length of centrum	0.0030
Diameter of ball, transverse	.0017
Diameter of ball, vertical	.0016
Width between parapophyses	.0024
Depth of entire vertebra	.0045

APHELOPHIS, Cope, *loc. cit.*, p. 16.

Char. gen.—Similar to the preceding in the absence of acuminate diapophysial process, the zygosphene exceeding the articular extremity in width, and the simplicity of the posterior border of the neural arch. There are no longitudinal ridges, the hypapophysis being entirely wanting. The articular faces of the parapophysis and diapophysis continuous without intervening concavity.

APHELOPHIS TALPIVORUS, Cope, *loc. cit.*, p. 16.

Char. specif.—Vertebræ short and wide; the neural spine stouter and more obtuse than in any other species here described, occupying less than half the neural arch with its basis. Zygosphene wide, depressed, with nearly straight posterior margin, not sending any ridge backward from the posterior face. Articular faces of centrum a depressed oval; ball looking upward, its axis making 45° with that of the centrum. Parapophysis not projecting below centrum.

Measurements.

	M.
Length of centrum	0.0026
Diameter of cups, transverse	.0018
Diameter of cups, vertical	.0012
Width between parapophyses	.0017
Depth of entire vertebra	.0034
Width of zygosphene	.0020

Represented by three vertebræ of an individual about the size of *C. truxalis*.

CHAPTER V.

THE LOUP FORK EPOCH.

In the Pliocene strata already described, mammalian remains are exceedingly abundant over limited areas; those of horses in an especial manner. Those obtained are as follows:

	Species.
Carnivora	4
Perissodactyla	8
Artiodactyla	7
Proboscidia	1
Testudinata	1
Total	21

The most important paleontological results are, (1) the discovery that the camels of this period possessed a full series of upper incisor-teeth; (2) that the horses of the genus *Protohippus* are, like those of *Hippotherium*, three-toed; (3) that a *Mastodon* of the *M. ohioticus* type existed during the same period.

List of species.

CARNIVORA.

CANIS, Linn.

CANIS, *sp. incerta.*

Represented by a portion of the left ramus of the mandible, which contains alveoli for, and portions of, I., 3; C., 1; and P. m., 4. The incisors are closely crowded by the huge canines, which have larger proportions than dogs generally, resembling more those of the bears, or large feline carnivora. The first premolar is one-rooted, and separated by a long diastema from the canine. The second premolar is two-rooted, and separated from the first by a short diastema. The third is also separated by a diastema from the second, which exceeds that in front of the latter. The fourth follows the third immediately. The mental foramina are two, one large, below the first premolar, the other smaller, but little below the alveolar margin, opposite the posterior margin of the second premolar.

Measurements.

	M.
Length of fragment	0.175
Length from incisors to P. m. 4	.095
Length of basis of P. m. 3	.017
Length of basis of P. m. 2	.013
Vertical diameter of canine at basis	.029
Length of symphysis	.075
Depth of ramus at P. m. 2	.047

This large species is about as large as the *Canis haydenii* of Leidy, and may be identical with it. It is characterized, among dogs, by the weakness of its premolars as much as by the strength of its canines.

CANIS SÆVUS, Leidy, Anc. Fauna Neb., p. 28.

TOMARCTUS, Cope.

Paleontological Bulletin, No. 14, p. 1.

Established on a mandibular ramus, supporting a perfect carnassial tooth and fangs of the following dentition: C., 1; M., 4; the last incomplete; hence the number of posterior teeth unknown. The ramus is much narrowed in front. The carnassial has an inner tubercle within and behind the median lobe, and a large posterior heel supporting both inner and outer tubercles. The succeeding tooth was wide.

This genus is apparently one of the *Canidæ*. The carnassial tooth is identical with that of the genus *Canis*, but the existence of only two premolars in advance of it is a feline rather than canine character. The jaw diminishes rapidly in size anteriorly, and the fragment contains part of the fang of a large canine tooth, whose crown, like that of the two succeeding teeth, is broken off. The form was evidently a short-faced type of dog, concerning which additional information will be looked for with interest.

TOMARCTUS BREVIROSTRIS, Cope, Pal. Bull., No. 16, p. 2.

Second premolar two-rooted. Anterior half of the carnassial with the usual sectorial structure; the anterior lobe the smaller. The inner tubercle bout the same height. The heel constitutes one-third the length of the tooth, and its lateral tubercles are angular; the posterior low. Enamel slightly rugose.

Measurements.

	M.
Length of first three molars	0.041
Length of third molar, (carnassial)	.033
Elevation of third molar, (carnassial)	.014
Width of third molar at middle	.009
Length of heel of third molar	.007
Depth of ramus at third molar	.021

In the abbreviation of the dental series in front, this species resem

MARTES, Cuv.

MARTES MUSTELINUS, Cope, Pal. Bull.,* No. 14. (*Ælurodon.*)

A small, single-rooted, second molar of the lower jaw. First molar sectorial, with a rather narrow posterior heel, one-third its length, and a small inner tubercle at the base of the second outer cusp. Last premolar with a short posterior heel, and distinct outer tubercle on the posterior side of the cusp. Margin of jaw strongly everted below masseteric fossa.

Measurements.

	M.
Length of three last molars	0.018
Length of sectorial molars	.010
Width of sectorial molars, (greatest)	.005
Height of posterior cusp, (greatest)	.005

This species was about as large as the domestic cat, and less than one-third that of *Ælurodon ferox*, Leidy.

PERISSODACTYLA.

ACERATHERIUM, Kaup.

ACERATHERIUM MEGALODUS, Cope, Pal. Bull., No. 14, p. 1.

This large species and the *A. crassus*, Leidy, were very abundant during the Pliocene period in Western North America. Their remains are everywhere mingled with those of horses and camels. The former, and probably the latter, are to be referred to a distinct section of *Aceratherium* on account of the existence of but three premolar teeth in the mandibular series, and probably in the maxillary also. One of our specimens exhibits the missing superior premolar on one side. The outer incisor below is a large tusk, while the inner is small and caducous, points in which this genus resembles the genera above named, and differs from the African and tichorhine species, or genus *Atelodus* of Pomel.

A posterior upper molar represents the *A. crassus* in the original collections described by Leidy. A well-developed tubercle, which rises

* These publications may be procured at the Naturalist's agency, Salem, Mass., or of the writer.

from the bottom of the valley between the inner extremities of the cross-crests in the last and penultimate molars of *A. megalodus*, is wanting in the *A. crassus;* partly on this account I refer my second large Pliocene rhinoceros to the latter, represented by a perfect cranium, with dentition of both jaws nearly complete, with large portions of skull and dentition, with other bones, of other specimens.

The nasal bones are not co-ossified, and but little convex. They are smooth and long and slender, indicating that this rhinoceros was without a horn. The inion is anterior to the line of the occipital condyles, and is considerably elevated and bilobed. The temporal fossæ approach each other, being separated by a narrow rib only. The ramus mandibuli is rather slender, and projects well in front of the line of the nasals. The dentition is I., $\frac{?}{2}$; C., $\frac{0}{0}$; P. m., $\frac{3(-4)}{3}$; M., $\frac{3}{3}$. The usual anterior premolars are wanting in the lower jaw, and in the upper jaw in one specimen and on the right side of the other; hence I suspect $\frac{3}{3}$ to be the normal dentition of the species. As they are $\frac{4}{4}$ in *Rhinocerus* and *Aceratherium*, the present animal may be placed in another genus under the name of *Aphelops*. The middle incisors were caducous. The outer are very large and cylindric at base; the attrition of their inner faces would indicate an opposing pair, but these I did not find, and the premaxillary sutures of the maxillary are exceedingly slender. The first lower premolars are not very narrow. The transverse crests of the superior molars widen inwardly, but do not come into contact with each other. On the posterior margin of the posterior is a deep notch, which almost divides it across. There are no other lobes. The last molar is narrowed. These teeth are notable for their very large size as compared with that of the skull generally. In one specimen, P. m. 2 (the anterior) is 0.8 the second molar in transverse diameter; but in an older specimen it is less than half the same.

Measurements.

	M.
Length of molar series	0.255
Length of second molar, crown	.050
Width of second molar, crown	.050
Width of second premolar, crown	.033
Length of second premolar	.032
Length of first (second) lower premolar	.028
Width of first (second) lower premolar	.016
Total length of cranium	.560
From inion to end-nasals	.456
From foramen magnum to inion	.138
Width at orbits	.173
Depth of mandible at first molar	.070

About the size of the Indian rhinoceros, but with much larger teeth.

ACERATHERIUM CRASSUM, Leidy; *Aphelops crassus*, Cope, Bull. U. S. Geol. Surv., No. 1, 1874, p. 12; *Rhinoceros crassus*, Leidy, Anc. Fauna Dak. and Neb., &c., p. 228.

Leidy states that the formula of dentition of this species is identical with that of the Indian rhinoceros, and elsewhere that it is probably a true rhinoceros, as distinguished from *Aceratherium*. He does not appear to have possessed material to verify these statements.

An imperfect mandibular ramus, containing the last molar and alveoli of the four teeth which precede it, differs from the corresponding one of *A. megalodus* in the greater thickness in proportion to the depth. It is absolutely both shallower and thicker than a corresponding ramus of the allied species, while the teeth are larger, the last three occupying exactly a space equal to that supporting the last four of *A. megalodus*. The last molar is larger than the penultimate in *A. crassum*, (larger in *A. megalodus*,) and encroaches on the base of the coronoid process; in all the jaws of *A. megalodus*, this tooth is considerably in advance of this process, which rises more abruptly than in it. This tooth is shown to be the last molar by the absence of any trace of alveolus or crown of a successional tooth behind it in the various jaws in question. In *A. crassum*, the coronoid process rises gradually from the front of the last molar.

Measurements.

	A. megalodu.	*A. crassus.*
Length of last four molars	0.160	0.215
Length of last molar	.044	.062
Length of first true molar	.036	.055
Width of first true molar	028	.033
Depth of ramus at M. 2	.087	.078
Width of ramus at M. 2	.047	.055

The last molar is not quite protruded in the type specimen of *A. crassum*.

Near to the specimen just described, I found the left maxillary bone, with nasal, frontal, and other elements, of a rhinoceros, which differ in some respects from corresponding parts of *A. megalodus*. The rather larger teeth would coincide with the type of *A. crassum;* but that the specimens belong to the same individual is not certain. It is characterized by the same increase in size posteriorly of the molars; the M. 2 exceeding that of the *A. megalodus*, while the P. m. 2 (the first) is considerably smaller. The latter measures less than half M. 2, while it is 0.8 the diameter of the same in the *A. megalodus*. There is no rudiment of P. m. 1. Hence, this specimen displays fully the characters of the genus *Aphelops*. The nasal bones are long, acuminate, straight, and not co-ossified. They are tectiform, and distally compressed, instead of flattened, as in two specimens of the *A. megalodus;* they are also quite rugose at the extremity. These characters may be only sexual.

HIPPOTHERIUM, Kaup.

HIPPOTHERIUM SPECIOSUM, Leidy, Anc. Fauna Dak. and Neb., 282.

HIPPOTHERIUM PANIENSE, *sp. nov.*

Indicated by molar teeth in the collection. Two of these have elongate-curved crowns; the longer is a left posterior, the more abraded a right median. The latter is characterized by the generally greater simplicity of the enamel-boundaries of the lakes, as compared with the same portions of *H. speciosum*, with which it agrees in size. The only plications to be observed are the usual opposite ones entering the lakes from the middle of their adjacent boundaries, and a slight one at the inner angle of the same border of the anterior lake. The inner crescents are united, the posterior retaining its width posteriorly, and giving off the posterior inner column from its anterior half. Both the internal columns are longitudinally oval and rather small, the anterior well separated. The adjacent enamel-border gives off the usual projecting fold. Outline of crown nearly quadrate.

A second molar, less worn, presents therefore a little greater complexity of enamel-folds. Thus the anterior inner part of each lake is folded into a loop, and there is a second pair of opposite folds outside of the usual pair on the adjacent borders of the lakes.

A third molar is much more worn than either of the preceding, so as to throw the inner and median posterior areas together. The anterior median is well isolated and subround. There are no folds of the enamel-plates whatever.

Measurements.

	M.
Length of No. 1 from roots	0.027
Width of antero-posterior	.019
Width of extero-interior	.020
Length of No. 2	.032
Width of antero-posterior	.021
Width of extero-internal	.018
Length of No. 3	.018
Width of antero-posterior	.021
Width of extero-interior	.022

From the neighborhood of the Pawnee Buttes, Colorado.

PROTOHIPPUS, Leidy.

PROTOHIPPUS LABROSUS, Cope.

Having obtained a number of fragmentary and entire crania referable to species of the present genus, it becomes possible to correlate the mandibular with the maxillary forms, dentition, &c., as it has not been possible to do heretofore. Of mandibles there are four types, which I refer to species as follows:

Symphysis flat, shallow; no diastema between their incisor and canine teeth.—*P. labrosus.*

Symphysis narrower, deep; inferior molars smaller.—*P. sejunctus.*

Symphysis narrow, deep, contracted, and smaller; lower molars larger.—*P. perditus.*

These comparisons are instituted on one mandible of the first; two entire and three incomplete ones of the second; and two of the third types, all but two accompanied by superior molars or crania. The specimen of *P. labrosus* embraces the right maxillary bone, containing five molars; a second specimen includes three superior molars of the left side; it is also represented by several isolated molars.

Protohippus labrosus resembles the two species described by Leidy as *Merychippus* in the short crowns and long roots of the molar teeth, with thickened external ridges, separated by thin bands of cementum. It therefore differs from *Protohippus perditus* and *P. placidus*, resembling the first named in size. It is exactly intermediate between the *P. insignis* and *P. mirabilis* in size, and to it is no doubt to be referred Dr. Leidy's No. 4 of the latter.* Either there are three species of the present character, or Dr. Leidy's and the present forms must be arranged under one appellation. I prefer retaining them as distinct for the present, since I have nearly identical measurements in six different individuals, and four of the *P. perditus* equally uniform in dimensions. The latter always slightly exceed those of the *P. labrosus*, and differ in the longer dental crowns, with subacute exterior ridges; typically, the internal columns are oval in section, but may occasionally be subcylindric; they are cylindric in *P. labrosus*. The first specimen above mentioned I regard as typical, and describe it as follows:

The first premolar is well developed; in the first molar, the anterior lake is isolated from the inner fold. The anterior inner column is cylindric in all the teeth; the posterior similar, but joined with its crescent by attrition in most of them. The boundaries of the crescents are all simple, except a tendency to the middle infolding of the adjacent borders

* Ancient Fauna of Dakota and Nebraska, p. 300, figured plate xvii, Figs. 8–9.

of the crescents. The teeth are but little curved, and the base of the crown, with termination of the broad longitudinal gutters, is visible, although the attrition of the teeth, especially of the inferior incisors, does not indicate advanced age.

The mandible is distinguished by the length of the diastema and the flatness and shallowness of the symphysis. The permanent molars are all present in the specimen, and are robust in form. Except in the first and last, they are characterized by the small development of the anterior crescent horn and posterior tubercle of the inner side of the crown. The horn of anterior crescent of the first molar is well produced inward, broad, and simple; the entire tooth is narrower than the other molars except the fifth and sixth. The latter is a little longer than the others, and possesses a posterior crescent smaller than the others. The canines issue from their alveoli very close to the third incisors; the two pairs of first and second incisors are in a nearly transverse line, in consequence of the flatness of the symphysis. The median lake is half worn-out in the second incisors.

Measurements.

	M.
Length of four premolars and one molar	0.087
Length of crown of first premolar	.008
Length of crown of second premolar	.022
Width of crown of second premolar	.019
Length of crown of first molar	.018
Width of crown of first molar	.022
Height of crown of first molar	.011
Length of six inferior molars	.113
Length of first inferior molar	.020
Width of first inferior molar, (medially)	.009
Length of second inferior molar	.019
Width of second inferior molar	.012
Width of symphyseal trough, (least)	.015
Depth in front of *foramen mentale*	.016
Expanse of two middle pairs of incisors	.041

About the size of the ass.

This species is readily distinguished from the more common *P. perditus* by the peculiar form of the symphysis, more simple molar teeth, with shorter crowns, and the constantly smaller size; four mandibular teeth of the latter occupying the same space as five mandibulars in the *P. labrosus*. The first premolars are also larger and two-rooted, those of *P. perditus* in three specimens before me and of *P. sejunctus* in one example being but one-rooted.

PROTOHIPPUS SEJUNCTUS, Cope, Bull. U. S. Geol. Surv., No. 1, 1874, 15.

Represented in my collections by a nearly complete skeleton, with cranium and entire dentition; both mandibular rami and symphysis of a second; mandibles and dentition of two others, with appropriate molar teeth.

The skeleton, which I excavated with my own hands from the side of a bluff, adds considerably to our knowledge of this genus of horses. The side of the cranium displays a considerable depression in front of the orbit, which, though not so deeply impressed as described by Dr. Leidy in the known species, will refer this animal to the group regarded by him as a genus under the name of *Merychippus*. That the latter is distinct as a genus may be questioned, and I shall follow Dr. Leidy's later conclusion in uniting them.*

The structure of the feet in this genus, as indicated by the specimens of the present species, and of the *Protohippus placidus*, proves to be identical with that of *Hippotherium*, *i. e.*, tridactyle; the lateral toes of

* See Report on Geological Survey of the Terrs., vol. i, p. 322.

reduced proportions. This is important as distinguishing the genus trenchantly from *Equus;* and while the union of the inner columns of the superior molars distinguishes it from *Hippotherium*, a form of *P. perditus* is described below, in which the columns are more distinct than in individuals heretofore known.

The *P. sejunctus* is identical in measurements with the *P. labrosus*, and agrees with it in the simplicity of the enamel boundaries. It is also a short-crowned type, but the character is not so marked as in the latter. It differs strikingly in the deep and convex symphysis, and, in the only specimen in which its alveolar border is preserved, in the hiatus separating the inferior canine from the incisors. It exhibits also the small and one-rooted first premolar of the *P. perditus*.

The adjacent horns of the lakes of the molars are more produced outwardly than the remote ones, and the enamel borders have no plications. The sections of the inner columns are oval posteriorly and subround anteriorly. The wearing of the last molars indicates the full maturity of the animal; the canines are separated by a considerable interval from the third incisors. The inferior molars are similar in general to those of *P. labrosus;* in three individuals, the last lobe of the last molar is a cylindroid instead of a trough-shaped column.

The cranium in general form partakes of the shorter and more elevated outline seen in all the three-toed horses. The free part of the nasal bones and the diastema behind the canines are short. The outline of the vertex, from the nose to the sagittal crest, is quite plain, while the posterior part of the nasal bones, &c., is much narrowed by the large facial depression at the sides. This occupies the space between the nasal bones and the malar ridge above and below, and is bounded behind by the anterior border of the orbit; in front it is open, but its depression follows below the nasal bones to the diastema. While its area is strongly impressed, especially superiorly and inferiorly, it is not nearly so much so as indicated by Leidy in *P. insignis* and *P. mirabilis*, but more marked than in his figure of *P. perditus*. My specimens of the latter are not well preserved in the region in question.

The infraorbital foramen issues above the anterior border of the first true molar and the malar ridge above its posterior portion. The orbit is closed behind, and the sagittal crest is but an angle, and originates above the glenoid cavity. The inion is narrowed above, and projects backward over the upper edge of the foramen magnum; posteriorly, the occipital presents a pair of vertical fossæ, separated by a low ridge. Its external crest is not continued to that of the squamosal part of the zygoma. The meatus auditorius is quite small, as is also the mastoid tuberosity. The paramastoid is large and stout.

Measurements of cranium.

	M.
From occipital condyle to incisor-teeth	0.330
From occipital condyle to last upper molar	.140
From occipital condyle to fundus of palatal notch	.165
Length of entire molar series	.124
Length of crown of first premolar	.011
Length of crown of second premolar	.025
Width of crown of second premolar	.018
Length of crown of first true molar	.017
Width of crown of first true molar	.020
Height of crown of first true molar	.013
Length of diastema	.027
Height of crown of canine	.015
Width of arc of incisors	.050
Length from first incisor to first premolar	.069
Length from first incisor to nasal notch, (oblique)	.080

	M.
Length from first incisor to orbit	0.198
Diameter of orbit	.045
Width of nasals at notch	.031
Width of front at middle orbit	.076
Width of zygomata posteriorly	.132
Width between meatus	.088
Width between middle molars	.038
Width of occipital foramen and condyles	.054
Length of mandibular ramus	.270
Length from end-incisors to last molar	.190
Length from end-incisors to first molar	.077
Length from end-incisors to canine, (axial)	.025
Depth of symphysis in front of *foramen mentale*	.028
Depth of ramus at first premolar	.043
Depth of ramus at sixth premolar	.063

The *skeleton* is noteworthy for the disproportionately large size of the cervical, as compared with the dorsal vertebræ. The large size of the head, compared with the rest of the animal, was supplemented by the length and slenderness of the limbs, which considerably exceeded the proportions they bear in the existing horse. The lumbar vertebræ are slightly opisthocœlian, the dorsals strongly so. The cervicals are large and moderately elongate; the size results from the great development of the processes, since the centra do not materially exceed those of the lumbars. The atlas is not much expanded, and has a well-marked *tuberculum atlantis* and very low neural keel.

The limbs are slender and the hoofs small. The humerus is more curved than in the horse, and has a strong tubercular deltoid crest. The proximal tuberosities are very different from those of the horse. The external is largely developed, but is not produced into a hook nor extended into a longitudinal crest. The inner bicipital tuberosity is a little more prominent, and curves hook-like outward, inclosing with the outer a deep notch. It is continued at right angles along the inner aspect of the head into a straight crest; their angle of union is prolonged downward as the deltoid crest. The outer tuberosity in the horse is double, and, while not hooked as in *Rhinocerus*, is a little more prominent than in the present species; the inner is not hooked as in the *P. sejunctus*. There is an ala on the inner side of the distal end of the humerus, and a supracondylar foramen, both of which are wanting in the horse.

The *radius* differs from that of the horse in being considerably longer than the humerus instead of a little shorter. It is gently curved and flattened, with the transverse ends about equally wide. The ulna is co-ossified with it throughout the length, excepting a small portion beyond the humeral cotylus, as in the horse.

The *femur* is stout, with the lesser trochanteric ridge well developed. The trochlea is wide, with subequally elevated bounding ridges. The *tibia* is considerably longer than the femur, and presents a long and prominent cnemial crest. The shaft is transverse, with external edge and inner plane narrower than the anterior. The trochlea is very oblique, the astragaline grooves well defined by the internal and external tuberosities. Fibula not preserved.

The right posterior foot, among others, is perfectly preserved. It is, like the radius and forefoot and the tibia, distinguished for its elongation and slender proportions, as compared with the horse. The *astragalus* differs from that of the horse in having the cuboid facet on a more pronounced neck, and in the narrowness of the trochlea. The navicular facet is subpentagonal and without emargination. The *cuboid* is largely extended posteriorly, where it bears a large tuberosity. The *naviculare* is shallow and concave proximally. The *ectocuneiforme* is of similar length; behind it a well-developed *mesocuneiforme*, which supports the internal metatarsal. The external metatarsals are situated behind the median, except for an inch at their distal extremities. Their articular surfaces are compressed, and present an obtuse trochlear angle, but no keel; they reach to the base of the condyle of the median metatarsal behind. The latter is very convex above, slightly flattened below. The lateral digits only reach to the distal end of the first phalanx. The penultimate phalanx of each is much produced behind; the last or ungueal is much compressed, and is literally a half-hoof. The coronet is half as long as the pastern, and the unguis or coffin-bone is acuminate in outline and elevated on the middle line. It is deeply fissured at the extremity, and the margin abounds in foramina. The nutritious foramina of the base are each in the apex of a triangular fossa, which is open posteriorly. This bone has proportions not unlike those ascribed by Leidy to a specimen from the Niobrara, but is rather smaller; but the foot to which it pertains measures but 10.5 inches, while that of *P. sejunctus* (without tarsals) is 11 inches in length.

Measurements.

		M.
Length of atlas, (extreme)		0.061
Width of atlas medially below		.035
Width of atlas in front of diapophyses		.060
Length of odontoid process		.023
Length of three posterior dorsal vertebræ		.076
Diameter of articular face of centrum of vertebræ	transverse	.021
	vertical	.015
Length of humerus, (axial)		.192
Diameter of proximal end	antero-posterior	.065
	transverse	.055
Diameter of condyles		.044
Length of radius		.229
Transverse diameter of radius	proximally	.045
	at middle	.026
	distally	.038
Antero-posterior diameter of radius	proximally	.026
	medially	.018
	distally	.023
Diameter of femur	shaft	.040
	condyles	.058
Length of tibia		.250
Length of foot, including tarsus		.325
Length of foot without tarsus		.277
Outside length of calcaneum		.075
Depth of calcaneum behind		.027
Width in front		.033
Total length of astragalus		.045
Total width		.041
Width of trochlea of astragalus		.018
Width of navicular facet		.022
Depth of navicular facet		.022
Width of cuboid facet		.008
Width of cuboid bone fore and aft		.023
Length of cuboid bone		.015
Length of internal metatarsus		.170
Transverse width of trochlea of median metatarsus		.021
Length of pastern		.042
Width of pastern proximally		.025
Length of coronet		.027
Width proximally		.025
Length of coffin		.036
Width of articular face		.021
Width between angles		.036
Elevation behind		.023

Remarks.—Professor Leidy has already observed that the structure of the molars in this genus is in type the same as that of the deciduous molars of *Equus*, and that hence *Protohippus* represents the more primitive condition of horse. In further confirmation of this view, I may add that the proportionate size of the head and length of limbs to size of body is greater than in the recent species of *Equus*, resembling in these points the colts of that genus. Acceleration of the growth of the body and prolongation of the face, the same in the widening (fore and aft) of the internal columns of the molar teeth, with retardation of the growth of the lateral phalanges, would express the process of evolution of the modern types of horse.

PROTOHIPPUS PERDITUS, Leidy.

Represented in the collections by the entire molar dentition of one cranium; the greater part of that of another, with incisors and canines; the four median molars of another; two superior molars, with mandible and teeth of a fourth; mandibular dentition of two others, with parts of mandibles and symphyses; and isolated molars of a large number of additional specimens.

Without this material, I should have hesitated to separate the two species above described as new; as it is, I have no question that they are well defined, and are not the species described by Dr. Leidy under the name of *Merychippus*. The two lower jaws at my disposal agree in dimensions with each other and with the superior molars and with Dr. Leidy's types, with which I have compared them, four of them having the same extent as five of those of the two species above described. In two successional superior molars little worn, one of the inner columns (the anterior) is not yet united with its corresponding crescent, and the borders of the lakes are more plicate than in more worn examples.

PROTOHIPPUS PLACIDUS, Leidy.

A portion of the skeleton of this species was excavated by myself from the rock of the Pliocene formation, which was accompanied by two teeth, characteristically those of this species, and the only ones I obtained which are referable to it. They are readily known from their small size absolutely, and it would seem relatively also. The vertebræ are similar in size and proportions; but the metatarsus is materially shorter than that of *P. sejunctus*, and the phalanges of all the toes, and especially the coffin-bones, considerably stouter. Compare measurements with those given above.

Measurements.

	M.
Length of median metapodial bone	0.173
Expanse of condyles of lateral metapodials	.042
Length of first lateral phalanx	.024
Antero-posterior width of first lateral phalanx	.016
Length of coffin-bone medially	.041
Width between angles	.037
Width of articular face	.026
Height of coffin-bone behind	.022

Thus both coffin-bones are larger, wider, and flatter than those of *P. sejunctus*, a character provided for by the greater lateral distal expansion of the metapodial bones. The shortness of the metapodial bone may be due to the fact of its being a metacarpal; the femoral condyles are adherent to it in the matrix, and there is a proximal facet like that for the cuboid bone in *P. sejunctus*. Were the bone a metacarpal, this facet would relate to the trapezoides, a contact which does not exist in either of the genera of three-toed horses, *Hippotherium* and *Anchitherium*, according to Kowalevsky.*

ARTIODACTYLA.

MERYCHYUS, Leidy.

MERYCHYUS MAJOR, Leidy, Anc. Fauna Dak. and Neb., 121.

A single superior first molar, presenting some peculiarities perhaps individual.

MERYCHYUS ELEGANS, Leidy, *loc. cit.*, 118.

A mandibular ramus, with the molars and last premolar; a little larger than Leidy's specimens from Nebraska.

PROCAMELUS, Leidy.

PROCAMELUS, *sp.*

Numerous parts of skeletons of a large species without teeth; possibly the *P. niobrarensis*, Leidy.

PROCAMELUS ANGUSTIDENS, Cope, Bull. U. S. Geol. Surv. Terrs., No. 1, 20.

Represented by the nearly entire mandibles, with most of the teeth of two individuals, and two superior molars referred with probability to the same.

This camel is the size of the *P. robustus*, Leidy, but differs from it in the much narrower teeth, especially the last molar and last premolar, the much smaller first molar, and totally different form of the second premolar. Thus, while the last molar has the same length, it supports an anterior expansion whose angles are the summits of ridges on the inner and outer sides of the crown, which are wanting in *P. robustus*. Behind the outer rib in *P. angustidens*, there is a considerable groove. While the third molar is as large as that of *P. robustus*, the first molar is strikingly smaller, while the third premolar is about as long, is only half as wide when worn to the same degree. The second premolar, instead of presenting a contracted subconic crown, is longitudinally extended and compressed, resembling closely the third premolar. The molars are remarkably flat on the outer side; each lobe being devoid of a median ridge, and the first and second even wanting that between the lobes. The diastemata are long, and the first premolar is compressed and equidistant between the canine and the second premolar. The diastema in front of the canine is not wider than one tooth. The lower incisors are broad and oblique. The lower posterior boundary of the symphysis is almost immediately below the first premolar.

Measurements.

	M.
Total length of dental series to first incisor	0.240
Length from first to third incisor on crowns	.035
Length from first incisor to canine	.040
Length from first incisor to first premolar	.073
Length from first incisor to second promolar	.103
Length of molar series	.134
Length of premolars 2–3–4	.039
Length of second premolar	.016
Length of fourth primolar	.016

* Palæontographica, 1873, pl. vii.

	M.
Width of fourth premolar, (half worn)	0.005
Length of first molar, (half worn)	.019
Width of first molar, (half worn)	.014
Length of third molar	.047
Width of third anterior column	.013

In the second specimen the molars are a little narrower.

PROCAMELUS HETERODONTUS, Cope, Bull. U. S. Geol. Surv. Terrs., 1874, No. 1, 20.

Represented by the right distal portion of a mandibular ramus, with incisor, canine, and premolar teeth, and by the greater part of the dentition of the premaxillary and maxillary bones. These indicate an animal of the size of the species last described.

An interesting fact in the structure of the genus is indicated by these specimens, namely, that the premaxillary bones support a full series of incisor-teeth, a fact not heretofore known, as the pieces in question had not been previously identified by authors. The median incisors were inserted into rather small sockets, and were separated by diastemata from the third or caniniform incisor, from each other, and from the anterior extremity of the bone.

A second result of the investigation is that the genus *Homocamelus*, Leidy, is probably the same as *Procamelus;* and that *H. caninus* should be regarded as the *P. robustus*, unless new evidence exists to the contrary. The former was established on dentition of the upper series alone; the latter on that of the lower jaw. In the present species, we have the two kinds of teeth combined. The relations are, however, quite different from those found in the *P. robustus* and the *P. angustidens*. As to the reference of *H. caninus* to the former rather than the latter of these two, it depends on their coincidence in the transverse width of the premolar teeth, and is rendered probable by the fact that they are from the same horizon and approximate locality.

In the superior and inferior dentition of *P. heterodontus*, it is to be noticed that the first premolar is situated well anteriorly, the space separating it from the second premolar being twice as long as that between it and the canine; in *P. robustus*, these interspaces are equal (in the lower jaw) as in *P. angustidens*. In the present camel, the third incisor is separated from the canine in the lower jaw by a space nearly equal to that between the canine and first premolar; in *P. angustidens*, and, probably *P. robustus*, (= *H. caninus*,) this space is very much less, and just sufficient to admit the superior caniniform incisor. In the present species the lower border of the symphysis is below the canine, and hence the symphysis is much shorter than in *P. angustidens*, as it is steeper and concave on the antero-inferior face. It is not co-ossified in the specimen, while it is so in the *P. angustidens*. On each side of the suture below is a small, compressed, descending tuberosity. The mental foramen is below the first premolar. The second and third lower premolars are two-rooted and compressed; the third presents an angle inward at its anterior end.

The premaxillary bones attenuated and simple in front, with little indication of contact or connection across the middle line. The side of the muzzle is concave above the first premolar. Last incisor vertical in direction.

The maxillary teeth associated with the above-described premaxillary bones represent the entire series, except the second and third premolars. These present strong exterior ribs between the columns, and weak ones between on the third molar. These teeth present no extra lobes, tubercles, nor columns, and the cement-deposit in the lakes is very small. The third premolar and first molar are about as broad as long.

Measurements of the upper jaw.

	M.
Length of true molars	0.083
Length of last molar, (outside)	.036
Width of last molar, (anterior column)	.016
Length of first molar	.020
Width of first molar	.019
Length of last premolar	.014
Width of last premolar	.013
Length from first premolar to canine	.016
Length from first premolar to third incisor	.036
Length from third incisor to end of premaxillary	.038

Measurements of the lower jaw.

	M.
Length from apex of third incisor to end of third premolar	0.120
Length from apex of third incisor to second premolar	.698
Length from apex of third incisor to first premolar	.052
Length from apex of third incisor to canine	.025
Depth at third premolar	.040
Depth at canine	.041

From the heads of Pawnee Creek, Colorado.

PROCAMELUS OCCIDENTALIS, Leidy, Anc. Fauna Dak. and Neb., 151.

Specimens in fine preservation, but referred, with some doubt, as above. The dimensions of the teeth are intermediate between those of the species above named and the *P. gracilis*, Leidy.

MERYCODUS, Leidy.

MERYCODUS GEMMIFER, Cope, *loc. cit.*, 22.

A small ruminant, represented by jaws and teeth of three individuals found in association with the species above described by the writer. These embrace only the true molar-teeth in good preservation. They resemble those of *M. necatus*, Leidy, in form and size, but differ in having a rudimental column between the principal columns at their bases, a character which I have satisfied myself does not exist in the Niobrara specimens described by Dr. Leidy by autopsy. These only appear on the grinding faces after prolonged attrition. First molar equal to the last premolar in antero-posterior diameter.

Measurements.

	M.
Length of four posterior molars	0.037
Length of true molars	.030
Length of second molar	.090
Width of second molar	.040
Length of third molar	.013
Width of third molar	.006
Depth of jaw at second molar	.015

PROBOSCIDIA.

MASTODON, Cuv.

MASTODON PROAVUS, Cope, Synop. Vert. Col., 1873, 10.

Represented by an entire anterior molar, portions of posterior molars, and an astragalus, all found associated by the writer. They probably pertain to the same individual.

The general character of the transverse crests of both kinds of teeth is similar. Each crest is composed of two obtuse lobes, whose diameter is greatest exteriorly, but contracts toward their point of contact on the median line. Their section is therefore pyriform, with the apex inward. In an anterior tooth, the cutting-edges are obtuse and descend from the outer margin to the line of division between them. This line is a narrow fissure in the anterior tooth dividing the cones for more than half their height. This fissure is similar in the posterier molars, but the cones are more elevated and compressed, and are irregularly lobed with low tuberosities, especially on the posterior face. The outer face of the cone of the last pair is separated from the posterior by a low, vertical, ridge. There is a posterior heel, whose summit is continuous with one of the cones.

The valleys are open and spreading, as in *M. ohioticus*, and there appear to have been no intermediate nor accessory lobes or cones. There is a cingulum round the anterior molar, which is strongest behind. One of the cones sends a rib inward and downward to a position on the cingulum, which partially incloses a fossa on the outer side.

Enamel generally smooth.

The tibial face of the astragalus is convex antero-posteriorly, little concave, and oblique transversely. The inner side is elevated, and also shortened from the back forward, so as to leave a considerable neck for the navicular facet. This is convex and oblique, extending nearly to the edge of the tibial face on the outer side. The peroneal face is shallow, and exhibits a small facet and a fossa. The calcaneal facet of the inner side is much produced inward. The external one is a broad oval.

Measurements.

	M.
Length of crown of anterior molar	0.055
Width of crown of anterior molar	.050
Elevation of cones of the same	.025
Width of valley between apices of the cones	.027
Elevation of cone of posterior molar	.042
Transverse diameter of the same at base of fissure	.035
Long diameter of the astragalus	.093
Transverse diameter of the astragalus	.100
Exterior depth of the astragalus	.025
Interior depth of the astragalus	.058
Transverse width of navicular facet	.055

The anterior molar described has but two transverse crests, but is considerably larger than the two crested teeth in *Trilophodon ohioticus*. As the other portions indicate a smaller species, the position of this tooth becomes a matter of question. This point, together with the isolated or conic and furrowed character of the divisions of the crests, with the smaller size, separate it from the common species. It also belongs to an earlier geological period. From *M. mirificus*, the wide, open valleys, simplicity of the cones, and larger size distinguish it.

TESTUDINATA.

STYLEMYS, Leidy.

STYLEMYS (?) NIOBRARENSIS, Leidy.

Abundant.

APPENDIX.

The essays and papers in which the descriptions and determinations of most of the species of extinct *Vertebrata* included in the preceding report originally appeared are the following:

Cope, Paleontological Bulletin, No. 14; published July 25, 1873.
Cope, Paleontological Bulletin, No. 15; published August 20, 1873,
Cope, Paleontological Bulletin, No. 16; published August 20, 1873.
Cope, Paleontological Bulletin, No. 17; published October 25, 1873.
Cope, Synopsis of New Vertebrata from the Tertiary of Colorado; published October 16, 1873.
Hayden, Bulletin of the United States Geological Survey of the Territories, No. 1; published January 21, 1874.
Hayden, Bulletin of the United States Geological Survey of the Territories, No. 2; published April 19, 1874.

PART III.

ZOOLOGY.

REPORT OF LIEUT. W. L. CARPENTER ON THE COLLECTIONS MADE BY HIM IN 1873, WHILE CONNECTED WITH THE UNITED STATES GEOLOGICAL SURVEY.

WASHINGTON, D. C., *January* 1, 1874.

SIR: Having been permitted by the courtesy of my superior officers to accompany the United States geological survey of Colorado, and by yourself kindly appointed naturalist of the party, I take pleasure in presenting for your consideration a brief summary of the collections made in this department during the season.

In ornithology and oology, a thorough collection, embracing many rare and valuable specimens, was made by Mr. J. H. Batty. The branches to which I paid particular attention, and the collections made by myself, are as follows:

Hymenoptera.	Myriopoda.	Parasites.
Lepidoptera.	Eggs of insects.	Land-shells.
Diptera.	Larvæ.	Fish.
Coleoptera.	Chrysalides.	Reptiles.
Hemiptera.	Galls.	Mammals.
Orthoptera.	Arachnida.	Skeletons.
Neuroptera.		

The entomological collection was made as thorough as circumstances would permit; and a large amount of material obtained for future study, including sediment of streams and ponds at extreme elevations, which will require a considerable time for examination, and cannot, therefore, appear in this report. The several orders of insects were placed in the hands of eminent scientific gentlemen, specially interested in their study, who cheerfully undertook their examination; the classification of species as arranged by them is herewith annexed. A separate miscellaneous entomological collection was also made in the mountain-region, entirely above timber-line, which I have classified, thinking it would prove interesting in determining the geographical distribution and range of species. As many skeletons of mammals were made as possible, including one of the grizzly bear, which I believe is the first complete skeleton of that animal ever secured.

Regarding the general results obtained, and the inferences to be drawn therefrom, I can only say that the thorough observations of Dr. A. S. Packard, jr., Dr. Cyrus Thomas, and Dr. Horn, published in the reports of your previous surveys, have been so exhaustive as to leave little of interest to be said which will not be a repetition of former publications. In fact, I find that nearly all my notes upon the habits and range of species singularly verify the facts noted by those who have preceded me in this field. I shall, therefore, merely call attention in the catalogue by a brief note to any which may merit particular attention.

Allow me, sir, to tender my sincere thanks to yourself, Professor Gardner, Mr. Stevenson, and, in fact, to all the members of the party, for the cordial assistance rendered me in the pursuit of my duties as naturalist of your survey.

I am, sir, very respectfully, your obedient servant,

W. L. CARPENTER,
Lieutenant, United States Army.

Dr. F. V. HAYDEN,
United States Geologist.

DESTRUCTION OF PINE-TIMBER IN THE ROCKY MOUNTAINS.

By LIEUT. W. L. CARPENTER, U. S. A.

While attached to the United States geological survey for 1873, my attention was attracted to a singular destruction of pine-timber in the Rocky Mountains, in the Territory of Colorado, by some agency unknown to myself. While personal observation satisfies me of the existence of such a baneful influence, I can only hope that a description of its effects will enable others to determine its cause, as my limited observation does not permit me to arrive at any satisfactory conclusion concerning it.

In the region of country lying between the eastern slope of the national range and the southern waters of the Colorado River, many pine-trees may be noticed stripped of their bark in such a way as to cause their decay. Sometimes the tree will be seen completely girdled, at others only denuded of a small patch of bark, which does not seem to affect its growth. The injury appears at any part of the trunk of the tree, and may often be seen at a distance of forty feet from the ground, which precludes the possibility of human agency. This fact was carefully verified, as it is well known that the Ute Indians strip the pine-trees of bark in the spring of the year to obtain the pulpy substance next the wood for food; but the bark is by them always stripped off smoothly in large pieces near the ground, and from trees in the vicinity of good camping-places; while the girdled trees referred to may be found in the most inaccessible places, and often near timber-line. As far as known, there is but one species, the yellow pine (*Pinus ponderosa*), so attacked; and although the white spruce and quaking-aspen are to be found in the same vicinity, they never appeared to suffer.

The injury first begins with a row of holes about one-fourth of an inch in diameter at the surface of the bark, and terminates in a point at the wood. These holes are generally drilled in nearly parallel lines, perpendicularly and horizontally, then gradually enlarged, until finally they connect with each other, and the tree appears entirely stripped of bark for a vertical distance of two or three feet.

A careful examination of these trees in their various stages of decay was made for traces of insects, but nothing could be discovered which would lead one to suppose that it was their work. If attributable to the ravages of coleopterous insects, such as the *Curculionidæ* and *Cerambycidæ*, those most destructive to vegetation, then the damage must have occurred in some previous year extraordinarily productive of these insects; for although found there this season, they were quite rare. Nor could any unusual signs of coleopterous larvæ be found in the bark or wood of these trees. It also seems improbable that such extensive damage could have been inflicted by birds of the *Picidæ* family, noted for their hammering and pecking proclivities in search of larvæ, as these birds are by no means abundant in that region.

The section of country most affected seems to be the mountains near the source of Twin Lake Creek and the branches of the Gunnison; it was not noticed in Middle Park and Northern Colorado. The damage is so considerable that in a walk of one mile through a dense pine-forest on Twin Lake Creek, sixty large trees were counted, dead, or fast losing their vitality from this cause.

REPORT ON THE ALPINE INSECT-FAUNA OF COLORADO.

By Lieut. W. L. Carpenter, U. S. A.

A separate entomological collection was made by myself over an extensive area, at extreme elevations, in all cases exceeding an altitude of 12,000 feet above the level of the sea. Here amid the region of eternal snow, where both the animal and vegetable kingdoms, exposed to a climate of arctic severity, seem struggling for existence, are found many lowly forms of life, extremely interesting from their peculiar choice of a home. Only a short distance below the timber-line, at an altitude of about 11,000 feet, insect-life may be found in abundance; but an ascent of a few hundred feet causes a wonderful diminution in species; and when the summits of the loftiest peaks are reached, at an altitude greater than 14,000 feet, unless the weather be unusually mild, it requires very close scrutiny to disclose the presence of any life. It is probable that some insects, such as the *Orthoptera*, a few *Hemiptera*, *Diptera*, and *Coccinellidæ*, are carried to the tops of mountains by storms and atmospheric currents; while the *Arachnida*, *Lepidoptera*, *Neuroptera*, and most *Coleoptera*, many of which have been found in Alaska and Labrador, are undoubtedly peculiar to high latitudes and great elevations. In the early spring, long before any bare ground was visible, *Coccinella transversogutta* and *Lygæus reclivatus* were found at an elevation of 14,000 feet, in abundance upon the surface of the snow. *Lygæus reclivatus* seemed to be widely distributed; it being always found above the timber-belt, from May to October, throughout an area of 20,000 square miles. By removing the snow and searching under stones and in moss, *Arachnida*, *Coleoptera*, and larvæ were found. A microscopic examination of snow-water collected in pools, made during the months of May and June, failed to reveal the existence of any animal life; and it was then thought that aquatic insects would not be found; but a shallow pool discovered on Elbert Peak above timber-line, July 22, proved to contain considerable life, and was especially productive of a species of *Entomostraca*.

Myriads of grasshoppers of the species *Caloptenus spretus* swarm from the Pacific slope in the months of July and August, and in their journey eastward are arrested by the high peaks and ridges of the Rocky Mountains, and, becoming benumbed by cold, drop down to perish. The barrier thus presented by these mountains is of great benefit to the agricultural interest of Colorado; for, although upon a favorable season some swarms may pass by to the eastern plains, it will be safe to estimate that not more than one-tenth of the number which rise from the plains and valleys of Utah ever succeed in crossing the divide.

Five species of butterflies were found; the *Parnassius Smintheus* and

Chionobas Semidea being the most abundant. Of the moths, the beautiful *Arctia Quenselii*, which occurs also on Mount Washington, New Hampshire, and in the Alps, seemed to have the most extensive geographical distribution. If the sun were shining, the *Lepidoptera* might be seen flying about with all the activity of species in a warmer climate; but if a passing cloud obscured the sun for a few moments, they quickly took refuge in the rocks, so sensitive did they seem to a change of temperature.

The spiders appeared to thrive best; being always present at all elevations, and apparently indifferent to climate. The geometrical web-spinners were rarely found at high altitudes, owing to the absence of trees and plants upon which to build their webs. The habits of the species found above the timber-line were, however, well adapted to their peculiar surroundings. Those found in the crevices of rocks and holes in the ground generally lined their habitations with silk, and were thus enabled to entrap their prey; but the greater number were true wanderers, and roamed from place to place without ever spinning webs. Twenty-three species were found above timber-line, and, as far as now known, they are nearly all new to science.

The plant-bugs (*Hemiptera*), as might be supposed from the almost total absence of vegetation, were not numerous. This order of insects was found to be very limited in species throughout the mountains, owing probably to the scarcity of the cultivated plants found in more civilized regions, upon which they feed. The vegetables, fruit, and grain raised in the foot-hills are consequently quite free from the attacks of these pests, which so much annoy eastern farmers.

The collection of flies (*Diptera*) was so much damaged in transportation that it was difficult to determine even the genus in many cases. It is to be hoped that future collectors will not overlook this interesting order of insects, and that they may be more fortunate in preserving their collections from the many mishaps inseparable from mountain-travel. The horse-flies (*Tabanidæ*) were found in great numbers at the timber-belt, but seldom ventured far above it, and were never seen on the summit of the higher peaks. The blow-fly (*Musca erythrocephala*) was found everywhere at all elevations, and seriously interfered with the preservation of natural-history specimens, besides proving very destructive to articles of food at altitudes below 10,000 feet.

The bee-order is well represented in the collection; four new species of *Hymenoptera* being found. The humble-bee was always to be seen in midsummer at the verge of the alpine flora, busily engaged in collecting its store of pollen from the few flowers to be found.

The principal and most interesting result obtained from the study of this collection, is the demonstration of the fact that the alpine insect-fauna of the Rocky Mountains is nearly identical with that of Mount Washington (New Hampshire), Labrador, and Alaska; and that insects which are found upon mountains at great elevations will likely occur in a much higher latitude at a less elevation.

Insect-life, with the exception of the grasshoppers, is more abundant in the foot-hills than the plains near the foot of the mountains. An altitude of about seven thousand feet appeared to produce the greatest variety of species.

I desire to express my thanks to Dr. A. S. Packard, jr., for valuable assistance rendered in the determination of species; also to Prof. T. Glover, of the Agricultural Department, who kindly placed his admirable entomological plates and the public collections at my service.

HYMENOPTERA.

Atlantus basilaris, Say.
Lyda Carpenterii, Cress., new species.
Ichneumon ——— (?).
Ichneumon ——— (?).
Lampronota ——— (?).
Cryptus robustus, Cres.
Ammophila robusta, Cres.
Odynerus tigris, Sauss.
Bombus termarius, Say.
Formica ———.

LEPIDOPTERA.

Pieris occidentalis, Reakirt.
Parnassius Smintheus, Doub., 3 varieties.
‡ Chionobas Semidea, Say.
Argynnis Freya, Esper.
Militæa Nubegina, Edw.
Anarta ———.
†‡ Arctia Quenselii, Paykull.
† Agrotis Islandica, Staudinger.
Tortricidæ ———.

DIPTERA.

Tabanidæ, 2 species.
Therevidæ, 1 species.
Tipulidæ, 2 species.
Syrphus obliquus, Say.
Musca erythrocephala, Meigs.
Musca ———.
Musca ———.
Musca ———.
Bibionidæ, 1 species.
Dolichopus (?).
Chironomidæ, 1 species.

COLEOPTERA.

* Carabus tædatus, Fabr.
†* Nebria Sahlbergii, Fisch.
* Amara terrestris, Lec.
† Amara obtusa, Lec.
Silpha ramosa, Say.
† Podabrus lævicollis, Kirby.
Collops cribrosus, Lec.
* Dendroctonus obesus, Mann.
Calopus angustus, Lec.
Stereopalpus guttatus, Lec.
* Adoxus vitis, Linn.
Chrysomela dissimilis, Say.
Trirhabda convergens, Lec.
Hippodamia parenthesis, Say.
Coccinella transversogutta, Fald.
* Alophus alternatus, Say.

HEMIPTERA.

Lygæus reclivatus, Stal.
Lygæus circumcinctus, Stal.
Aradus americanus, Fab. (affinis).

ORTHOPTERA.

Caloptenus spretus, Uhl.
Platyphyma montana, Thos.
Stenobothrus Carpenterii, Thos., new species.
Decticus ———.

LARVÆ.

Phryganeidæ.
Arctia ———.
Agrotis Islandica (?).
Tortricidæ ———.
Bibionidæ (?).
Harpalus ———.
Tipulidæ ———.

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* Found also in Alaska.
† Found also in Labrador.
‡ Found also on Mount Washington, New Hampshire.

PUPÆ.

Mycetophilidæ.

Vespariæ.

MYRIOPODA.

Lithobinus Americanus, Newport.

ARANEINA.

Attoidæ, 1 species.
Drassoidæ, 5 species.
Theridoidæ, 1 species.
Thomisoidæ, 2 species.
Lycosoidæ, 14 species.

ENTOMOSTRACA.

Daphnia pulex.

MOLLUSCA.

Zonites nitidus, Müller.

LIST OF SPECIES OF BUTTERFLIES COLLECTED BY LIEUT. W. L. CARPENTER, U. S. A., FOR THE UNITED STATES GEOLOGICAL SURVEY OF COLORADO, 1873.

By W. H. Edwards.

Papilio Rutulus, Boisduval.
Eurymedon, Boisduval.
Parnassius Smintheus, Doubleday.
Pierio oleracea, Boisduval.
Protodice, Boisduval.
occidentalis, Reakirt.
Anthocaris Julia, Edwards.
Ausonides, Boisduval.
Colias Eurytheme, Boisduval.
Keewaydin, Edwards.
Scudderii, Reakirt.
Alexandra, Edwards.
Meadii, Edwards.
Danais Archippus, Cramer.
Euptneta Claudia, Cramer.
Argynnis Halcyone, Edwards.
Eurynomes, Edwards.
Hesperis, Edwards.
Freya, Esper.
Helena, Edwards.
Militæa nubigeria, Behr.
Militæa minuta, Edwards.
Phyciodes Carlota, Reakirt.
Camillus, Edwards.
Grapta zephyrus, Edwards.
Vanessa Antiopa, Linnæus.
Pyrameis Atalanta, Linnæus.
Limenitis Weidemeyerii, Edwards.
Cœnonympha ochracea, Edwards.
Satyrus silvestris, Edwards.
Charon, Edwards.
Ridingsii, Edwards.
Erebia Epipsodea, Butler.
Chionobas Chryxus, Doubleday.
Semidea, Say.
Chrysophanus Helloides, Boisduval
Lycæna Acmon, Hewitson.
rustica, Edwards.
Eudamus Tityrus, Fabricius.
Hesperia tesselata, Scudder.
Ocytes Draco, Edwards.

ON THE GEOGRAPHICAL DISTRIBUTION OF THE MOTHS OF COLORADO.

[Figs. 1–15.]

By A. S. Packard, Jr., M. D.

The following remarks are based largely on specimens of moths collected in Colorado by Lieut. W. L. Carpenter, attached to the United States geological and geographical Survey of the Territories, in the summer of 1873. The material is particularly interesting as throwing more light on the alpine insect-fauna of the Rocky Mountains than any collection previously made, so far as I am aware. I have also been allowed, through the kindness of Mr. T. L. Mead, of New York City, to incorporate much valuable material collected by him at different points in Colorado Territory, with the special localities and elevations given. The aid thus afforded by Mr. Mead's collections is invaluable. I have also received a few specimens from Colorado, collected and presented to me by Mr. Ridings, of Philadelphia. With the aid of these collections, and quite a full series of Californian *Lepidoptera*, collected by Mr. H. Edwards, and a large number of *Phalænidæ*, obtained by Mr. G. R. Crotch in Vancouver Island and neighboring localities (contained in the Museum of Comparative Zoology), we are furnished with some most important facts in the geographical distribution of the *Lepidoptera*, and particularly of the family of geometrid moths (*Phalænidæ*).

First, as to the nature of the alpinre fauna of the mountains of Colorado. The results obtained by Lieutenant Carpenter are extremely interesting, as showing that on the peaks above a line of 12,000 feet the fauna is as truly alpine as on the summits of the Alps or the top of Mount Washington, in New Hampshire. Several species occur there which are also found on the Swiss Alps, as well as Mount Washington, and in Labrador and Greenland, at the level of the sea.

Among the butterflies, I learn that *Chionobas semidea* Say, heretofore only found on the summit of Mount Washington, New Hampshire, has been discovered by Lieutenant Carpenter at the same elevation (12,000 feet and upward) as the moths mentioned in the following table. This establishes the complete identity of the faunas of the alpine summits of the United States at or above the snowiline. The following table shows the distribution of the five alpine and arctic *Lepidoptera* up to this time known to inhabit the alpine summits of Colorado:

	Colorado.	Mount Washington.	Labrador.	Greenland.	Iceland.	Alps.	Lapland.
Chionobas semidea	x	x					
Arctia Quenselii	x	x	x			x	
Anarta melanopa	x	x	x			x	x
Agrotis Islandica	x		x	x	x		
Plusia Hochenwarthi	x		x			x	x

Two specie of *Anarta* were collected by Lieutenant Carpenter in company with *Arctia Quenselii*, &c., but they were too much rubbed for identification. It is possible that they were *Anarta quadrilunata*, Grote, and *A. subfuscula*, Grote, (recorded from Colorado in Proc. Bost. Soc.

N. H., Jan., 1874, 244), and closely allied to *Anarta melanopa* and *A. Richardsoni* (*A. algida*), respectively. I should state that *A. melanopa*, Thunb., is recorded as occurring there on the authority of Mr. Grote. All three species were collected by Mr. T. L. Mead in Colorado. It should be borne in mind that the alpine fauna of Colorado also comprises a few species not found in other alpine regions; such are the two species of *Anarta* and two of *Chionobas* (*C. Chryxus* and *C. Uhleri*, the former occurring at Hudson's Bay).

The following table shows the distribution of eight species of *Phalænidæ*, which are found at an elevation of about 8,000 to 9,000 feet, around the base of the mountains. They are subalpine and circumpolar species, and also occur in the lowlands of north temperate America and Europe.

	Colorado.	Mount Washington.	Labrador.	Iceland.	Alps.	Lapland.	Mountains of Asia.
Larentia cæsiata	x	x	x	x	x	x	x
Cidaria populata	x	x	x		x		x
Cidaria lugubrata	x		x				
Cidaria testata	x				x		x
Coremia ferrugata	x	x	x	x	x	x	x
Melanippe hastata			x			x	x
Melanippe tristata	x				x		x
Melanippe lugubrata	x		x		x	x	x

Cidaria testata and *C. lugubrata* will undoubtedly occur in the White Mountains, as well as *Melanippe lugubrata*, since all except *C. lugubrata* have been found in different parts of Northern New England. We are also to look for *Larentia dilutata* (S. V.) in Colorado, as it occurs in New England, and in Europe and Asia. From the facts here presented, it will be seen how important it is to compare species occurring in nearly identical isothermal lines around the globe, and to study the variations in those species as occurring on opposite sides of the same continent, in comparison with those on different continents. The facts offered in this paper are exceedingly scanty, but yet indicate, so far as they go, some interesting laws of climatic variation, which tend to confirm the generalizations established by Professor Baird and Mr. J. A. Allen, as regards the avifauna of North America. I should, however, state that the fact of variation in species common to both sides of our continent were forced upon me by a study of the specimens themselves, without at the time having the views of our ornithologists in mind. The species below belong to but four lepidopterous families, the *Pterophoridæ*, *Phalænidæ*, *Noctuidæ*, and *Bombycidæ*. In all those enumerated, as noticed more fully in the remarks under each species, the Colorado (when the species occurs there) and Pacific coast individuals are larger, and, in some cases, with longer, more pointed wings, than in those from Labrador or New England, and in a few species show a tendency to become lighter in color. I believe that it will be found that these differences are due almost solely to climatic causes. The climate of the Colorado Mountains and of Vancouver Island is much warmer than that of Northern New England and Labrador. The mean annual temperature of Victoria, Vancouver Island, is 50°, that of New York being the same; while that of Labrador is 32°–30°. According to Professor Guyot (Physical Geography), the annual rain-fall of Astoria (about one hundred and twenty miles south of Vancouver Island) is 86 inches, while that of Saint John's, Newfoundland, is 63 inches (this is probably the same as the southern and eastern coast of Labrador). The rain-fall of the Rocky Mountain region is colored on Guyot's map the same as that of the Ural and Altai Mountains. The annual rain-fall of Fort Dalles, Oreg., is 22 inches, while that of Nertchinsk, in the Altai Mountains, is 17 inches, that of Peking being 24 inches; so that the rain-fall of the elevated plateau of Eastern Asia and of Colorado is nearly the same. Again, the annual rain-fall of the Alps on their southern slopes is from 60 to 90 inches; here we have quite similar conditions to those of the Cascade range in Oregon. These facts seem to explain the corresponding facts in the variation of the moths in the table given below. The warmer and more humid Pacific slopes of America cause a more luxurious growth, a greater development of the peripheral parts of the body, and slight changes in coloration. The climatic conditions of the Rocky Mountains and Alps being more alike than the White Mountains and Alps, we have certain identical features in the variation of the alpine species of moths of those two ranges of mountains which are not found in comparing White Mountain and Labrador specimens with those from the Alps of Europe.*

	New England.	Labrador.	Colorado.	Pacific coast.
Pterophorus cinereidactylus	Wings shorter			Wings longer.
Larentia cæsiata	Smaller	Smaller	Larger.	Larger.
Larentia cumatilis *	Smaller		Larger.	Larger.
Cidaria truncata †	Smaller	Smaller		Larger.
Cidaria lugubrata	Stunted	Stunted	Larger	Larger.
Cidaria abrasaria ‡	Smaller	Smaller		Larger.
Scotosia dubitata	Smaller and paler.	Smaller		Larger and darker.
Camptogramma fluviata, ♀	Smaller			Larger.
Macaria dispuncta	Smaller	Stunted and darker.		Larger and paler.
Eumacaria brunnearia	Smaller		Larger	
Zerene catenaria	Smaller		Larger	
Azelina Hübneraria §	Smaller			Larger.
Tephrosia canadaria ‖	Smaller			
Drasteria erechtea **	Smaller		Larger	Larger.
Plusia Hochenwarthi		Smaller, with faded whitish hind-wings.	Larger, with highly colored yellow hind-wings.	Larger and highly colored.
Agrotis Islandica		Smaller	Larger; bleached.	
Lithosia argillacea	Smaller			Larger.

* Seven out of ten Colorado and Californian examples (length of fore-wing, ♂, 0.62 inch) are considerably larger than three eastern examples from New York and Maine (0.55 inch).

† Three specimens from Iceland are darker than four from Labrador, and show great variation. Labrador and White Mountain specimens the same. All are smaller than those from the Pacific coast. In specimens from San Diego, Cal., the wings are much broader than in Vancouver Island ones. Length of fore-wing in three Iceland specimens, 0.61 inch; four Labrador, 0.64 inch; eight White Mountain, 0.64 inch; three Vancouver Island, 0.70 inch; two San Diego, 0.76 inch. This species varies much as *Macaria dispuncta*.

‡ This species also varies in the same way as *Macaria dispuncta* and *Cidaria truncata*. Two Lapland individuals are much smaller and darker than two Labrador and one White Mountain; and the latter are smaller and slightly darker than seven from Vancouver Island. Length of fore-wing in largest Lapland moth, 0.50 inch; Labrador, 0.54; Vancouver Island, 0.64 inch.

§ Five ♂ Californian examples (0.90 inch) are much larger than six from New England and Illinois, in which the fore-wing in the largest specimen is 0.77 inch long. The Californian moths have the notches and points much better marked on both pairs of wings than in eastern examples.

‖ Two Californian moths (0.80 inch) are a little larger than eight from the Atlantic States; (length of fore-wing, 0.88 inch).

** On comparing 100 specimens, the California and Oregon examples measure thus: Length of longest fore-wing, 0.97 inch; of New England examples, 0.82 inch.

It will be seen from the facts here presented that the moths probably follow, as regards size, a law the reverse of that established by Professor Baird† for the birds and mammals, who shows that they decrease in

* In this connection we may state that it would be very desirable to notice what changes, if any, have been induced in European species introduced by man into the Moravian settlements of Labrador.

† "The distribution and migrations of North American birds," Amer. Journ. Sc., xii, Jan. and March, 1866. See also J. A. Allen, Bull. Mus. Comp. Zool., ii, 1871, "On individual and geographical variation among birds. &c.; and R. Ridgway, "On the relation between color and geographical distribution in birds as exhibited in melanism and hyperchromism," Amer. Journ. Sci., iv, Dec., 1872, p, 454; v. Jan., 1873, p. 39.

size southward, though his law of increase in the length of certain peripheral parts westward also obtains in the *Lepidoptera*. The increase of size westward, as seen in the table on p. 541, is of course equivalent to the well-known southward increase of size in insects; though in a few species the Coloradian and Californian examples are larger than Floridan or Texan insects of the same species.

The Esquimaux of the Pacific coast show the effect of the difference of climate, being much taller and larger than the stunted Greenland and Labrador Esquimaux. Mr. W. H. Dall, in his "Alaska," remarks that "the average height of the Orarians [Innuit, Aleutians, and Túski], except among the stunted tribes of the extreme north, will average as great as that of their Indian neighbors." Even the white inhabitants who have moved to California from the Eastern States are said to find the climate more favorable to health than in the Atlantic States. Cultivated fruits are well known to grow larger and more luxuriantly in the Pacific States than in the Atlantic, whence they have been brought.

As regards the causes of these climatic changes, I find I have, without having previously read Mr. Allen's valuable chapter on this subject (*loc. cit.*, 239), written the foregoing remarks on the relation of the climatic variation of these insects to the temperature and humidity of the region they inhabit, which agree with his views. Of the insects above mentioned, *Plusia Hochenwarthi* and *Agrotis Islandica* are the clearest examples (1) of the increase of size westward and southward; (2) increase in length of peripheral parts westward; (3) brighter, deeper colors westward; (4 *Agrotis Islandica*) of brighter, more reddish colors in Pacific-coast specimens than in those from the more elevated portions of the Rocky Mountains, near the snow-line, where the winters are arctic, *i. e.*, cold and dry, those from the Alpine summits of the interior being bleached. This law should not be confounded with that established by the ornithologists, which refers to the bleached appearance of individuals from the dry, hot plateau of the interior, or middle zoological province of North America. These facts in the geographical distribution of insects, though they can hardly be called laws until confirmed by a greater number of data drawn from all orders of insects, yet illustrate, to my mind, how far climatic variation goes as a factor in producing primary differences in faunas within the same zone of temperature. Varietal, and, in some cases, specific, differences may have arisen in Asia and Europe and in America, from the climatic causes above stated; but these must have been largely inoperative in causing, for example, the present wide distribution of the circumpolar species. Here continuity of land, geological and not climatic causes, alone came in as a factor. And so, on the other hand, in accounting for the species and types of genera, distinguishing faunas in zones of similar temperature, geological causes have been the main factor in their production. For example, we cannot explain the similarity between the insect-fauna of the Pacific States and Colorado, and that of Eastern Europe and Central Asia without supposing the original migration of those identical generic forms from a Mesozoic and Tertiary continent in the arctic region, and their preservation through similar climatic and physical causes in their present areas.

In an essay on the geographical distribution of the *Phalænidæ* of California,* I divided the phalænid fauna into four groups. To the second of these groups, embracing species of genera found in Southern and Eastern Europe and Western Asia and Asia Minor, can be added the following species (which live in part both in Colorado and California):

*American Naturalist, vii, 453, 1873. Proceedings Bost. Soc. N. H., Jan., 1874, xvi, 13.

Lithostege triseriata (Colorado and California); *L. rotundata* (California); *Lobophora montanata* (Colorado); *Euaspilates spinataria* (Colorado); *Phasiane Meadiana* (Colorado); *Acidalia quinque-linearia* (California and Colorado); and *Caulostoma occiduaria* (Colorado and Oregon). Each of these species have representatives which do not occur in Eastern North America nor in Western Europe, *i. e.*, on the Atlantic coast, but in Central and Southern and Eastern Europe and Asia Minor, Turkey, and Western Asia, but not in India or Eastern Asia, *i. e.*, China or Japan, so far as yet known. Now, to account for this community of generic types in regions so remote, we must suppose that the nearly identical general climatic features of those two areas favored the preservation of these generic forms, which are almost exclusively north temperate, and characteristic of broad, elevated plateaus in the interior of the two continents. These forms are not of tropical origin, and I cannot account for their origin otherwise than from an ancient arctic continent. The fauna of the Eastern Atlantic States is, as regards the continent, a littoral assemblage, and thus equivalent to the fauna of Eastern Asia (*i. e.*, Japan and China and India), which occupies the region bordering the Pacific Ocean. Whatever may be our theories regarding the origin of these great zoological regions,* we have similar regions with analogous (*i. e.*, having the same generic) types in Asia and Europe combined, dividing the north-temperate zone into six zoological (and probably botanical) divisions, with analogous geological and meteorological features; and to account for closely similar features in moths inhabiting the elevated plateaus of Colorado and California and Central Europe and Asia, we can only say that the similar climatic features of those regions have induced their preservation there and extinction elsewhere, while originally descended from a common stock, which had its origin to the northward. I imagine that much the same continuity of life existed in Mesozoic and Tertiary times in the ancestors of these north-temperate forms, as now exists in the circumpolar fauna, and that in fact this north-temperate fauna of the globe was in Mesozoic and Tertiary times the then circumpolar fauna.

It will be seen by the present list how largely we have been able to add to the range of circumpolar forms, by a glance at the tables preceding. Those tables, which show how limited is the distribution of the moths there mentioned in alpine regions south of the polar regions of America and Europe and Asia, which form small "islands" rising out of the north-temperate zone, evince the degree of change undergone by the circumpolar fauna since the wane of the glacial period. It shows the inadequacy of climatic causes within the present geological period to account for the origin of any except varietal, and, in some cases, specific forms. Many of the forms, the study of which has led me to these reflections, I have at first regarded as distinct species, and in some cases described them as such, but I fully agree with Mr. Allen's practice of uniting many so-called species, whenever we can find connecting links. It is of the greatest importance to follow circumpolar and north-temperate faunas around the globe, from continent to continent, with ample means for comparison before us. It will then be seen how inadequate must be our views of the geographical distribution of the animals and plants of our own continent, without specimens from analogous regions in the same zone in the Old World. It will be found that for the study of our insect-fauna of the Rocky Mountain and Pacific States we must have ample collections from the Ural and Altai Mountains and sur-

* The Eastern, Middle, and Western North American, as limited by Professor Baird (Amer. Journ. Sc., Jan., 1865, p. 5, 6).

rounding plateaus, while a study of the Japanese and Hindoo-Chinese faunas must accompany examinations of the eastern or Atlantic faunas; just as we are daily obliged, while examining the Middle American temperate fauna, to study West Indian and Central American and even tropical South American forms, some of which spread as far north as the headwaters of the Mississippi and even Maine and Canada.

TORTRICIDÆ.

A larva of this family, with a flattened, pale, flesh-colored body, and pale, testaceous head and prothorax, length, 0.40 inch, occurred at an elevation of above 12,000 feet (Lieutenant Carpenter).

PYRALIDÆ.

Crambus Carpenterellus n. sp. (Fig. 1, wing enlarged), 5, ♂; 3, ♀; a large species, allied in its style of markings to *C. agitatellus*, Clem., of the Eastern States. Head, thorax, and palpi tawny ochreous; abdomen and hind wings white; fore wings with a broad, prominent, longitudinal, white streak, occupying the discal area, *i. e.*, between the subcostal and median veins, extending from the base of the wing rather nearer the outer edge than in *C. agitatellus*. Just before the end of the streak, a linear, minute branch is sent off from the costal side, and from the middle of the lower side a short snag is sent off, with a dark streak in continuation; while along the opposite side is a dark streak. There is no parallel white costal streak, as in *C. agitatellus*. Below the white streak, the wing is clearer yellow than elsewhere. The outer transverse, angulated, silvery-white line is somewhat as in *C. agitatellus*, but nearer the edge of the wing, and bent angularly, and not incurved below the bend. The line is bordered on each side by two oblique costal lines, widening on the costa; apex brown, with a white triangle below; still below a marginal row of about six distinct black dots; within the transverse white line the usual parallel golden lines; fore wings beneath dusky; hind wings much paler.

Length of body, 0.44 inch; of fore wing, 0.55 inch.

Mountains of Colorado, July 19, August 12, September 8 (Lieutenant Carpenter).

This fine species, named in honor of Lieut. W. L. Carpenter, U. S. A., who has done much to add to our knowledge of the lepidopterous fauna of Colorado Territory, particularly the more elevated portions, appears to be a common species. It is allied in the general style of markings to *C. agitatellus*, Clem., of the Eastern States, but differs from it in wanting the costal white streak; in the submarginal white line being bent angularly, not sinuous below the bend; and in being nearer the outer edge of the wing. I have no Californian species with which to compare it. It is still nearer allied to *C. hamellus*, of Europe.

Crambus, a species allied to *C. mutabilis*, Clem., but not in a proper condition for description, occurred at Fair Play, July 16 (Lieutenant Carpenter). The same species apparently occurs in Oregon (Museum Peabody Academy of Science, Salem, Mass.)

Another, smaller species, dark slate-colored, with dark hind wings occurred at Twin Lakes and on the mountains of Colorado, July 22 to August 12, (Lieutenant Carpenter).

Nomophila noctuella, Schiff.—One specimen was taken at Fair Play, July 16 (Lieutenant Carpenter), which does not differ from specimens from Oregon and California and the Eastern States. The occurrence of this species among the mountains of Colorado is additional evidence that it is autocthonous in North America.

Family PHALÆNIDÆ.

Baptria albofasciata, Grote.—"Pike's Peak" (Grote). It may here be said that four *Baptria albovittata*, Guen., from Victoria, Vancouver Island, do not differ in size or coloration from eastern examples.

Lithostege triseriata, Pack. (Rep. Peab. Acad. Sc., 1874).—Denver City, Col., June 3, 27 (T. L. Mead).—This is the first occurrence of this genus in America. Another species inhabits California.

Larentia cæsiata, S. V. (*Cidaria aurata*, Pack., Proc. Boston S. N. H., XI, 51, 1867).—Vicinity of Georgetown, 8,000 or 9,000 feet elevation, Colorado (T. L. Mead). The Colorado examples expand from 1.45 to 1.55 inches; the markings just as in Labrador and White Mountains (New Hampshire) specimens, though with perhaps more golden scales. The Labrador specimens are a little stunted, expanding from 1.40 to 1.45 inches; they agree with specimens from Iceland as to general appearance and size, but are not quite so dark and have more golden-yellow specks. I have seen no specimens from this country or Labrador with such clear markings as in those received from the Austrian Alps, though the American specimens are rubbed. In size, the Colorado individuals resemble the European ones. Near Turkey Creek Junction.

Lobophora montanata, Pack. (Rep. Peab. Sc., 1874).—Colorado, June 28 (T. L. Mead). This very interesting species is closely related to *L. halterata*, which occurs in Central and Southern Europe and Middle Lapland. It is also closely allied to *L. carpinata*, found in Central and Southern Europe as well as in Eastern Siberia, the Ural Mountains and Amur.

Cidaria populata (Linn.)—One specimen occurred in the vicinity of Berthoud's Pass, Colorado, 12,000 to 13,000 feet elevation, August 16 (T. L. Mead). On comparing this single example with specimens from Massachusetts, the White Mountains of New Hampshire, and several from Victoria, Vancouver Island (G. R. Crotch, Mus. Comp. Zool.), it differs in there being three well-marked teeth in the outer edge of the median band; the inner edge above the median vein is jagged instead of straight as usual, while the coloration is the same. I have had no European specimen for comparison, but it agrees with figures. It occurs, however, in Labrador (Moeschler). In Europe, it occurs in the central and southern portions and in the Ural and Altai Mountains and Amur.

C. lugubrata, Moeschler (*C. nubilata*, Pack., Proc. Bost. S. N. H., 1867). Mountains of Colorado, July 19, September 8 (Lieutenant Carpenter); Denver City, Col., June 1, (T. L. Mead); California (H. Edwards); Victoria, Vancouver Island (Crotch., M. C., 2). Though my Labrador specimen differs somewhat from Moeschler's description and figure, yet I am inclined to unite it with *C. lugubrata*. I have before me a specimen from Mount Marcy, New York (August), and Mount Washington, New Hampshire (Sanborn), and numerous specimens from California and Vancouver Island. The extremes are presented by the Labrador and Vancouver Island examples. The Pacific coast forms are larger, blacker, the fore-wings more elongated toward the apex than the eastern specimens, much as observed in *Macaria dispuncta* (Walk.), in which the Labrador individuals are stunted, while the west-coast (Vancouver Island) specimens are larger. They are paler, however, than the Labrador and New England individuals. The Colorado *C. lugubrata* scarcely differs from the Californian and Vancouver Island ones. My Labrador individual (well preserved) has already been described. The Adirondack (Mount Marcy) one is very similar, but differs in being of a peculiar reddish-brown tint, especially along the costa and veins. The outer line between the costa and median vein is angulated outward, instead of curved regularly outward as in the Labrador example. The Adirondack is very near the Labrador one, though a little browner along the veins. In the Colorado and Pacific specimens, the outer line near the costa is scalloped four or five times. The middle band of the fore-wings is much darker than the rest of the wing; the inner and outer portions being much paler than in the eastern examples. Expanse of wings of Colorado and Vancouver Island specimens, 1.43 inches; of Labrador and alpine Eastern United States, 1.25 inches.

In the general style of markings, this species closely resembles *C. populata*, as remarked by Moeschler. I do not much doubt but that both have come from a common stock; *lugubrata* being perhaps originally derived from a melanotic variety of *populata*.

C. testata, Linn.—Bailey's ranch, on South Park road, twenty-five miles from the park; elevation, 8,000 or 8,500 feet; Colorado, August 29 (T. L. Mead); also occurs in Massachusetts (Shurtleff). This does not seem to differ from figures in English works, but still needs to be compared. It occurs in Central and Southern Europe, Ural Mountains, Altai Mountains, and Amur.

Melanippe hastata (Linn., *M. gothicata*, Guen.)—The single individual, taken at the Kenosha House, Colorado, June 30, by Mr. Mead, has larger white bands and spots than any Alaskan specimen I have seen, and exactly agrees with certain Labrador specimens, and is unlike any I have seen from any other region.

M. tristata, (Linn.)—Three specimens, Beaver Creek, near Fair Play, South Park, at the border of the surrounding mountains, elevation, 9,000 feet, or a little over; and Turkey Creek Junction, Colorado, June 16–25, do not differ from European examples received from Prof. P. C. Zeller. This is its first occurrence in America. It occurs in Central and Southern Europe and Turkey, and is reported by Staudinger, with a query, from the Ural Mountains and Amur.

M. lugubrata (Staudinger), (*M. luctuata* [S. V.], *Cidaria obductata*, Moeschler, Wiener Ent. Monatssch; *M. concordata*, Walk. (!); *M. Kodiakata*, Pack.)—Turkey Creek Junction, Colorado, June 27 (Mead). Compared with an Alaskan example, the Colorado moth is larger, with the white band on the hind-wings three times as wide, thus leaving a narrow, dark margin, and a faint dusky shade at the base of the wing. I had regarded the Alaskan and Maine specimens as quite distinct, and the latter as distinct from the Labrador var. *obductata;* but a Pacific-coast specimen, just received from Mr. James Behrings, labeled "Kenay" (near Kodiak, Alaska), is intermediate between vars. *Kodiakata* and *obductata*. The Pacific-coast individual has the white band on the fore-wings much bent, as in Maine specimens, and the hind-wings almost black, as in *Concordata;* the white line being almost obsolete. The Labrador individuals are more stunted than the Maine ones, but both have black hind-wings; while the Pacific-coast and Colorado examples are much whiter, with broader white bands. The Alaskan moth closely resembles Duponchel's figure. Thus the Pacific and Colorado forms resemble the European much more than the New England and Labrador examples. It inhabits Central Europe, Lapland, the Ural and Altai Mountains, and Amur. It is reported by Grote as having been collected by Kennicott on the Mackenzie River to Lake Athabasca.

Coremia lignicolorata, Pack.—Turkey Creek Junction, Colorado, August 24 (Mead). These specimens do not differ from Californian examples. It is pale-gray as a ground-color, while most of the Californian moths are of the color of pine-wood which has been long unpainted; this may, however, be due to their state of preservation.

C., sp.—Perhaps *defensaria*, but too much rubbed for identification, occurred at Twin Lakes July 16–27, and in the mountains July 19, September 28 (Lieutenant Carpenter).

C. ferrugata, Clerk.—One ♂, Bear Creek, June 24 (Lieutenant Carpenter).

Phibalapteryx intestinata, Guen.—Colorado divide, June, 1 ♀ (Lieutenant Carpenter).

Hypsipetes Californiata, Pack.—Kenosha House and Turkey Creek junction, Colorado, June 18, 21 (Mead). Some fresher specimens than those received from Mr. H. Edwards from California, are much paler; the median band whitish; the reddish band on each side very distinct; the hind-wings are almost whitish, with a faint diskal dot, and a faint band about half-way between the dot and the outer edge of the wing.

Scotosia Meadii, Pack. (Rep. Peab. Acad. Sc., 1874).—Near Turkey Creek junction, Colorado, August 23 (Mead). This is structurally allied to *S. Californiata*, Pack., but differs in the longer fore-wings, while the scallops on the hind-wings are larger and shallower.

Zerene catenaria, (Cramer), (Fig. 2).—Common at Plum Creek, September 22, 25. In coloration, the ten specimens collected by Lieutenant Carpenter do not differ from eastern specimens; but on comparing them (5 ♂ ; 5 ♀) with fifteen (5 ♀ ; 10 ♂) specimens from Massachusetts, I found that the wings of the Colorado moths were uniformly more pointed toward the apex, the outer edge more oblique, and the wing narrower than in the eastern examples. The fore-wing of the largest Colorado moth measured 0.95 inch, and that of the Massachusetts specimen 0.90 inch.

Aspilates quadrifasciaria, Pack. (Fig. 3).—This interesting form is not known to inhabit Colorado, but lives in Kansas, whence I have received it from Professor Glover, entomologist of the Agricultural Department, at Washington, and Professor F. H. Snow, Lawrence, Kans. It is a pure white moth, flecked with ochreous scales, with four slightly oblique parallel bands on the fore-wings.

Platœa Californiaria, H. Sch. (*Gorytodes uncanaria*, Guen).—"Pike's Peak" (A. R. Grote).

Euaspilates spinataria, Pack. (Fig. 4), (Rep. Peab. Acad. Sc., 1874).—This very interesting form may be recognized by its pure white body and wings, with peculiar pale-brown bands on the anterior wings; also by the full bulging head, the short palpi, and especially by the stout spine at the base of the anterior tibiæ. I have received it from Mr. Grote, from Colorado. It is very nearly allied to, and repeats the style of markings and colors of *Aspilates mundataria*, Cr., which differs generically from the other species of *Aspilates*. This latter species is recorded in Staudinger's catalogue as occurring in Russia, Amur, and the Altai Mountains. The occurrence of a representative species in the mountains of Colorado is another interesting fact in the geographical distribution of this family of moths.

Fidonia acidaliata, Pack. (Rep. Peab. Acad. Sc., 1874).—This singular form at first sight would be mistaken for an *Acidalia*, and differs from the ordinary forms of *Fidonia* in the long, slender palpi and the very slightly pectinated antennæ. Mountains of Colorado, August 12–29 (Lieut. W. L. Carpenter). More numerous specimens were collected by Mr. T. L. Mead, August 7, at a locality twelve miles below Montezuma, Colo., on Snake River, Middle Park, Pacific slope; elevation most likely 9,000 to 10,000 feet.

Selidosema juturnaria, Guen., var. *Californiaria*, Pack.—My single specimen from Colorado (collected by Mr. Ridings) is in some respects intermediate between *S. juturnaria* and my types of *S. Californiaria*, so that I would consider the latter as simply a variety. In the Colorado example, the outer line on the fore-wing is bent very distinctly; the hind-wings beneath not mottled, but tinted obscurely with reddish pink, like the under side of the fore-wings. There is also a faint band common to both wings.

Phasiane sinuata, Pack.—Mountains of Colorado, July 22, August 12 (Lieut. W. L. Carpenter).

P. Meadiaria, Pack. (Rep. Peab. Acad. Sc., 1874).—This species is named after its discoverer, Mr. T. L. Mead, who captured it June 1, at Denver, Colo. It differs from all the other species by the two blackish, shortened, sinuous lines, the outer one shaded externally, and in the body and wings being flesh-colored, almost reddish. The fore-wings are rather short, and the antennæ densely ciliated. It is closely related to *P. Rippertaria*, Dup., of Europe.

P. excurvaria, Pack.—In this species, all the lines are dusky, with no yellowish shade; the species derives its name from the outer line being curved outward. "Rocky Mountains" (A. R. Grote).

P. flavofasciata, Pack. (Fig. 5).—One ♀ specimen of this species, heretofore only described as inhabiting California, is contained in the museum of the Peabody Academy of Science, having been collected in Colorado by Mr. Ridings. It is well preserved, and differs but slightly from one of my Californian individuals. The markings are much the same; it is slightly darker, the outer line on fore-wing slightly narrower; the discal dots are the same. The under side of the wings is distinctly mottled and strigated, with a clear, mouse-colored, broad, marginal shade, free from the strigæ.

Length of body, 0.42 inch; of fore-wing, 0.58 inch.

Marmopteryx tessellata, n. sp. (Fig. 6).—1 ♀. Compared with *M. marmorata* from California, its nearest ally, the fore-wings are rather narrower, and the outer edge more oblique, while the apex is more pointed. The head is exactly as in that species; the front being full and bulging. Head and thorax pale-gray, with a reddish tinge. Palpi blackish at tip. Front of head with a slight yellowish tint, reddish between the antennæ. A dark streak on each side of prothorax, and a long, narrow, dark-brown slash on the patagia. Both wings of a rich golden-yellow, with dusky slate-brown margins. Fore-wings, with the costa, pale slate-color, checkered broadly with five large, square, white spots, and two minute, whitish, linear spots near the apex. Outer edge dusky, the dark margin narrowing toward the inner edge. Fringe very long and slate-colored, checkered conspicuously with white. Hind-wings like fore-wings; the costa is narrowly edged with slate. Beneath, the wings are brightly colored; the anterior pair dull golden-yellow, with a reddish tinge on the costal side. Borders of the ring checkered very conspicuously, as above; the apex, however, whitish. Hind-wings pale fawn-colored, marbled with white, with a costo-apical, oblong (transversely) white spot, and a large square white spot in the middle of the wing below; costa marbled with whitish; abdomen pale fawn-color, like the thorax.

Length of body, ♀, 0.45 inch; of fore wing, ♀, 0.64 inch. Arizona—(Dr. Palmer, Department of Agriculture).

Though this species is described from Arizona, it may be confidently looked for in Southern Colorado. The species is so remarkable, that I venture to describe it from a single individual. It may be readily recognized by its rich, golden-yellow wings, the checkered costa of the anterior pair, and the broad, dusky margin of both wings, while the hind-wings beneath are beautifully marbled.

Macaria Californiata, Pack. (Fig. 7).—This common Californian species has also been collected by Mr. Ridings in Colorado, and by Prof. F. N. Snow in Kansas; it is also frequently taken in Texas.

M. dispuncta, Pack. (*Tephrosia dispuncta*, Walk.; *Macaria sex-maculata*, Pack., Proc. B. S. N. H., 44, 1867). One individual was collected in Colorado by Mr. Mead. It is rather larger than specimens from Victoria, Vancouver Island, collected by Mr. G. R. Crotch, and is much darker, being much as in eastern specimens. The lines on the fore-wings are rather broad, and the dark, broken spot in the middle of the wing, near the outer edge, is obscure and united to form a faint patch. The hind-wings are without any submarginal shade, as in some eastern examples.

I am disposed to regard my *M. sex-maculata* from Caribou Island, Labrador, Straits of Belle Isle, as a variety of this species. It is very closely allied to it. It is rather smaller than usual; the fore-wings tinted with an obscure olive-gray, while the hind-wings are uniformly ochreous-brown, not mottled with whitish as usual; the costal spots on the fore-wings are rather large. It chiefly differs, however, in having a large brown spot in the course of the median line next to the usual large brown spot, the two forming twin-spots. Beneath, it does not differ from other examples from Maine. The specimens from Norway, Me., closely resemble the Labrador form, in having the inner spot much enlarged, though otherwise of the typical mode of coloration.

Two males and two females from Vancouver Island, collected for the Museum of Comparative Zoology by Mr. G. R. Crotch, are rather larger than the average of our eastern specimens, with longer wings; but they do not materially differ. One specimen scarcely differs from an individual from New York. They are, however, rather whiter than usual, with the submarginal band nearly obsolete. All have the inner division of the median dark patch on the fore-wing broad, thus exactly resembling the New York example, though not so well marked as in the Labrador specimens. Beneath, the common, broad, submarginal band is ochreous and nearly obsolete. It is interesting to notice how the species varies away from its apparent geographical center, the North-eastern States. In Labrador it grows much smaller, is stunted and darker; while at Vancouver Island, about one hundred and fifty miles farther south in latitude, it grows rather larger than in the Eastern States, with the wings decidedly more elongated and paler. This species is very common in the New England States, Norway, Me. (S. I. Smith, Mus. Comp. Zool.), Cambridge, Mass. (Mus. Comp. Zool., A. Agassiz), and occurs at London, Canada (W. Saunders, Mus. Comp. Zool.)

Macaria enotata, Guen.—This species, though only recorded heretofore from Brazil, Surinam, and Cayenne, occurs in the Northeastern States and in Kansas, whence I have received it from the museum of the Department of Agriculture at Washington, through Prof. T. Glover. It will undoubtedly occur in Colorado.

Eumacaria brunnearia, Pack.—Head of Plum Creek, June 29 (Lieutenant Carpenter). The larger of ten eastern and Texan specimens measures 0.48 inch on the fore-wing, while the single Colorado one is 0.53 inch.

Corycia vestaliata, Guen.—Colorado (Ridings); near the South Platte, June 28 (Lieut. W. L. Carpenter).

Acidalia Californiata, Pack.—Mountains of Colorado, July 22 to August 12–29 (Lieutenant Carpenter); banks of Blue River, Middle Park, elevation about 9,000 to 10,000 feet (Mead); Colorado (Mr. Ridings). Having received additional specimens of this species from California through Messrs. Edwards and Behrens, I am led to regard *A. Pacificaria*, Pack., as a synonym.

Acidalia quinque-linearia, Pack.—Colorado near Denver, and near Kenosha House on the South Park road, four miles from the park; elevation 9,000 feet; Colorado (Ridings). This species, also common in California, is closely related to *A. strigilaria* from Central and Southern Europe, Russia, and Amur.

Caulostoma occiduaria, Pack. (Rep. Peab. Acad., 1874), (Fig. 8).—This interesting species, the first of the genus yet observed in America, is closely allied to *C. flavaria*, which is reported in Staudinger's catalogue as occurring in Galicia, Hungary, Southern and Eastern Turkey, Middle Russia, and Armenia. I have received it from Colorado, where it was collected June 3, near Denver, by Mr. Mead, and also near Pike's Peak by Mr. Ridings. I have also an example collected in Oregon by Mr. W. G. W. Harford.

It differs from the European *flavaria* in having broader wings, both pairs being much less excavated on the outer edge. The antennæ are much the same, and the markings similar in the two species. The body and wings are deep lemon-yellow, with four nearly equidistant brown spots on the costa of the anterior pair. From the third spot arises a broad, diffuse, sinuous, brown shade, extending in the hind-wings and forming a slightly-curved median band.

Angerona crocataria, Fabr.—This species occurred in considerable abundance at the head of Plum Creek, June 29. It does not differ from Massachusetts specimens (Lieutenant Carpenter).

Ennomos Coloradia, G. and R.—"Colorado." (Grote).

Caberodes majoraria, Guen.—Head of Plum Creek, June 29 (Lieutenant Carpenter).

Endropia vinosaria, G. and R. (Fig. 9.)—Colorado Springs, July 4 (Mead).

Family NOCTUIDÆ.

Several of the more difficult forms of this family have been kindly identified by Mr. A. R. Grote. Only those species collected by the survey are noticed here.

Catocala Walshii, Edwards.—A specimen was collected at Clear Creek, September 20, by Lieutenant Carpenter.

Erebus odora, Latreille.—Three specimens at the Colorado divide (Lieutenant Carpenter).

Plusia Hochenwarthi, Hochenw. (*P. divergens*, Fabr. *P. alticola*, Walk.; *P. ignea*, Grote).—This species has been identified by Mr. Grote as Walker's *P. alticola;* on comparing my specimens (which were collected in the mountains of Colorado, July 22 to August 12, by Lieutenant Carpenter), however, with one labeled "*P. divergens*, Alps," sent me by the Vienna museum, I find but slight differences, scarcely varietal. It is also identical with specimens obtained by me at Hopedale, Labrador. While the European and Coloradian forms are nearly identical, that from Labrador might by some be regarded as a distinct species. It is much smaller than the European form, much faded and bleached out. The markings on the fore-wings are much the same, but the forks of the silvery spot are lost in the pale costal margin. There is no yellow tinge on the hind-wings; they are white, dusky on the basal half, and with a broad marginal band, the inner edge of which is indistinct. Length of fore-wing, 0.48 inch.

Ten Colorado individuals compared with one from the European Alps are larger, with the yellow on the hind-wings deep orange, being much higher colored than in the European. The body of the European is nearly as large, but the wings are shorter and smaller. The European example also differs in the smaller silver spot, in the line across the wing just beyond the silver spot being more curved just below the costa, and in the smaller veniform spot; but in both of the former characters there is a slight amount of variation in the Colorado specimens.

One European example, ♂, length of body, 0.63 inch; length of fore-wing, 0.53 inch.

Ten Colorado examples, ♂, length of body, 0.65 inch; length of fore-wing, 0.60 to 0.63 inch.

In Europe, this species has been found in the Alps, Scandinavia, and Lapland.

Tarache candefacta, Hübner.—Head of Plum Creek, June 29 (Lieutenant Carpenter).

Heliothis armigera, Hübner.—Foot-hills of Long's Peak, May (Lieutenant Carpenter).

Hydrœcia lorea, Guen.—Head of Plum Creek, June 29 (Lieutenant Carpenter).

Mamestra picta, Harris.—A larva occurred in the alcoholic collection (Lieutenant Carpenter).

Scoliopteryx libatrix (Linn.)—This was collected by Lieutenant Carpenter in the Rocky Mountains of Wyoming in 1872. It has also been found by Kennicott on the Yukon River (Grote).

Agrotis Islandica, Staudinger (Stettin Ent. Zeitung, 232, 1857), (Fig. 10).—8 ♂; 2 ♀. This fine species is allied in its form and structure, in the strongly-ciliated antennæ, the tufts on the prothorax, and in the form of the wings to *A. subgothica*, Haworth, and less strongly to *A. jaculifera*, Guen. Male antennæ stoutly ciliated to near the end. Palpi much as in *A. subgothica;* third joint rather stout, lilac-gray, like the head, blackish along the upper side and on the end. Prothoracic scales light tawny-yellowish at base, concolorous with the light tawny costa of fore-wings; beyond, a blackish curved line; outer edge of the scales lilac-gray, like the rest of the thorax. Fore-wings pale-tawny, sometimes with a reddish or whitish-gray tinge. Two or three faint, small, costal, dark, transverse, oblique streaks within the middle of the costa. Subcostal and median veins from reniform spot to base of wing white, dilating into a very narrow triangular streak at base of discal space. Discal dot and reniform spot large, white. Dot oblique oval, widening on median vein, scarcely separated at other end from the pale costa. A black space between the two spots about as long as the dot itself (the space varying, however). Reniform spot large, white, with two median, curved, dark lines, a dark shade beyond, equal to the reniform spot in width. Beyond is a clear reddish-brown space crossing the wing, interrupted by the black venules, and bordered internally by dark intervenular scallops (sometimes obsolete). The clear space has in the outer half a series of black intervenular slashes, terminating in a fine, irregular, scalloped, whitish line, the line dislocated and situated much nearer the outer edge, below the middle of the wing. Just below the median vein, on inner half of wing, a black stripe, interrupted by a transverse, acutely-curved, reddish-brown line extending from the median to the submedian vein, and sometimes extending beyond the edge of wing; beyond this the outer half of the black streak is broader, lanceolate-oval, and terminates on the submedian fold at a point opposite the outer end of diskal dot. Fringe concolorous with the clear portion of the wing. Hind-wings wihtish near the base, becoming gradually smoky on the outer third.

Fringe, white. Beneath, ashy-gray, with the costa of fore-wings inclined to be reddish; a dark spot on the outer quarter of the costal edge, and dark diskal spots on both wings.

Length of body, ♂, 0.70 inch; ♀, 0.76 inch; of fore-wing, ♂, 0.70 inch; ♀, 0.80 inch.

Long's Peak, June 3, W. S. Carpenter. Above timber-line, above 12,000 feet, mountains of Colorado, one specimen. California, H. Edwards, No. 181, Vancouver Island, H. Edwards.

This species varies somewhat in the tint of the wings; being, in the California and Vancouver Island specimens, usually of a decided reddish. One Californian fresh example is partially tinged with reddish tawny, especially on the costa and prothorax.

The alpine specimen, collected above the timber-line, only differs from the one taken on Long's Peak (which does not differ much from the Californianin dividuals) by being, as it were, bleached out, the portions tinged with tawny and reddish being in this individual pale-gray. Though the specimens at first sight differ so much from those specimens of *A. Islandica* from Iceland, received from Dr. Staudinger, yet the bleached appearance of the alpine individual from Colorado seems to connect the two races. In the Californian form, the individuals are slightly larger and with strongly-ciliated antennæ; the Iceland species are in one case stunted, bleached out, and with faintly-ciliated antennæ, in the other nearly as large as the Californian ♂. Still the style of markings is absolutely the same. Staudinger also received specimens from Labrador, though I collected none. This identification is of exceeding interest, and forms a new link connecting the alpine fauna of the Colorado Mountains, above 12,000 feet, with that of Labrador and Iceland. The species has not yet occurred in Europe.

Staudinger places this species near the European *A. tritici.* The Iceland ♂ specimens expand 1.20–1.95 inches; the alpine Colorado, ♀, 2.20 inches. It may be recognized by the round discal dot directed obliquely inward, sometimes running into the costal region, and by the V-shaped transverse line, cutting across the dark streak under the median vein; the outer half lanceolate-oval, pale in the middle, with its end resting on the submedian fold, and not passing beyond the outer end of the discal dot, which is obliquely directed inward toward costa and base of wing, instead of outward, as in *A. jaculifera* and *subgothica.* I might state that the single species placed by Staudinger in his catalogue between the present one and the common very variable European *A. tritici* is *A. Norwegica* (Stgr., Stett. Ent. Zeitung, 383, 1861), with the remark added, "Præc. var. ? uno ♂ condita!" Three larvæ, which I refer doubtfully to this species, occurred at an elevation of above 12,000 feet (Carpenter). The body is smooth and cylindrical, tapering nearly alike toward both ends. Body and head dark, with a median dorsal whitish interrupted line, and a subdorsal similar line on each side. The whole of the dark surface is finely marbled with whitish; length, 0.75 inch. The half-grown one is paler, with a reddish tinge above. The median pale line is interrupted by a large black patch on each suture.

Family BOMBYCIDÆ.

Hepialus pulcher, Grote (Fig. 11).—This fine species occurred frequently in the mountains of Colorado, July 19, 22, August 12, 29; on the Pacific slope, August 29 and September 6; and on the foot-hills September 8–30 (Lieutenant Carpenter). It is rather larger than the typical species of the genus, and may be readily recognized by the figure.

Clisiocampa.—The larva and cocoons of this genus occurred, but none of the moths.

Euleucophæus tricolor, Pack. (Rep. Peab. Acad., 1872), (Pl. 2, Fig. 12).—I reproduce in part the description of this most interesting and exceptional form, with the hope that observers may find it in Colorado. Only one specimen is in existence, having been received from New Mexico by Mr. Henry Edwards, who loaned it to me for study. It is closely allied to *Hemileuca Juno* and *Diana*. The body, including the antennæ, is larger, while the wings are much smaller than usual. The hind-wings are shorter and rounder than in *Hemileuca*. Instead of being dark-brown, with white bands, as common in the allied forms, the wings are of a faded whitish, with a broad, median, grayish-brown band occupying the middle third of the fore-wing, and inclosing a white, irregular, lunate, discal spot. It has a generally faded appearance, adapting it for concealment while resting on the dry, parched ground, and it will be interesting to learn whether its exceptional style of coloration adapts it for a life on the deserts of New Mexico. Its occurrence in Southern Colorado is to be looked for.

Hemileuca Diana, n. sp., one ♀ (Fig. 13).—This species is structurally near *H. Juno*, Pack., from the border of Arizona and Sonora; the wings being opaque and with much the same shape, though the apices of both pairs are rather more acute, and the veins are much less prominent. It also approaches *H. Io* in the style of coloration; the prothorax being white, and in having a broad white band common to both wings. It cannot be the female of *H. Juno*, as the markings are so different from the two males in my possession. It is also very different from *Coloradia Pandora*, Blake, which is quite a different genus from *Hemileuca*.

Body and wings dark opaque-blackish-brown. Head dark. Fore femora tufted with deep rich vermilion. Prothorax white; whitish hairs mingled with those of the rest of the thorax, and forming a long dull-whitish fringe on the basal half of the inner edge of the fore-wings and along the entire hinder edge of hind-wings. Two rust-red tufts on each side of hind end of thorax, just as in *H. Maia*. Abdomen as in ♀ *H. Maia*, black, with whitish hairs, giving it a grizzly appearance, but with numerous rust-red hairs near the tip, not present in *H. Maia*. Both wings dull blackish-brown; the veins scarcely apparent beyond the middle of the wing, with a broad white band from 0.10–0.15 inch wide, common to both wings, and not quite reaching the costal edge of both wings. On the fore-wings, the band does not quite reach the inner edge, ending on the internal vein. Discal dot a small, transparent, lunate, pale-yellowish spot half as large as in *H. Maia* or *Juno*, surrounded by a large, round, black area, which nearly cuts the white band in two. Beyond the white band, the wing is dusted with white. Hind-wings with the discal dot obsolete, but opposite its site an excavation in the white band. Beneath as above; the discal dot on the fore-wings rather deeper yellow than above.

Length of body, 0.95 inch; of fore-wings, 1.05 inches; expansion of wings, 2.10 inches. Plum Creek, September 12 (Lieutenant Carpenter).

From *H. Juno*, to which it is nearest allied, it differs in the white prothorax, the small diskal spot, the conspicuous white band common to both wings; and from *H. Maia* it differs in the opaque, more pointed, and triangular wings, the narrower white band, and smaller discal dot, none being present on the hind-wings. From Harris's *H. Hera*, which has not yet been rediscovered since Harris described it, it seems to differ very materially; *H. Hera* being described as pale-yellow, with two transverse black bands, and expanding three inches. It was "taken by Mr. Nuttall near the Rocky Mountains" (Harris), and will doubtless occur in Colorado.

Hemileuca Maia, Walk.—Several specimens from Denver City, October 4 (Lieutenant Carpenter). These specimens only differ from New-England examples in the wider white band. I am inclined to regard Mr. Stretch's *H. Nevadensis* as a local variety of the present species, since it differs apparently only in the "prothorax being pale-rusty." In a ♂ from Massachusetts, "the halo around the discal spot is separated from the basal patch," as in the Nevada form. It should be observed that the width of the band varies greatly in the Massachusetts specimens. In one ♀ from Massachusetts, the white band on both wings is nearly as wide as in any of the Colorado specimens. The patagia are also whitish at base, thus approaching, though not very closely, Mr. Stretch's figure of *H. Nevadensis*.

Telea Polyphemus, Hübner.—The larva of this species was found on the willow at Clear Creek by Lieutenant Carpenter. It spun a cocoon September 21.

Cerura borealis, Boisd.—One rubbed, imperfect specimen occurred in Montana, where it was obtained by Hayden's expedition in 1872.

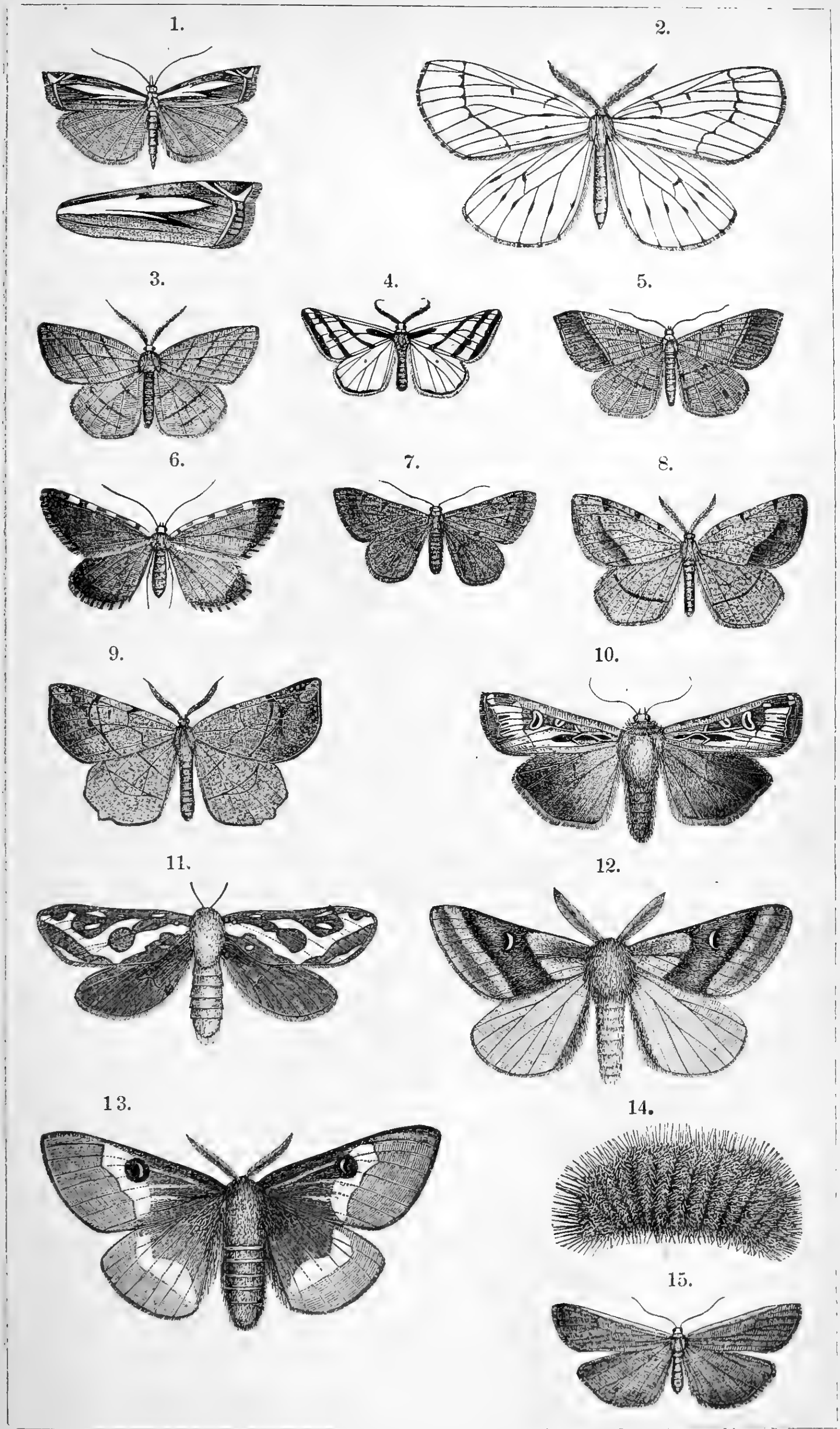
Euchætes Egle, Harris.—An albino form occurred at Plum Creek, June 29 (Lieutenant Carpenter). It differs from an albino of the same species from Kansas (Mus. Bost. Soc. Nat. His., collected by W. H. Dale) in the thorax being white. It apparently differs specifically from Mr. Stretch's *E. Oregonensis* from Oregon.

Arctia Blakei, Grote.—"Colorado, Ridings" (Grote).

Arctia Quenselii, Paykull.—The occurrence of this species on the alpine summits of Colorado is of great interest, as extending its wide geographical range. It occurs in the Alps at the height of about 8,000 feet, on the elevated portions of Lapland, in Labrador near the level of the sea, and again on the summit of Mounts Washington and Madison of the White Mountains of New Hampshire. The two Labrador individuals in the Museum of the Peabody Academy of Science at Salem are the typical *Quenselii*; the White-Mountain specimen, in the yellow fringe of the fore-wing, and a V-shaped white spot on the hind-wings, while otherwise closely resembling the typical Labrador *Quenselii*, has a tendency to resemble Moeschler's *Arctia speciosa*, which I would regard simply as a variety of *Quenselii*. A third variety, or race, is indicated by the two Coloradian specimens, in which the veins are black; the wing is less slashed with yellow, but the other markings are the same, both on the wings and body. The two Coloradian species differ; one in having the hind-wings dark as in *Quenselii*, and the other with whitish wings slashed at the base with black, and with two series of marginal dark spots, somewhat as in var. *speciosa*; in the latter individual, the markings on the fore-wings are broader and the two outer triangles formed by the bands much smaller than in the other.

The supposed larva of this species (Fig. 14, magnified twice) has been discovered on Mount Washington by Mr. F. G. Sanborn, June 25, and I have collected it on the 8th of July, at Square Island, Labrador, on the larch. It is remarkably short, thick, and broad, a little flattened, and so densely covered with short, evenly-cut hairs, with long, spreading spinules, that the body cannot be seen. The dorsal hairs are shortest and thickest; those on the sides are longer and more uneven. Seen from above, both the head and tail are covered by overarching hairs, both ends thus appearing alike. Head black, body beneath black; abdominal legs livid. Hairs dark-brown, appearing as if dusted over,

Moths of Colorado.



owing to the remarkably long spinules. On each side of the body, a subdorsal, obscure, rather broad band of yellow on the eight first abdominal rings, not appearing on the thorax. It is an inch in length, and a third of an inch broad.

Epicallia virginalis, Boisd.—Two larvæ, apparently of this species, and a third half-grown, occurred at an elevation above 12,000 feet. The larger ones (alcoholic specimens) were covered with dense, rather long hairs; those on the three thoracic segments being reddish-yellow, and shorter than those behind, which are blackish. The hairs of the young are all black-brown.

Nemeophila geometrica (Grote).—Bear Creek, June 24 (Carpenter).

Crocota brevicornis, Walk.—Bear Creek, June 24 (Carpenter).

Crocota ferruginosa, Walk.—Platte River, June 24 (Carpenter).

Crocota quinaria, Grote.—Bear Creek, June 24, Twin Lakes, at about 8,000 feet elevation (Carpenter); also Athabasca River, July, Kennicott (Grote).

Lithosia argillacea, Pack. (Fig. 15).—Twin Lakes, July 16–27. It is rather larger than eastern specimens, one ♀, expanding 1.30 inches. It has also been found on Athabasca River by Kennicott, as reported by Mr. Grote.

Family Zygænidæ.

Gnophœla vermiculata, Grote.—"Pike's Peak" (Grote), mountains of Colorado, August 12–29. Pacific slope, August 29 to September 6 (Lieutenant Carpenter).

Psychomorpha epimenis, Drury.—Colorado (Ridings).

Family Sphingidæ.

Smerinthus. A larva of this genus was collected by Lieutenant Carpenter.

Deilephila lineata, Fabr.—Colorado (Carpenter).

Macrosila quinque-maculata (Haworth).—Camp in Colorado, May 28 (Carpenter).

Besides three species of lepidopterous larvæ, found on Elbert Peak, in a shallow pool, 12,500 feet high, were the larvæ of *Bibio*, of *Scenopinus* (?), and the pupa of a *Mycetophilid* (?); also, a coleopterous larva allied to that of *Acilius*, but the body slenderer and much narrower, the head wider, and the legs much longer. At the same elevation occurred the cocoons of some fossorial hymenopter, not, however, an ant, and the larva of a *Harpalus*, which, in the proportions of the body, closely resembles Schiödte's figure of the larva of *Harpalus æneus*, Fabr. The head is rather longer, the sculpturing on the upper side much simpler, and the teeth on the clypeus quite different, there being six equal, long, slender, prominent teeth. The labium is shorter and broader than that of the European *H. ruficornis*, Linn.

The alcoholic collections made by Lieutenant Carpenter also contain a larva of *Agabus* from a lake near Long's Peak; elevation 9,000 feet; June 1.

EXPLANATION OF PLATE.

Fig. 1. *Crambus Carpenterellus*, Pack.
2. *Zerene catenaria* (Drury).
3. *Aspilates quadrifasciaria*, Pack.
4. *Euaspilates spinataria*, Pack.

5. *Phasiane flavofasciata*, Pack.
6. *Marmopteryx tessellata*, Pack.
7. *Macaria Californiata*, Pack.
8. *Caulostoma occiduaria*, Pack.
9. *Endropia vinosaria*, Grote and Rob.
10. *Agrotis Islandica*, Staudinger.
11. *Hepialus pulcher*, Grote.
12. *Euleucophæus tricolor*, Pack.
13. *Hemileuca Diana*, Pack.
14. *Arctia Quenselii*, Payk., larva, enlarged twice.
15 *Lithosia argillacea*, Pack.

REPORT ON THE DIPTERA COLLECTED BY LIEUT. W. L. CARPENTER IN COLORADO DURING THE SUMMER OF 1873.

By C. R. Osten Sacken.

A report on the *Diptera* of the Western Territories must necessarily be influenced by the imperfect condition of the dipterology of the Eastern States. It would be premature to describe the numerous new species contained in most of the western collections, when many common *Diptera* in the Atlantic States have not been named or properly identified yet. The task to be performed, under such circumstances, is to single out from such collections the most remarkable forms the description of which is of an immediate interest, to take note of the facts bearing upon the geographical distribution of insects; and to preserve the rest of the material, carefully labeled, for future detailed study. The accumulation of such collections will, at some future time, render it worth the while to treat the single groups monographically. The indiscriminate working-up of collections, with promiscuous describing of new species, would only increase the already unbearable ballast of synonymy without any real profit to science.

A few words on the mode of preservation of the collections of Lieutenant Carpenter may not be superfluous. Most of the collections of *Diptera* previously received from the western exploring expeditions were preserved in alcohol, which made them entirely worthless for scientific purposes.

The present collection was sent to me in small wooden pill-boxes, in which the specimens, well dried, were closely packed together. Although, with this mode of treatment, many specimens were broken and most of the antennæ lost, still the specimens remain recognizable and afford useful scientific material for the study of the geograpical distribution, and even in some cases for description, provided only the specimens are numerous enough. The only satisfactory mode of collecting *Diptera* is to pin them immediately after catching; but as, under some circumstances, this cannot be conveniently done, the mode of collecting used by Lieut. W. L. Carpenter in the present instance is by far preferable to alcoholic treatment.

The collections of *Diptera* during the summer of 1873, were principally made at very high altitudes (8,000 to 10,000 feet, some even higher) in the Colorado Mountains. The materials for the geographical distribution of insects which these collections afford are, therefore, of considerable interest. The chief character of the fauna of those high altitudes, as might be expected, is a northern one. Nearly all the species which could be identified (as will be seen in the enumeration given below) had been first described from specimens received from the British possessions in North America. I would name, for instance, *Hesperinus brevifrons*, Walker, which Mr. Kennicott brought from about latitude 65°, on Mackenzie River, and which I found on Mount Washington, above tree-line. It was brought from Fair Play (latitude 38°, elevation 9,000 to 10,000 feet).

The higher the elevation at which the insects were taken, the more this boreal character of the fauna was marked. Lower down, the peculiar fauna of the plains becomes more apparent on each side of the mountains, with its own peculiarities. The plains east of the mountains, for instance, seem to be very rich in forms of *Dasypogonina;* on the Pacific side the *Bombylina*, especially *Anthrax*, *Exoprosopa*, &c., seem to be numerously represented. The materials, however, as to this feature of the fauna are not abundant enough to admit of general conclusions.

I will now give the result of my examination of the collections in the order of the families.

Family CULICIDÆ.

Twin Lakes, July 21, a species of *Culex* (preserved in a bottle and spoiled).

Family CHIRONOMIDÆ.

Twin Lakes, July 29, several specimens of minute *Chironomus.*

Eagle River, August 29, minute *Ceratopogons.*

Family SIMULIDÆ.

Eagle River, August 29, *Simulium*, sp., annoyed horses.

Family TIPULIDÆ.

Tipula (Twin Lake Creek), allied to *T. longiventris*, Lw., and resembling it closely, but differing in the picture of the thorax.

Tipula grata, Lw., or allied species (Pacific slope).

Tipula macrolabis, Lw. (Twin Lake Creek), a species easily identified by the peculiar structure of its male forceps. I possess specimens of it from Fort Resolution, Mackenzie River, Hudson Bay Territory.

Several other *Tipulæ* are too badly preserved for identification.

Family BIBIONIDÆ.

Bibio, sp., ♂, ♀. Very like *femoratus*, Wild., but smaller and apparently different; the basis of the wings (in ♀) is pale; the forked veins (in ♂) are less infuscated. (Twin Lake Creek and Colorado Mountains, Pacific Slope.)

Another *Bibio* (Colorado Mountains) is too badly preserved for identification.

Plecia longipes, Loew (probably a synonym of *Bibio heteroptera*, Say), a common species in the United States, has been brought from the Colorado Plains.

Hesperinus brevifrons, Walk. (Fair Play, Colo.) I possess this species from Mackenzie River, and I found it myself on Mount Washington, N. H.

Family BLEPHAROCERIDÆ.

Bibiocephala grandis, new genus and species (Colorado Mountains); the most interesting in the whole collection. It will be described in detail at the end of this report.

Family BOMBYLIDÆ.

Exoprosopa, sp. (Twin Lake, Creek), somewhat resembling *fascipennis* Say, but different. A single very much damaged specimen.

Exoprosopa decora, Loew (Colorado Plains). This is a northwestern species, which I possess from Iowa, Illinois, and the Red River of the North. A single damaged specimen.

Exoprosopa, sp. (Colorado Mountains). A single, indifferently preserved specimen.

Anthrax sinuosa, Wild. (Twin Lake Creek and Colorado Mountains, Pacific slope). A rather common species in the United States. Five specimens.

Anthrax, sp. (Fair Play, Colo.), a single denuded and broken specimen, not unlike *Hemipenthes seminigra*, Lw., from Saskatchewan River and Canada.

Anthrax, sp., closely allied to *A. flaviceps*, Lw. (Colorado Mountains, Pacific Slope.) I possess the same species from Utah Territory, selected by Mr. Suckley.

Anthrax alcyon, Say (Colorado Mountains), a northwestern species which I have from Saskatchewan, the Red River of the North, &c.

Anthrax, sp. (Twin Lake Creek and South Park), several indifferently-preserved species, which cannot be identified.

Anthrax fulviana, Say (Twin Lake Creek; Colorado Mountains), a northwestern and northern species. (I have before me specimens from Maine, Canada, Lake Superior, and Yukon River.)

Systœchus candidulus, Loew (Colorado Plains), a western species, also occurring in Illinois.

Systœchus, sp. (Twin Lake Creek).

Systœchus, sp. (Colorado Mountains), apparently identical with a Californian species.

Bombylius (*sensu strict.*), spec. (Twin Lake Creek and South Park).

Family STRATIOMYIDÆ.

Odontomyia nigrirostris, Lw. (Colorado Mountains, Pacific Slope), was originally described from specimens caught in Northern Minnesota.

Odontomyia, (between Clear Creek and Colorado City), identical or closely allied to *O. intermedia*, Wied. (?), a species common in the Northern States.

Stratiomyia nymphis, Walk. (Twin Lake Creek), was originally described from specimens from the British possessions in North America.

Family ASILIDÆ.

Laphria (Colorado Mountains), apparently identical with *L. bi-lineata*, Walk., from the British possessions.

Erax, about five species, one of which (Twin Lakes) bears a decidedly northern aspect; the others, on the contrary, seem to belong to the fauna of the plains.

Dasypogonina, several species; general character of the fauna of the plains.

Family LEPTIDÆ.

Atherix variegata, Walk., also found in the British possessions.

Family TABANIDÆ.

Contains no striking forms; the two or three species of the collection all belong to the common type of the European *T. tropicus*, Lin., *quatuornotatus*, Meig. *Bromius*, Lin., &c., which is represented by several species in the northern portions of North America. Many descriptions of these species exist, but, unfortunately, none of them precise enough for identification.

One of these *Tabanus* occured on the mountains, above the tree-line.

Family SYRPHIDÆ.

Volucella, sp. (Colorado Plains); a single specimen. I have received another specimen of this species from Mr. James Ridings in Philadelphia, who caught it in the same district.

Volucella, sp. (Twin Lake Creek); probably new; type, northern; unfortunately a single imperfect specimen.

Artophila sp. (Colorado Mountains); again a northern insect.

Sericomyia militaris, Walk. (Colorado Mountains); the same insect occurs frequently in Canada and also in the White Mountains.

Helophilus bilineatus, Curtis (Twin Lakes), first described from specimens brought back by Captain Ross from his polar cruise. I possess it also from Labrador.

Helophilus, n. sp.? (South Park, Colorado), which I also received from Fort Resolution, on Mackenzie River, and from other parts of the British possessions.

Chrysotoxum derivatum, Walk., (Colorado Mountains), described by Mr. Walker, from the British possessions in North America. I have specimens from Alaska.

Eristalis, two or three species (specimens principally from Twin Lake Creek), which I could not identify with any species I know.

Melithreptus, sp. (Twin Lake Creek), very like *M. cylindricus*, Say, but apparently different.

Syrphus corollæ (Fair Play), *vitripennis* (?) and one or two others which I could not identify.

Syrphus obliquus, Say, was found above the tree-line.

Family ŒSTRIDÆ.

The common horse-bot, *Gastrus equi* (Colorado Mountains).

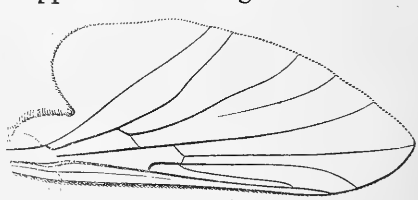
The families *Tachinidæ*, *Anthomyidæ*, *Muscidæ* are represented by a considerable number of specimens, although not so many species. I will notice especially the frequent occurrence of species of *Gonia* in the mountain-region, and a large *Echinomyia* from the plains. The common blue bottle-fly has been found ascending the mountains above the tree line.

As the above-named families have not been worked up in the Eastern States yet, it would be premature to attempt any further identification of the species.

The most interesting novelty in the whole collection is a species of the family *Blepharoceridæ*, a family rather anomalous in its structure, of very doubtful position in the system, and counting, as yet, but a few members. Only *seven* species, distributed among five genera, are known from the whole world.* Four of these species are from Europe; the remaining three are from Ceylon, from South America, and from the United States. The new species from Colorado is thus the eighth in the group, and requires the formation of a new genus, the sixth in the family.

Bibiocephala, nov. gen. Closely allied to *Blepharocera*, but differing prncipally in the venation of the wings, the shortness of the antennæ, and the structure of the head. I possess only male specimens.

Eyes divided in two halves; the upper one with larger and the lower one with smaller facets; these two halves are of nearly equal size, (the upper one even seems to be a little larger), and both are clothed with a dense and short microscopic pubescence; besides this pubescence, the lower half is beset with long, erect pile; the two halves are contiguous, and not separated by a narrow band, without facets (at least, I am not able to perceive any such band). The eyes are



*All that is known about this family may be found in the paper "La famiglia dei *Blepharoceridi*," by H. Loew, in the "Bulletino della Soc. entom. italiana," vol. i, p. 85–101, tab. ii.

contiguous; no linear front being perceptible between them. (In *Bl. capitata*, Lw., ♂, the upper half of the eyes is much smaller than the lower one; there is no long pile on the lower half; both halves are separated by a distinct band, without facets; the eyes are separated by a narrow, linear front. *Bl. capitata*, Lw., the only American species hitherto known, was discovered by me in the woods, near Washington, D. C., June 7–10, 1862. In life, the upper half of the eyes was reddish-green, the lower purple.)

Ocelli in the usual position, on the vertex (they are proportionally smaller than in *Bl. capitata*).

Antennæ short; about equal in length to the longitudinal diameter of the head, 15-jointed; the second joint has more than double the length of the first, and is curved; the first joint of the flagellum is subcylindrical; the other joints are short, broader than long, and beset with short pile; the last joint is pointed. (In *Bl. capitata*, the antennæ are comparatively longer, being at least twice as long as the head; the second joint is not longer than the first; the joints of the flagellum are cylindrical, slender, which gives the antenna a filiform appearance. The second joint of the antenna of *Bibiocephala* resembles that of *Apistomiay*, the blepharocerid from Corsica, as figured in Loew, *loc. cit.*, fig. 2.)

Face, mouth, and palpi seem to be very like those of *Blepharocera;* about the latter two, it would be unsafe to judge from dry specimens (About *Bl. capitata*, which I examined alive, I took at the time the following note: "The mouth of the female consists of several lancet-like, horny organs, protected by a fleshy, movable under lip; in the male, the horny lancets are absent, or else indistinct. The last joint of the palpi is elongate, slender." It is very probable that the mouth of *Bibiocephala*, ♂, has a similar structure; only the last joint of the palpi seems to be proportionally shorter.)

Thorax rounded; thoracic suture appears as a distinct, curved groove on both sides, but is interrupted in the middle (similar to that of *Bl. capitata*).

Hypopygium large, projecting like that in a male *Erax*. (The forceps seems to be analogous in structure to that of *Bl. capitata*; only the two principal projecting pieces are broader, shorter, and bfid at the tip)

Feet long, strongly built, and bare, excepting a microscopic pubescence; front and middle parts about equal in length, the last pair much longer, especially through the great length of the femora. Front coxæ separated by a considerable space; the second joint of the trochanters very long; middle coxæ more approximated; the hind ones contiguous.

Front tibiæ strongly arched, no distinct spurs at the end; middle and hind tibiæ straight; the middle ones with two stout, but very small spurs, the hind ones with two short, stout, and very distinct spurs at the end. The joints of the tarsi on all the feet gradually diminish in length, the first being by far the longest; the last joint, however, is nearly twice as long as the preceding one. Ungues elongated, strong at the basis; their under side, under a magnifying-power of 80–100, shows a dense brush of exceedingly minute, erect hairs, which extends to about half of the under side on the first pair, and to about three-quarters on the two others. The basis of the ungues shows some longer bristles. No distinct empodia. (The curved front tibiæ seem to indicate a habit of throwing the front feet backward and clasping the thorax with them; at least some of the dried specimens were in that position In *Bl. capitata* the feet are comparatively longer and more slender; the front tibiæ are straight; the last tarsal joint is not longer than the preceding; the middle coxæ are contiguous, e&.)

Wings (see the figure), in shape, are like those of most of the known *Blepharoceridæ*, having the same projecting anal angle, with a rounded end (compare Loew, *loc. cit.*, Fig. 3, 6, and 12). The venation is very like that of *Blepharocera* (*loc. cit.*, Fig. 12), only there is an intercalary longitudinal vein between the first and second veins. It begins near the origin of the second vein, runs alongside of the first, and ends in it a little before its tip. Near its end, it bears a short stump of a vein, which is indistinct in some specimens. The large fork formed by the penultimate longitudinal vein is connected at its basis by a cross-vein with the preceding vein (which is not the case in *Bl. capitata*). An auxiliary vein is apparent, but it does not reach beyond the origin of the second vein.

There is an alula and an alar excision. In the alar excision, between the alula and the anal angle, a peculiar, apparently horny knot, of irregular outline, is apparent, connected with a vein encompassing the alula.* The fringe of hairs bordering the wing is exceedingly minute, hardly visible with a lens of moderate power, except in the alar excision, where the hairs are longer. The surface of the wings is bare to the naked eye, but shows microscopic hairs under a magnifying power of 80–100. The peculiar spider-web-like net-work existing on the wings of all the known *Blepharoceridæ* is also apparent here.

The name of the genus is derived from the resemblance of the head, with its contiguous eyes and short antennæ, to that of a male *Bibio*.

B. grandis, n. sp., ♂, black, opaque, clothed with blackish pile; antennæ black; first joint of the flagellum somewhat paler; thorax with a slight yellowish-gray bloom above, forming an indistinct design and two faint stripes; abdomen black, with indistinct markings of yellowish-gray bloom; the margins of the ventral segments and the under side of the hypopygium brownish-yellow. Halteres pale yellowish-brown. Feet brownish, except the coxæ and the basal half of the femora, which are brownish-yellow. Wings with a brownish tinge. Length, 10–11 millimeters; length of the wing, 9 millimeters. Five male specimens taken in the Colorado Mountains in August.

OBSERVATION.—In comparing the figure of the wing of this species with that of *Protoplasa* (Monogr. of N. A. Diptera, vol. iv, p. 317), one cannot help being struck by the great resemblance of both. If we prolong the interrupted vein in *Bibiocephala* until it reaches the cross-vein above it, we obtain very nearly the venation of *Protoplasa*. The differences are (1) the undeveloped end of the auxiliary vein of *Bibiocephala* (which is made too weak in the wood-cut); (2) the absence of the supernumerary longitudinal vein of *Protoplasa* (which vein, as I have shown, *loc. cit.*, p. 319, is but the thickening of a fold existing in the same place in *Ptychoptera*); (3) the absence of the cross-veins forming the discal cells. These differences are of far less moment than the analogies. The shortness of the basal cells and the squareness of the anal angle are also characteristic of both wings. The additional vein which distinguishes *Bibiocephala* from the other *Blepharoceridæ* is the ordinary branch of the second vein, apparent in *Protoplasa* and very common among the *Tipulidæ*.

Thus, *Bibiocephala* serves to confirm the hint thrown out by me some time ago (Monographs, &., IV, p. 3) about the relationship between the *Blepharoceridæ* and the *Ptychopterina*.

*Mr. Burgess first called my attention to this peculiar structure, which I also perceive in *Blepharocera*, and which does not seem to have been noticed before.

NOTICE ON THE GALLS COLLECTED BY LIEUT. W. L. CARPENTER.

BY C. R. OSTEN SACKEN.

A.—OAK-GALLS, Colorado Springs, September 25.

1. Leaf-gall, globular, hollow, very similar to the gall of *Cynips singularis*, Bassett, although not identical. The gall-fly, a *Cynips*, was cut out of the gall inside of which it had died before being hatched.

2. Leaf-gall of the same class as that of *Cynips pegomachoides*, O. S., and *Cynips erinaceus*, Walsh.

3. Bud-gall, different from all other galls known to me in this country; probably likewise a *Cynips*.

It is to be regretted that the species of oak on which these galls were found were not taken note of.

B.—WILLOW-GALLS.

All the galls examined, from four different localities, belonged to a hymenopterous insect, *Nematus* (family *Tenthredinidæ*), very common on willows.

The galls taken July 7 were very young; those taken on East River, August 12, still contained the caterpillar; those of September 1 to 18 were empty. A lot taken near the Twin Lakes, July 29, had a peculiar shape, and was covered with a whitish bloom. It may have been a different species, although it is undoubtedly a *Nematus*.

C.—COTTONWOOD GALLS.

September 18, Clear Creek; galls formed by *Aphides* at the point of attachment of the leaf-stalk to the leaf. They are very similar to the galls of *Pemphigus populicaulis*, Fitch, on poplar, and may be produced by this very species.

July 15, South Park; woody swelling of the branches. It does not seem to be a gall, as it is entirely solid on the inside. It may have harbored insects, as several round holes upon its surface seem to indicate, but the deformation is not necessarily caused by the presence of these insects.

D.—GALLS ON SAGE-BUSHES.

September 8, pupa-shells, found inside of these galls, seem to belong to the genus *Trypeta*.

LIST OF SPECIES OF COLEOPTERA, COLLECTED BY LIEUT. W. L. CARPENTER, UNITED STATES ARMY, FOR THE UNITED STATES GEOLOGICAL SURVEY OF COLORADO, 1873.

BY HENRY ULKE.

CICINDELIDÆ.

Cicindela longilabris, Say.
pulchra, Say.
Cicindela purpurea, Olio.
tranquebarica, Herbst.

CARABIDÆ.

Elaphrus californicus, Mann.
Carabus tædatus, Fabr.
Cychrus elevatus, Fabr.
Nebria Sahlbergi, Fisch.
Pasimachus elongatus, Lec.
obsoletus, Lec.
Brachinus conformis, Dej.
Metabletus americanus, Dej.
Cymindis reflexa, Lec.
Calathus ingratus, Dej.
dubius, Lec.
Platynus placidus, Say.
chalceus, Lec.
Pterostichus protractus, Lec.
longulus, Lec.
lucublandus, Say.
scitulus, Lec.
Luczotii, Dej.
Amara lacustris, Lec.
obtusa, Lec.
Amara patricia, Dej.
fallax, Lec.
erratica, Sturm.
terrestris, Lec.
subænea, Lec.
polita, Lec.
Chlænius sericeus, Forst.
Nothopus zabroides, Lec.
Harpalus caliginosus, Say.
amputatus, Say.
funestus, Lec.
oblitus, Lec.
pleuriticus, Kirby.
opacipennis, Hald.
ellipsis, Lec.
Anisodactylus rusticus, Dej.
Eurytrichus terminatus, Say.
Bembidium Mannerheimii, Lec.
lucidum, Lec.
quadrimaculatum, Gyll.

DYTISCIDÆ.

Laccophilus truncatus, Mann.
Colymbetes quadrimaculatus, Aube.
densus, Lec.
binotatus, Harris.
Colymbetes agilis, Fabr.
Acilius fraternus, Harris.
Dytiscus marginicollis, Lec.

GYRINIDÆ.

Gyrinus affinis, Aube.
Gyrinus maculiventris, Lec.

HYDROPHILIDÆ.

Hydrophilus lateralis, Fabr.
sublævis, Lec.
Berosus striatus, Say.
Hydrobius fuscipes, Linné.

SILPHIDÆ.

Silpha lapponica, Herbst.
ramosa, Say.
Necrophorus velutinus, Fabr.

STAPHYLINIDÆ.

Creophilus villosus, Grav.
Porrhodites, one species.
Homalota, one species.
Oxypoda, one species.
Oxytelus, one species.

HISTERIDÆ.

Saprinus oregonensis, Lec.

NITIDULIDÆ.

Carpophilus pallipennis, Say.
Ips Dejeannii, Kirby.

DERMESTIDÆ.

Dermestes marmoratus, Say.
fasciatus, Lec.
Dermestes nubilus, Say.

BYRRHIDÆ.

Cytilus varius, Fabr.

LUCANIDÆ.

Platycerus depressus, Lec.

SCARABÆIDÆ.

Canthon vigilans, Lec.
ebenus, Say.
Onthophagus latebrosus, Fabr.
Phanæus carnifex, McL.
Trox porcatus, Say.
Aphodius ruricola, Mels.
Diplotaxis obscura, Lec.
Tostegoptera lanceolata, Say.
Polyphylla 10-lineata, Say.
Trichius affinis, Gory.
Euryomia inda, Lac.

BUPRESTIDÆ.

Melanophila longipes, Say.
Ancylochira confluens, Say.

ELATERIDÆ.

Alaus melanops, Lec.
Corymbites morulus, Lec.
Corymbites tinctus, Lec.

TELEPHORIDÆ.

Calopteron terminale, Say.
Photinus lacustris, Lec.
angustatus, Lec.
Chauliognathus basalis, Lec.
Podabrus lævicollis, Kirby.

MALACHIDÆ.

Collops cribrosus, Lec.
Dasytes Hudsonicus, Lec.
Listrus senilis, Lec.

CLERIDÆ.

Trichodes ornatus, Say.
Clerus sphegeus, Fabr.
Hydnocera subfasciata, Lec.

SCOLYTIDÆ.

Xyleborus septentrionis, Mann.
Dendroctonus obesus, Mann.

TENEBRIONIDÆ.

Asida sordida, Lec.
elata, Lec.
opaca, Say.
polita, Say.
Coniontis ovalis, Lec.
Eleodes obscura, Lec.
suturalis, Say.
hispilabris, Say.
Eleodes tricostata, Say.
extricata, Say.
obsoleta, Say.
nigrina, Lec.
humeralis, Lec.
pimelioides, Mann.
Blapstinus pratensis, Lec.
Iphthimus sublævis, Bland.

CISTELIDÆ.

Hymenorus obscurus, Say.

ANTHICIDÆ.

Corphyra Lewisii, Horn.
Stereopalpus guttatus, Lec.
Notoxus bifasciatus, Lec.
subtilis, Lec.

MORDELLIDÆ.

Mordella scutellaris, Fabr.

MELOIDÆ.

Meloe near angusticollis, Say.
Nomaspis parvula, Hald.
Epicauta maculata, Say.
pruinosa, Lec.
Lytta Nuttalli, Say.[1]
sphæricollis, Say.
Nemognatha lurida, Lec.

ŒDEMERIDÆ.

Calopus angustus, Lec.

CERAMBYCIDÆ.

Spondylis upiformis, Mann.
Criocephalus agrestis, Kirby.
Batyle suturalis, Say.
Tachyta liturata, Kirby.[2]
Acmæops proteus, Kirby.
Acmæops pratensis, Laich.
longicornis, Kirby.
Monohammus scutellatus, Say.
Monilema annulatum, Say.
Tetraopes femoratus, Lec.

CHRYSOMELIDÆ.

Adoxus vitis, Linné.
Chrysochus auratus, Fabr.
cobaltinus, Lec.
Doryphora decem-lineata, Say.[3]
Chrysomela exclamationis, Fabr.
Chrysomela dissimilis, Say.
Longitarsus, one species.
Trirhabda attenuata, Say.
convergens, Lec.
Cassida 6-punctata, Fabr.

COCCINELLIDÆ.

Hippodamia 5-signata, Muls.
parenthesis, Say.
convergens, Germ.
Coccinella transversoguttata Fald.
monticola, Muls.
picta, Rand.

EROTYLIDÆ.

Erotylus Boisduvalii, Lec.[4]

CURCULIONIDÆ.

Alophus alternatus, Say.
Cleonus trivittatus, Say.
Erirhinus, two species.
Ceutorhynchus, one species.

NOTES.

[1] *Lytta Nuttalli.*—The geographical distribution of this insect is extremely limited. It was found in South Park, near the head of the South Platte River, on the *Iris tenax*, in an area which might be bounded by a radius of five miles, and was not seen at any other place during the season.

[2] *Tachyta liturata.*—Found on the *Populus tremuloides* and *P. balsamifera* in great numbers at an altitude of about 8,000 feet.

[3] *Doryphora decem-lineata.*—Colorado potato-beetle. This insect is still marching eastward; not a single specimen having been seen west of the dividing-ridge. It is probable that, should the potato be cultivated on the western water-shed, it would be free

from the ravages of this destructive insect for a number of years; but that it would ultimately make its appearance in that region through the agency of the seed. This I believe to be the manner of their introduction to distant localities, as they are sluggish travelers, and quite incapable of spreading so rapidly by their own instinct. This belief is further sustained by their continued absence from the Salt Lake basin, occasioned by the cheapness of vegetables in the Mormon settlements excluding the importation of potatoes from Colorado. Not found at a greater altitude than 8,000 feet.

[4] *Erotylus Boisduvalii.*—Usually found upon the *Pinus ponderosa*, and never seen at a greater altitude than 9,000 feet. Very abundant in the eastern foot-hills of the Front range, but not found on the Pacific slope in Colorado, although it has been collected in Arizona.

Nemognatha lurida and *Lytta Nuttalli* verify the theory of the adaptability of the color of species to their food-plant; the former being found feeding upon the pistil of the *Cirsium undulatum*, which it so nearly resembles in color as to often escape close scrutiny; the latter, found upon the *Iris tenax*, is of precisely the same color as that plant.

W. L. C.

REPORT ON THE PSEUDO-NEUROPTERA AND NEUROPTERA COLLECTED BY LIEUT. W. L. CARPENTER IN 1873 IN COLORADO.

BY DR. H. A. HAGEN.

Family TERMITINA.

TERMOPSIS.

T. angusticollis, Hagen, Synop., 3, 1.

Rufous paler beneath; mouth infuscate; wings dusky hyaline; costal veins rufous; head oval flat; prothorax small, semicircular. Male and female.

Var. *Nevadensis.*—Dark reddish brown, scarcely paler beneath; wings dark, smoky; costal veins blackish-brown. Male and female.

Length to tip of wings, 23–26 millimeters; body, 11 millimeters; expansion of wings, 42–44 millimeters.

Soldier.—Stout, yellow; head and thorax rufous; head long, oblong, depressed, dark-brown anteriorly; labrum subquadrangular, yellow; mandibles black, long, straight, the pointed tip incurved; a tooth before the tip of the left mandible; palpi brown; eyes wanting, their place indicated; antennæ as long as the head, about 24 joints; the basis of the joints brown, darker on the basal joints; prothorax as large as the head, semicircular; mesothorax and metathorax rounded behind, with a small alar lobe each side, directed backward; abdomen ovoid; appendages four-jointed, long; last segment with two divergent, anal spines; feet strong, rufous; femora paler yellowish.

Length, 16 millimeters.

Larva.—Stout, elongated, flattened above, pale; head yellow, rounded; mouth darker; eyes indicated as in the soldier; antennæ 24 jointed; prothorax semicircular, small; mesothorax and metathorax larger, rounded behind, a small alar lobe on each side, directed downward; abdomen ovoid, the appendages two-jointed, but with indications of two more joints; last ventral segment with two anal spines; feet strong, yellow.

Length, 11 millimeters.

Nympha.—Size and color of the larva; eyes present, pale; alar lobes large, flat, triangular, horizontally covering the basal third of the abdo men; appendages four-jointed; anal spines divergent.

Habitat.—California, San Francisco, (Mann), San Diego, March, April (Crotch); Gulf of Georgia, Fort Steilacoom, Semialunoo (A. Agassiz); British Columbia, Quesnel Lake; Truckee, Sierra Nevada (Crotch); Louisiana (Pfeiffer).

The specimens are dry or preserved in alcohol. *T. angusticollis* is a real western species. I saw only one specimen from Nevada, collected on the western border of the State. An imago from Louisiana, collected by Mrs. Pfeiffer, is preserved in the museum at Vienna, Austria. So far as known, this species is not yet found in Texas or Mexico. Messrs. A. Agassiz and G. R. Crotch observed this species living beneath the bark of pine-trees.

The winged imagos differ in color, the typical specimens being rufous, though some of them are darker. The single male from Nevada is smaller and the wings not as broad, (one-fortieth inch), and throughout much darker; but among a number of alcoholic specimens from San Diego and Semialunoo there are some nearly as dark; and, moreover, it is not impossible that the Nevada specimen was darkened by carbolic acid in the collecting-bottle. The discovery of the soldiers and of the other stages is very important. *T. occidentis*, formerly supposed to belong as soldiers to *T. angusticollis*, is now to be considered as a different species, the imago of which is still unknown.

T. occidentis, Hagen, Synop., 3, 2.

Soldier.—Very stout, rufous; abdomen yellow; head large, nearly as broad as long; convex above, rounded laterally, depressed anteriorly, the anterior angles prominent, jointed, dark-brown; antennæ 19-jointed, pale, the first and third joint longer, dark brown; labrum ovoid, yellow; eyes present, black, oval; mandibles shorter than the head, black, stout, curved, the left one with a double tooth before the tip. Prothorax broader than the head, large, flat, cordiform, the anterior margin deeply notched; mesothorax large, broad, with a short, flat, triangular, alar lobe; metathorax shorter and narrower, the alar cover smaller. Abdomen large, long, ovoid; appendages very short, conical, 2-jointed; last ventral segment with two small spines placed near together; feet stout, brown; femora rufous.

Length, 19 millimeters.

Larva.—Pale-yellow; head brighter yellow, rounded, flat above; antennæ pale, about 22-jointed; eyes present, black, well defined. Prothorax as broad as the head, transverse; angles rounded, the hind ones more obtuse; mesothorax of the same size, flattened, transverse, a little broader; on each side a triangular, depressed alar lobe nearly as long as the metathorax; the latter similar but larger; the abdomen broader, thick, ovoid; the appendages and spines similar to those of the soldier. Feet less stout, yellow.

Length, 14 millimeters.

Habitat.—California: Cape San Lucas (Xanthus de Vesey). The type of Walker from the west coast of Central America. The described specimens are preserved in alcohol. The descriptions of the previous stages of *T. angusticollis* and *T. occidentis* prove the difference of the two species. The soldier of *T. occidentis* differs by the rounded shorter head; the two-toothed mandibles; the prothorax very large, broader than the head, and nearly bilobate; the alar lobes large, flat, horizontal; the appendages very short, two-jointed; the eyes black, well developed. The larva differs by the alar lobes large, directed downward; the prothorax transversely oblong; the abdomen thick, ovoid; the appendages similar to those of the soldier; the eyes black, well developed.

The imago is still unknown; I suppose they belong to the genus *Ter-*

mopsis; nevertheless, the well-developed eyes of the soldier, and even of the larva, make this supposition rather doubtful.

The genus *Termopsis* was formed by Professor Heer for fossil species preserved in the amber of Prussia, and in the schists of Oeningen. *T. angusticollis* and perhaps *T. occidentis* are the only known living species of this genus; and their occurrence in North America is the more interesting, as some other remarkable species of the amber-fauna are still represented by similar living species in the fauna of North America.

Family PERLINA.

PTERONARCYS.

Pt. californica, Hag. Synop., 16, 5 (Proc. Bost. Soc. Nat. Hist., xv, 284.)

A full description is given in the monograph of this genus in the quoted proceedings.

Habitat.—California; Washington Territory, between Rock and Cascade Rivers; Lake Winnipeg (Kennicott); Ogden, Utah, from a river tributary to Great Salt Lake, in June (C. Thomas). *Nymphæ* from the San Luis Valley, Colorado. I have seen a number of specimens, dry and in alcohol, male, female, and nympha. According to McLachlan's statement, the wings of the California specimens are very smoky and opaque; perhaps they were darkened by the carbolic acid used by the collectors. *Pt. californica* is a decidedly western species. *Pt. biloba*, from Trenton Falls, N. Y., a species, as yet, only represented by the female type in the British Museum, is very nearly related, but according to McLachlan's, a different species.

Pt. regularis, sp. nov.

Male.—Dark-brown, paler beneath; head dark-brown; the posterior margin, two large lateral spots connected by a line behind the ocelli, two flattened, round tubercles a little before, and the anterior margin all dull-yellowish; lateral margin carinated up to the tubercles; three ocelli well developed; labrum small, brown; antennæ slender, half as long as the wings, brown; the basal joints yellowish beneath. Prothorax as broad as the head, nearly square, the anterior angles sharp, the posterior rounded, dull-brown; a very fine median yellow line only indicated, and on each side some curved elevated marks. Abdomen pale beneath; setæ (partly broken) shorter than the abdomen, dark-brown, dull-yellow at the bases, stout, the five basal joints very short. Feet brown, pale beneath; wings smoky, hyaline; veins strong, dark-brown; areolation square. The vulvar lamina as broad as the segment, rounded in front, the middle more produced, as long as the segment, notched on the tips, black; on each side at the base is a small triangular tubercle.

Length to tip of the wings, 19 millimeters; alar expansion, 33 millimeters.

Habitat.—Truckee, Sierra Nevada; Nevada, June 10 (Crotch). I have seen only two specimens.

Pt. badia, sp. nov.

Pale-brown; head dull-yellowish, with a large square black spot around the ocelli; antennæ brown, paler beneath. Prothorax square, the anterior margin rather rounded, the angles right, pale-brown, with darker shading on each on the elevated marks. Abdomen pale above, darker in the middle, pale-brown beneath; the apical margin of the penultimate ventral segment largely excised; the dark-brown middle part of the segment somewhat produced, without reaching the last segment; setæ pale-brown; feet darker brown; wings yellowish hyaline, with a dull-yellow stigma; veins brown.

Length, 17–19 millimeters; alar expansion 31–33 millimeters.

Habitat.—Bridger Basin, Wyoming (Garman); Cache Valley, Utah (C. Thomas); Colorado Mountains, August (W. L. Carpenter).

I saw only three females, in a very bad condition, in alcohol. The two species above described are the dwarfs of this genus; the smallest species known, *Pt. proteus*, having twice the length of *Pt. regularis* and *Pt. badia.* The gills are well visible in the alcoholic specimens of *Pt. badia*, 26 pairs in number, to wit, 6 between the head and the prothorax; 6 between the prothorax and mesothorax; 6 between the mesothorax and metathorax; 2 between the posterior feet; and 6 on the basal segments of the abdomen. The maxillary palpi are longer than the mouth, the basal joint short, the other long, equal, thicker at the tip; the labial palpi are similar. The palpi show a similar formation as the apical joint in the phryganideous genus *Hydropsyche.* The external membrane is cut or split in a somewhat spiral manner, so as to give to every joint the appearance of a large number of small joints imperfectly soldered together. This formation of the palpi belongs to all the species of *Pteronarcys*, and is exceptional for this genus only in the whole family of *Perlina.*

These two small species agree in all characters with the larger species, at least so far as the females are concerned, as the males are still unknown. The wings are divided into quadrangular cells, perhaps a little more regular than in the larger species. The venation of *Pteronarcys* seems to resemble the most the remarkable fossil genus *Miamia.*

ACRONEURIA.

A. abnormis.

Perla abnormis, Hagen, Synop., 17, 1.

This species appears to vary in a very high degree. The late B. Walsh, after repeated observations of living specimens, confirmed variation in size and color, in the reticulation of the wings and in the number of the quadrangular areoles, which are sometimes nearly or altogether wanting; the shape of the prothorax and the vulvar lamina of the female, commonly of a constant shape in this family, offer also slight variations in this species.

The male has usually long and well-developed wings; however, two short-winged males now before me seem to belong to this species. The material in my collection of dry and alcoholic specimens, though rich in specimens from different localities, seems to be not yet sufficient to decide the question whether we have here several very closely-related species or simply varieties of *A. abnormis.*

Two females from South Montana and a male from Snake River, Southeastern Idaho, collected by Prof. C. Thomas, differ as follows: The colors are darker, the abdomen yellow beneath, on each side dark-brown. The male, in worse condition than the females, is a short-winged one; the shape of the prothorax somewhat different, perhaps only altered by the bad preservation. The vulvar lamina of the two females is more produced than usual, covering one-half of the following segment; the apical margin is nearly semicircular, notched very little in one female, and not at all in the other.

A cast nympha-skin from Eagle River, Colorado, August 30, collected by Mr. Carpenter, belongs to a very large species. Length, 33 millimeters; setæ, 26 millimeters. There is nothing known concerning the previous stages of the North American *Perlina;* even the different larvæ and skins in my collection are not yet thoroughly studied. After a closer comparison with a nympha-skin of *A. abnormis*, communicated by B. Walsh, I believe that the nympha-skin from the Eagle River belongs to the same genus, but certainly to a different species. It is not so much spotted; the apical half of the wing-cases is pale, without the black band, so conspicuous in *A. abnormis;* the abdomen is dark-brown above, without the regular paler marks of *A. abnormis;* the basis of the blackish setæ is pale instead of the throughout dark color of the setæ of *A. abnormis.* Even the size of the skin seems too large for the known American Perlids, except for some very large specimens of *A. abnormis*, collected at the Saskatchewan River.

Habitat.—Assuming the above-described specimens to belong to *A. abnormis*, this species would have a very wide distribution. The northern limits known are the Saskatchewan and Peel River and Canada; the southern limits, Georgia, and perhaps Mexico; it is known from all Eastern States on the Atlantic, and from many States between the Atlantic and the Rocky Mountains.

DICTYOPTERYX.

D. signata, sp. nov.

Yellowish-brown, pale beneath; labrum pale-brown; head flat, with two irregular brown stripes, connected transversely before the eyes in a manner to form an anterior large yellow spot, trilobate behind; space between the stripes with an anterior rounded spot, connected with a smaller triangular one on the hind border; a large yellow spot on each side near the eyes. Antennæ pale-brown; first joint blackish-brown above; second and third pale; palpi pale. Prothorax as broad as the head, nearly square; brown, with a large yellow median band somewhat dilated at the ends; on each side three carved marks, formed by rather irregular black polished scars; lateral margin straight, dark. Abdomen dark-brown above, pale-yellowish beneath; whitish around the base of the feet; segments darker at the base. Feet pale-brown, femora with an external vitta and a ring before the knee; base of the tibiæ and tip of the tarsi dark-fuscous. Setæ pale brown, darkest at the tip of the joints. Wings with a grayish-yellow tinge, darker on the costal margin; veins brown, darker, and very irregular on the tip of the wing, five or four, or even less, antecubitals; wings of the male as long as the abdomen, or one-third or more shorter; the apical areolets very irregular.

Male.—The last dorsal segment yellow; the apical margin recurvate, transversely cariniform, thickened, emarginate in the middle, scabrous, and rather villous exteriorly; appendages yellow; the superiors are small recurved lobes; between them the larger inferiors, darker on the triangular tip, which is sharp and a little emarginate beneath, just before the tip; an ovoid membrane between the inferiors belongs perhaps to the penis; last ventral segment produced between the setæ with an elliptical margin.

Female.—Last dorsal segment obtusely produced in the middle of the apical margin, with a median longitudinal impression; vulvar lamina large, rather inflated on the antepenultimate segment, forming two free circular lobes, very near together, beneath the penultimate segment.

Length with the wings, ♂, 13–17 millimeters; ♀, 18–21 millimeters. Alar expansion, ♂, 16–26 millimeters; ♀, 30–40 millimeters. Length of the setæ, 11 millimeters.

Habitat.—Foot-hills, Colorado, September, and mountains on the Pacific slope, August 16 to September 6. Several specimens in alcohol.

This genus is new for the American fauna; all species known belong to Europe and Siberia. This new species is far more interesting as an exception, bearing gills in the imago-state. There are on the ventral side five pairs of gills, formed by white, fleshy, blind sacs; two pairs on the under side of the head; the first pair widely separated on the basal part of the submentum; the second pair in the articulation with the prothorax; both pairs straight, placed transversely, looking outward. The three other pairs on the thorax, always before the feet, but separated from them, being placed just in the articulation of the segments; the three thoracic pairs are incurved.

The occurrence of gills in the imago-state of *D. signata* is the more exceptional, as all the hitherto-known species are without them. At least, a close examination of dry specimens of all the species in my collection (only one of Siberia is unknown to me) did not disclose anything similar to the gills in *D. signata;* Dr. Gerstaecker, in a recently-published paper, also states the absence of gills in living specimens of *D. intricata* and *D. alpina.* Formerly, the genus *Pteronarcys* was the only known exception for its gill-bearing imagos among the class of insects; now, besides the above-described *Dictyopteryx*, there are two other gill-bearing Perlid genera mentioned by Dr. Gerstaecker, *Damphipnoa lichenalis* from Chili, a genus closely related to *Pteronarcys*, and *Nemura cinerea* and *N. nitida*, with its male *N. lateralis*, both from Europe.

The papers by Dr. Gerstaecker are published in the *Festschrift zum hundertjaehrigen Bestehen der Gesellschaft naturforschender Freunde*, Berlin, 1873, 4to, p. 60, with figures; and *Sitzungsbericht derselben Gersellschaft*, October 21, 1873, p. 99.

ISOGENUS.

I. elongatus, sp. nov.

Female.—Brown; head with a posterior, triangular, yellow spot, extended on each side of the occiput; two small, ill-defined, yellow spots near the antennæ and eyes; antennæ brown. Prothorax as broad as the head, quadrangular; the angles sharp, with a large, yellow, median band, narrower before. Abdomen and feet brown; setæ brown; base of the joints paler. Wings long, hyaline; veins brown, with a pale-yellow tinge around the costal apical veins; costa pale; submedian areolet larger toward the tip, with seven transversal veins; the anterior vein of the submedian areolet somewhat curved. Vulvar lamina large, the base separated from the segment by a deep furrow in form of a transversely-enlarged W; apical margin nearly straight, covering only a little of the following segment; the lateral angles rounded; a small notch in the middle.

Length, with the wings, 24–28 millimeters. Alar expansion, 40–44 millimeters.

Habitat.—Foot-hills, Colorado (Mr. Carpenter); Ogden, Utah (by C. Thomas). Alcoholic specimens. *I. elongatus* is very similar to *I. frontalis*, but in this species the anterior vein of the submedian areolet is straight, and the anterior margin of the vulvar lamina rather incurved.

I. colubrinus, sp. nov.

Brown; head with a posterior, triangular, yellow spot; part before the ocelli yellowish; antennæ blackish-brown; prothorax rather smaller than the head, quadrangular; angles sharp, with a yellowish median band, a little narrower before; abdomen and setæ dark-brown; feet pale-brown, tips of the femora and tibiæ darker. Wings hyaline; veins pale-brown; costa, and its transverse veins, pale; submedian areolet less enlarged on the tip; the anterior vein less incurved; vulvar lamina similar to *I. elongatus*, but larger, subbilobed, the notch reaching nearly to the basal furrow, and the apical margin nearly circular.

Length, with the wings, 22 millimeters; alar expansion, 38 millimeters.

Habitat.—Snake River, Idaho (C. Thomas). I believe that some specimens from the Saskatchewan River, from the Slave and Winnepeg Lakes, all in my collection, belong here. The males are a little smaller, but long-winged. The comparison of dry and alcoholic specimens is so difficult that it seems more prudent to consider the identity of the specimens as still doubtful.

PERLA.

P. sobria, sp. nov.

Female.—Head dull-brown near the prothorax; the anterior part pitchy-black; three large yellow spots between the eyes, each side one near the border, and a middle rhomboidal one; three smaller spots on the clypeus between the antennæ, each side, a pale, whitish one near the border, and a middle quadrangular, yellow one just before the anterior ocellus, bordered on each side by a shining-black stripe; antennæ black, brownish beneath at the base. Prothorax as broad as the head, quadrangular, broader than long; hind angles less sharp, pale-yellow on each side, with a large, ill-defined rugulose band; a fine, impressed, median line with a spot in the middle, and a fine, transversal line just before the anterior and one before the posterior margin, all black. Mesothorax and metathorax shining-black above; abdomen brown on the under side, paler at tip; head and thorax brown beneath, with a large, black spot on each side before the second and third pairs of feet; setæ pale-yellowish. Feet dark-brown; wings hyaline, scarcely fumose; veins strong, blackish-brown, finer in the costal space; vulvar lamina large, bifid, the outer edge of the two lobes rounded; before them a small tubercle.

Length, with the wings, 14 millimeters; alar expansion, 26 millimeters.

Habitat.—Colorado Mountains, Pacific slope, August (Mr. Carpenter). One female, in poor condition.

P. ebria, sp. nov.

Female.—The single specimen, in bad condition, is very similar to *P. sobria* in colors and in shape. The genital parts are well preserved and the vulvar lamina is entirely different, a long oval lobe without any notching of the apex. So far as known, this important part never varies in such a manner, and it would be impossible to unite both specimens in one species, notwithstanding their great resemblance.

Habitat.—The same locality as *P. sobria.*

P. ——— (?), sp.

There is a third species from the same locality in worse condition still. It is a little smaller, the head and the prothorax somewhat different. As the abdomen is wanting, I prefer merely to indicate the occurrence of a third undescribed species.

CHLOROPERLA.

A small *Chloroperla*, of the size of *C. cydippe*, from the foot-hills of Colorado, belongs to a new species, but is too much damaged to be described.

Family EPHEMERINA.

EPHEMERA.

E. compar, sp. nov.

Male imago.—Light-brown; head blackish-brown; antennæ pale-yellow; a broad, pale-brown, dorsal band on the thorax; each side of the prothorax blackish; abdomen above on each side with two, black, longitudinal lines and two more in the middle of segments 6 to 9; last segment with two large, ill-defined, black spots; abdomen beneath on each side with one black, longitudinal line; penultimate segment with a large, quadrangular, black spot; setæ very long, pale-brown, the articulations hardly darker; appendices pale brown, long, arcuated on the tip; the two apical joints short, the last shorter; feet pale-brown; the anterior pair very long, black; the femora brown; fore-wings hyaline, with a yellowish tinge; veins dark-brown; the apical half of the two costal spaces dark-brown, and the basal half of the second costal space rather fumose; a series of four small, black spots in the middle of the wing near to the costa, another spot near the base of the wing, and one near the tip; hind-wings of the same color, with a large apical brownish band; some of the veins in the middle of the wing finely clouded with black.

Length of the body, 15 millimeters; alar expansion, 32 millimeters; length of the setæ, 30 millimeters.

Habitat.—Foot-hills, Colorado (Mr. Carpenter).

This species is very similar to *E. lutea*, Burm. (*E. lineata*, Eat.); as I have seen only one male, I believe it to be more prudent not to identify the American with the European species, the more so as some differences, though not important ones, are to be found. *E. lutea* has the third and fourth joints of the appendices of equal length, and together two-thirds the length of the second joint. *E. compar* has the fourth joint shorter than the third, and both together one-third the length of the second joint. But as the only male of *E. compar* is dry, and as the measures for *E. lutea* are taken from living specimens, the differences may not be certain. The discovery of *E. compar* fills a gap in the fauna of North America. There are four species of European *Ephemeræ* nearly related to each other. Till now only three species were known in the North American fauna representing three of the European species, and the discovery of *E. compar* imitating the fourth European species makes the parallelism of the Ephemerid fauna of both countries complete.

As the other three American species were formerly not well described, even some of them erroneously identified, I believe it is worth while to give here a more detailed description of them. It is presumed that at least two of them will be discovered within the area of country embraced in this paper.

E. decora, Hagen (Synop., 38, 1).

Male imago.—Luteous; head in the middle, prothorax on each side, dark-brown; antennæ pale; abdomen above with four large, beneath with two narrow, black lines; setæ pale, the articulations fine, brownish; appendages pale, the two last joints nearly equal in length, taken together about half of the second joint in length; anterior feet yellow; femora brown, darker at the tip; tibiæ at base and tip, tarsal joints at tip, blackish; the other feet pale; fore-wings hyaline, with a faint yellowish tinge, light-brown on the two costal spaces; transversal veins brown, faintly clouded near the costal margin and in the middle of the wing; some larger brown spots in the middle near to the costa, and one smaller near to the base; hind-wings hyaline. This male had apparently recently cast the skin, and is identical with the fragment of the type described in the synopsis. The type of B. Walsh in my collection is smaller (alar expansion, 23 millimeters), darker in color, but otherwise not different; the hind-wings have some transversal veins clouded, and a few blackish spots. A male from British America has the size of the male above described, but the colors of the specimen from B. Walsh.

Female imago.—Luteous; a darker line on each side of the prothorax; abdomen above with two larger triangular black spots on each segment, beneath with two longitudinal black lines; setæ pale; feet luteous; femora of the anterior feet brownish, tip of the joints brown; wings similar to the male, but the costal margin nearly hyaline, the spots smaller; some few spots on the hind-wings. A second female from British America is similar to the first.

Subimago, male and female.—Grayish-luteous; setæ pilose; wings dusky; spots the same as in the imago, none on the hind-wings; costal space a little darker.

Imago: length of the body, ♂, 10 millimeters; ♀, 11 millimeters; alar expansion, ♂, 23–27 millimeters; ♀, 30 millimeters; length of the seta, ♂, 30 millimeters.

Subimago: length of the body, 13 millimeters; alar expansion, 30 millimeters; seta, ♀, 15 millimeters.

Habitat.—New Haven, Conn., ♂; Norway, Me., ♂, ♀; Rock Island, Ill., ♂; Chicago, Ill., ♀; Virginia, ♂; British America, ♂, ♀, imago and subimago.

The wings of the two males from Virginia have darker spots, but probably belong to this species. *E. compar* is nearly related to *E. decora*, but is a little larger, brighter-brown, the anterior feet black, with the femora brown, the seta without blackish rings on the joints, the appendages visibly longer, the wings more yellowish, the costal margin brown, the spots smaller, the hind-wings with a larger apical brownish band.

This species is the *E. decora* of my synopsis, and according to the notes made by me in 1857, in the British Museum, also Walker's *E. decora*, I do not find the antennæ blackish; in the type-specimen of my synopsis, the antennæ are now wanting. I have no doubt about the rights of this species, which imitates well the European *E. glaucops*. The type of Mr. Walsh is the smallest specimen known, but, according to his paper, another male from the same locality was larger (alar expansion, 25 millimeters), nearly as large as the specimens above described.

E. guttulata, Pictet, Ephem., 135, 4, Pl. 8, Fig. 4. Male Imago.

SYN.—*E.*, sp. nov., Hagen, Proc. Ent. Soc. Philad., 1863, 177.—Trans. Ent. Soc. London, 1873, 393.—Eaton, Monogr., 71 (var. of *E. myops*).

Female imago.—Head and thorax luteous; a brown band each side on the prothorax, some darker spots on the thorax; abdomen pale-yellow, last segment brownish on the sides; setæ pale-yellow, faintly pilose, the articulations annulated with black; anterior feet yellow; femora, base, and tip of tibiæ, tip of tarsal joints, brown, the other feet yellow; fore-wings hyaline, fumose on the costal and apical margin; transversal veins except on the third part of the hind border strongly clouded with black; a larger confluent elongated black spot in the middle of the wing; hind-wings on the apical margin fumose, the transversals on the costal margin, and some apicals strongly clouded with black; a larger confluent black spot in the middle, and a small one near the base.

Length, 19 millimeters; alar expansion, 42 millimeters; setæ (broken), about 12 millimeters.

Habitat.—New York, by Osten Sacken.

This is the female *Eph.* sp. nov., quoted in Proceed. Ent. Soc. Philad., 1863, 177, as resembling *E. Danica* of Europe, and by Mr. Eaton in his Monograph 71 as a probable variety of *E. myops*, a statement refuted by me in Trans. Ent. Soc. Lond., 1873, 393.

I am now convinced that this female belongs to *E. guttulata*, Pict. The long anterior feet prove Pictet's specimen to be a male imago; the other feet and the abdomen are wanting. The colors and the pattern described by Pictet agree well, except the anal part of the fore-wings, nearly hyaline in the described females, faintly spotted in Pictet's type. The bright-yellow anterior feet in Pictet's description and figure (the number of joints is erroneous) represent very well this species, and are not to be seen in any other species. Pictet gives no dimensions, but the figure is without doubt of natural size, the alar expansion 36 millimeters. The locality of the type is not known; it was presented by Mr. Conlon, and may be, as many other species, communicated by this naturalist from the Western Hemisphere. In my Synopsis 38, I supposed *E. guttulata* to belong probably to *E. natata*, and Mr. Eaton, Monogr. 69, gives both species as synonymous. The type was not in Pictet's collection; at least, it is not among the species seen by Mr. Eaton in the collection (Monogr., p. 11).

The resemblance to *E. Danica* consists in the yellow-colored abdomen. The wings of *E. guttulata* are more spotted, the abdomen less so or not at all. The colors of the abdomen feet, setæ, and wings are very different from those in *E. natata*.

E. natata.

SYN.—*Palingenia natata*, Walk., Cat., 551, 13, fem. subim.
E. simulans, Walk., Cat., 530, 5, male subim.
E. natata, Hagen, Syn., 39, 4.
E. simulans, Hagen, Syn., 38, 2.
E. guttulata, Eaton, Monogr., partim.

Male imago.—Dark-brown; prothorax each side with a black band; abdomen brown, above with large, serrated, black spots; setæ pale-brown; articulations of the basal joints faintly marked with darker rings (partly broken); anterior feet brown; tip of joints darker; femora blackish; the other feet paler brown; appendages pale-brown, joint 2d and 3d darker on tip; 2d joint arcuated, not twice as long as 3d and 4th together; 4th half the length of 3d; wings hyaline; costal margin rather smoky; most of the transversal veins, except in the hind part of the wing, clouded with black; several larger quadrangular black spots in the middle of the wing and near to the base; hind-wings with the apical margin smoky; many transversal veins clouded with black, and several small spots blackish.

Female imago.—Similar to the male; thorax brighter brown; wings hyaline on the costal margin, except on the base, not so strongly clouded with black.

Male and female subimago.—Colors more dull; wings grayish; antennæ black; setæ dark-grayish.

Length, ♂, 13 millimeters; ♀, 15 millimeters; alar expansion, ♂, 32 millimeters; ♀, 40 millimeters; setæ ♀, 15 millimeters.

Habitat.—Saskatchewan River, British America, by R. Kennicott; a large number, in very bad condition; both sexes imago and subimago, Saint Lawrence River and Saint Martin's Falls, Hudson's Bay, by Walker; Chicago, by Osten Sacken and Woodwell; Maine, in Harris's collection.

This is the *E. natata* of my synopsis. The species imitates *E. vulgata*, of Europe, but the wings are more grayish than brownish. It differs from *E. decora* by the larger size, the darker marked wings, the less annulated setæ, the relative length of the joints of the appendages. At least, there can be no doubt about the difference of my *E. natata* and *E. decora*, brought together even with *E. guttulata*, as belonging to the same species, by Mr. Eaton.

It may be interesting to publish here a letter to the late Prof. L. Agassiz by Mr. George E. Woodwell, from the Tribune office, Chicago, Ill., July 23, 186 (?) (number not filled). The letter contained several dry specimens, imago and subimago, of *E. natata:*

> I send you a number of specimens of a fly which annually visits our lake-cities, and which has the present summer appeared in larger swarms than ever known before. During the recent hot nights they have poured in from the lake in myriads, rendering it necessary in lighted buildings to close the windows and doors in order to escape their visitation. For several nights past, they have thus swarmed upon us; and the morning would witness about the posts of the street-lamps large heaps, in some instances three inches deep, and covering an area of two or three yards square.

Couriously enough, the imitating species from Europe, *E. vulgata*, swarms in a similar manner; and Scopoli tells us that the farmers in Krain are not contented unless they are able every year to bring a number of cart-loads as manure upon their fields.

HEPTAGENIA.

H. brunnea, sp. nov.

Male imago.—Brown, the thorax and the body beneath paler; head blackish; prothorax deeply notched behind, with an elongated blackish spot on each side, and a similar one on the mesothorax; metathorax bright-yellow between the wings. Abdomen brown, the segments with a darker ring on the tip; setæ long, grayish-brown, darker at the base, the articulations scarcely darker; appendages long, cylindrical, darker brown, four-jointed; first joint very small; second somewhat longer than the apicals together, which are of equal length; piece between the appendages notched; penis long, bifid, divergent. Femur paler on the tip; the other legs pale-brown; femora with a darker external line; tarsi dark. Wings hyaline; veins brown; some transversal veins on the costal margin pale.

Female imago.—Similar to the male. Abdomen pale, on the upper portion of each side a series of triangular black spots and a longitudinal between them; beneath, on each side a series of black lines; setæ pale, articulations black; egg-valve broad-elliptical; legs similar, the four posterior with the tarsi pale; femora darker, pale at the base and tip; wings similar, the transversal veins in the costal space pale, very fine, not reaching the costa.

Length, ♂, 10 millimeters; ♀, 12 millimeters; alar expansion, ♂, 30 millimeters; ♀, 34 millimeters.

Habitat.—One pair from Nevada, Truckee, in Sierra Nevada range, June 10 (J. R. Crotch).

H. pudica.

SYN.—*Ephemera pudica*, Hagen, Synop., 39, 5.

Female subimago (dry, just casting the skin).—Grayish-brown; head large, triangular, flattened, luteous; eyes distant, black; posterior ocelli large, the anterior small; antennæ short, stout, brownish, paler at the base; the hind border of the occiput straight. Prothorax short, hind-margin deeply notched, nearly bilobed, pale, shining; thorax thick, pale, shining on the middle denuded parts. Abdomen stout, dull-yellowish above, with black oblique spots on each side of the segments, and some finer lines on the ventral side. The described parts, except the antennæ, are out of the nymph-skin belonging to the imago. Abdomen of the subimago pale, last dorsal segment with a small median projection; setæ strong, faintly pilose, long, grayish-brown; a large mass of eggs is protruded, but the parts are not in good condition; feet pale, grayish-brown, well developed, tarsi five-jointed; anterior wings large, opaque, pale yellowish-gray; the longitudinal veins yellowish, the transversals brown, somewhat fumose; hind-wings more yellowish, the apical border larger, grayish; reticulation similar to *Ephemera*.

Length, 14 millimeters; alar expansion, 42 millimeters; setæ, about 30 millimeters.

Habitat.—Washington (Osten Sacken); foot-hills, Colorado, August (Carpenter). Both female subimagos, and both in very poor condition.

In the type of the species, the femur, on the (only present) anterior foot, with a dark-brown ring in the middle.

LEPLOPHLEBIA.

L. pallipes, sp. nov.

Female imago.—Brown, shining; head light-brown; antennæ grayish, brown at the base; around the ocelli black; prothorax notched behind; mesothorax black, shining above; abdomen dark brown, segments on tip with a darker ring; setæ broken; vulvar lamina long, broad, bifid, the lobes elliptical; legs thin, pale-whitish, the femora darker on tip; wings hyaline, transversal veins very fine, nearly invisible, except a few on the tip of the costal margin.

Length, 6 millimeters; alar expansion, 15 millimeters.

Habitat.—Nevada, Truckee in the Sierra Nevada (Crotch).

Tarsi, 4-jointed; the reticulation and the shape of the hind wing similar to the wing of *L. helvipes*, figured by Mr. Eaton (Monogr., Pl. iv, 26, *d.*).

Nympha-skin (perhaps belonging to *Heptagenia pudica*).—Body broad, flattened; head small, half as long as broad, visibly enlarged in front; the hind part inflated with a rounded tubercle each side; the front border cut off straight; the sides oblique; the front angles rounded; the whole border fringed with wooly hairs. Antennæ short (not complete), a little longer than the front border; two stronger basal joints, second longer; and a conical seta, the joints of which could not be ascertained. The head (for the escape of the imago) split transversely behind the antennæ, and the occiput in the middle; the part above the mouth-parts (viewed from the front) is straight, and superseded by the described flattened border, which forms a triangular projection on each side; labrum transversely oblong, yellow, blackish on each side at the base; mandibles and maxillæ strong, yellow, with blackish apical teeth; labium transversely elliptical, four-lobed, a 2-jointed large palpus each side. Thorax large, nearly twice the breadth of the head, pale-gray, with some brown spots; prothorax flat above, short, larger behind, the angles sharp; each side near the middle of the flattened border an exserted, conical, sharp spine; meso- and metathorax rounded above, with triangular wing-cases covering the basal segments of the abdomen. The wing-cases are separated by the notched hind border of the metathorax; the cases of the posterior wings are not visible, and seem to be connected with the anteriors in the manner of *Bœtisca*. Abdomen a little longer than the other parts of the body, broad, flattened; the segments, 2 to 9, produced on each side, in a large triangular process, bent behind, very sharp at the tip; abdomen pale-gray on each side, above a series of brown spots, with some in the middle between them; the triangular processes, on the segments 4 to 9, dark-brown, with a pale ring before the extreme tip, which is again blackish; segments 4 to 7, above each side, with a large flattened orbicular gill inserted beneath the hind border of the segments, where the lateral process begins; all lateral processes covered and fringed with wooly hairs; last segment short, transversely oblong; the dorsal apical border produced in the middle; the three setæ a little shorter than the abdomen, equal, slender, pale; the fourth joint with a black, apical ring; on the apical third four segments black, also the tip; setæ fringed with long hairs; feet flattened; the femurs dilated in the dorsal middle, ending in a superior spine, pale with three brownish bands; tibiæ black at the base and the apical half; tarsal joint black on the basal half and on the tip; the single claw pointed black at tip. Genital parts of the male on the ventral side of the ninth segment, forming on tip a transversal lobe, with a triangular longer one on each side, and a little before an elongated bifid lobe; the female has the ninth segment produced in a larger elliptical lobe.

Length, without setæ, 15 millimeters; setæ, 7 millimeters; greatest breadth of the abdomen, 5 millimeters.

Habitat.—Colorado, mountains and plains, July 19, September 19, Mr. Carpenter. Three skins of the *nympha.*

The form of the *nympha* is a very extraordinary one; so far as I know, the next related is the *nympha* of *Heptagenia*, and considering the large size it would not be improbable that this *nympha* belongs to *H. pudica.*

Family ODONATA.

Subfamily LIBELLULINA.

The genera *Pantala*, *Tramea*, and *Plathemis* are not yet represented in the collection of the expedition; nevertheless, it is very probable that some of the widely-spread species of those genera occur in the Territories. *P. hymenæa*, *T. lacerata*, and *Pl. trimaculata* will, perhaps, be discovered there.

LIBELLULA.

L. 4-maculata, Hagen, Synop. 150, 1.

Habitat.—Snake River, Idaho, and Ogden, Utah, collected in 1871 by Mr. C. Thomas; Bridger Basin, Wyoming, by Mr. S. W. Garman. This species migrates in immense flocks in the Saskatchewan district, in Canada, in Wisconsin, and around Lake Michigan, just as in Europe and in Siberia. Stowe, Mass., is the most southeastern limit for the United States; it is very common in Northern and Central Europe and in Northern Asia as far as Kamtchatka.

L. nodisticta, Hagen, Synop., 151, 3.

Male adult.—Pruinose, clothed with white hairs. Labium yellow, with a large black band strongly coarctate just before the tip; labrum luteous, a blackish border on the anterior margin, not reaching the sides, and some ill-defined brownish spots in the middle and on the basal margin; rhinarium and epistoma luteous; front brassy, black above and before, with a bright-yellow spot on each side near the epistoma. Antennæ black; vertex brassy-black, inflated, narrower at the tip, the angles not sharply pointed, the vertex roughly punctured in front; occiput brown; eyes black behind, clothed with white hairs, a large yellow inferior spot near the margin, and a smaller quadrangular one above it; thorax black, densely pruinose, on each side an inferior yellow spot after the legs, and the indication of some ill-defined paler spots above and before them; abdomen tapering to tip, black, densely pruinose; segments each side on the ventral part with a large, reniform, somewhat irregular or divided bright-yellow spot; appendages black, the superiors as long as the two last segments, cylindrical, thicker before the outwardly-bent, pointed tip, beneath with a series of about eleven small teeth; inferior appendage a little shorter, triangular, broad, recurved; genital parts in the second segment, with the anterior lamina broad, cut straight, a small notch in the middle of the margin; hooks yellow, cylindrical, stouter on tip, which is excavated, the interior part of the excavation forming a produced unguiculated process; feet black; wings hyaline, with a blackish spot on the nodus, and a larger blackish band from the base to the triangle after the subcosta, somewhat enlarged along the anal border of hind-wings half-way of the whitish membranula; wings milky-white around the basal band and to the nodes; veins black, the first antecubital yellowish; pterostigma long, oblong, black; antecubitals 12 to 14, postcubitals 9 to 10; transversal veins in triangle, 2 to 3; four discoidal areolets, beginning with 5.

Male teneral.—The yellow color always brighter and more produced; dorsum of the thorax brown, with an ill-defined, broad, grayish band each side; on the humeral suture dark-brown; the crista and sinus black; the sides of the thorax paler, with four bright-yellow spots, two inferiors oval, bordered with dark-brown, and two superiors triangular, one between the wings, the other near abdomen; thorax beneath pale; abdomen fulvous, the sutures and margins black; a large black dorsal band, not reaching the base; each side oval, yellow spots on the segments; the two last segments black; abdomen beneath fulvous; the sides and the tip of the segments blackish; feet black; femora brown at base; the anteriors brown beneath; wings without the milky-white tinge.

Female adult.—Pruinose and similar to the adult male, combining in some parts the colors and pattern of the teneral male; labium yellow, with a narrow black line on the median lobe and the interior margin of the lateral lobes; labrum yellow, the middle part of the margin brownish; head yellow; space between the eyes black, the same color produced a little on the front above and on the sides; vertex brown, black on the sides; eyes behind bright-yellow, two transversal bands and the part near the occiput black; the head is exactly as in the teneral male, except a larger black band on the labium; dorsum of the thorax pruinose as in the adult male; the sides less pruinose, with the four yellow spots well defined; abdomen not tapering, the eighth segment enlarged, pruinose, segments 1 to 9 each side above and beneath with a large, oval-yellow spot; appendages a little longer as the last segment, black, villose, cylindrical, tapering to the outward bent fine tip; lobe between them lutrous, black at base; vulvar lamina exserted, short, notched in the middle, the sides thickened; eggs protruded, small, yellowish; feet black; wings similar to the male, but without the milky-white tinge, the black band ending before the triangle; 16 antecubitals, 11 to 12 postcubitals.

Female teneral.—Similar to the teneral male; head similar, black band of the labium broader; body not pruinose; dorsum of the thorax brown, yellow spots on the sides larger, forming two interrupted oblique bands; abdomen similar but not pruinose; wings similar, basal bands rudimentary, covering only the extreme base; 13 antecubitals, 9 postcubitals.

Length of the body, ♂, 47 millimeters; ♀, 46 millimeters; abdomen, ♂, 30 millimeters; ♀, 28 millimeters; alar expansion, ♂, 80 millimeters; ♀, 76–78 millimeters; appendages, ♂, 2; pterostigma, 4 millimeters.

Habitat.—Mexico, the colder region, by Mr. Saussure, a teneral male described in my Synopsis; an adult couple and a teneral female from Yellowstone, Hayden's expedition, 1872.

L. forensis, Hagen, Synop., 154, 9.

This species was first described after a male from California in the Berlin Museum. Now I have before me a pair from the Yellowstone, and a number of specimens from Victoria, Vancouver Island. This species is similar to *L. nodisticta*, but surely different.

In the adult male, the head is entirely black with the labrum; only the extreme lateral border of the labium, and an indication of the lateral spot of the front, yellowish; the thorax is much more villous, the fine hairs longer and more dense; the dorsum of the thorax pruinose, but a large, dark-brown band covered with brown hairs on the humeral suture; the sides brown beneath, two elongate yellow spots in the middle, and the part above them pale and covered with long fur-like white hairs, interrupted on the second suture by the brown color expanding upward; abdomen similar to *L. nodisticta*, pruinose, the yellow lateral spots on the dorsum more elongated, visible to the eighth segment; appendages similar, but the inferior more pointed; genital parts similar, but the anterior lamina forming an ovoid lobe, faintly notched on the tip; feet black; wings analogous, but more intensely colored; the basal band larger, exceeding the triangle; a large transversal black band beginning on the nodus and tapering to the hind margin, indented in the middle; the space between the bands and the pterostigma below the nodus largely milky white, but this color not reaching the apical or hind margin; 16 antecubitals; postcubitals.

Female adult.—Similar to the male; head paler in front, rhinarium, epistoma, brown; front above with two large, quadrangular, yellow spots, separated by the black middle furrow; abdomen pruinose, similar; vulvar lamina larger, opened in the middle; wings alike, the brown bands more or less developed.

One younger female from British Columbia has the thorax and abdomen not pruinose, dark-brown; the wings without milky-white tinge.

Length of the body, ♂, 51–44 millimeters; ♀, 48–44 millimeters; abdomen, ♂, 34–28 millimeters; ♀, 32–27 millimeters; alar expansion, ♂, 32–74 millimeters; ♀, 82–72 millimeters; appendages, ♂, 2; pterostigma, 4.

Habitat.—California, Berlin Museum; Victoria, Vancouver's Island, July, Mr. Crotch; British Columbia, Mr. Crotch; Yellowstone, Hayden's expedition, 1871. The latter ones have the smallest dimensions.

L. forensis imitates strongly *L. pulchella*, a species widely spread and very common everywhere east of the Rocky Mountains; the dark-brown tinge of the tip of all the wings in *L. pulchella*, the smaller size, and other differences, easily separate the two species.

A very similar case of imitation is afforded by the two known species of *Plathemis*, but *P. trimaculata* inhabits only the vast tracts of land east of the Rocky Mountains; *P. subornata*, west of them.

L. pulchella, Hagen, Synop., 153, 8.

Of this well-known species, one male is in the collection of the Hayden expedition of 1871, taken at Ogden, Utah, the only one known to have been found west of the Rocky Mountains. The species is very common in all States east of the Mississippi and in Northern Texas. The southern limit seems to be Mississippi and Georgia.

L. saturata, Hagen, Synop., 152, 4 (*partim*); Uhler, Proc. Acad. Nat. Sci., Phila., 1857, 88, 4.

Stout, reddish-yellow, subvillous; vertical vesicle narrower at the tip, the sides not emarginated; abdomen broad, narrower at the tip; genital parts in the second segment, with the hooks excavated transversely on the tip, both ends equally pointed, the interior end black. Body of the female brownish; sutures of the abdomen black; vulvar lamina widely emarginated; feet reddish-yellow, villose; wings of the male hyaline, the anterior margin and the basal half yellowish rufous; basal space and triangle fuscous, the second costal space of the nodus subfuscous; veins reddish, the transversals in the first and second costal space bright-yellow; wings of the female hyaline, the costal margin, the basal space, and the triangle colored as in the male; pterostigma narrow, long, fulvous; membranula black; 24 antecubitals, 15 postcubitals, 5 discoidal areolets; 3 to 4 veins in the triangle.

Length of the body, 55 millimeters; alar expansion, 90 millimeters; pterostigma, 5 millimeters.

Habitat.—Yellowstone (Professor Hayden's expedition), males and females; Arizona, August 5. This species was first described by Mr. Uhler after a single mutilated individual from the San Diego trip by Dr. T. H. Webb, perhaps not from California. At the time when I published my Synopsis, I knew only a male from the Berlin Museum, from Mexico, and a male and female communicated by Mr. Saussure, collected at Tampico or Cordova, Mexico. The latter pair belongs, as I now perceive, to *L. croceipennis*. As both species are very similar, I give the differences of the latter.

L. croceipennis, De Selys, Ann. Soc. Belg., 17; Bull., 67, 1.—*Lib. saturata*, Hag., Syn. 152, 4 (*partim*).

Very near and similar in colors to *L. saturata*, but a little smaller in size; the base of the wings in the male less colored; the basal space and triangle not fuscous; the veins in the two costal spaces reddish; second hooks in the male with the interior pointed end much longer, black; apical inferior lobe of the second segment of the abdomen larger. These differences are taken by comparing the male from California, described in the Synopsis as *L. saturata*, with De Selys's description, and the males of *L. saturata* from Yellowstone. The following statements are manuscript notes on the specimens, communicated by Mr. Saussure.

The male from Tampico has only the alar expansion 80 millimeters; the head in front and the feet darker; the wings less yellowish, the yellow color on the costal margin not reaching the nodus, going hardly beyond the triangle, which is not darker than the rest. The female from Cordova is a young one, paler mesothoracic crest yellow, a yellow band between the wings; appendages yellow; the eighth segment laterally dilated; vulvar lamina short, elevated, deeply emarginated, thickened on the sides; wings hyaline, costal margin to the principal sector and triangle yellowish.

Habitat.—Cape San Lucas, Lower California, by Xanthus de Vesey; Tampico, Cordova, Mexico, Mr. Saussure. After De Selys's Orizaba, Vera Cruz, Mexico, Guatemala, and perhaps Colombia.

I have no doubt about the identity of the male in my collection with

De Selys's *L. croceipennis*, and the fact that Mr. Uhler at once objected to my former opinion about its identity with his *L. saturata* confirms the statement made above.

L. flavida, Hagen, Synop., 156, 15.

In my last report I mentioned a fragment of this species from the Yellowstone, and I find the same statement in my note-book. The fragment not being at hand, other specimens would be required to corroborate the habitat. This species is known from Pecos River, Western Texas.

L. composita, Hagen, Hayden's Report, 1872, 728.

I have seen a single female only, which is fully described in the report, and provisionally placed in the genus *Mesothemis*, near *M. corrupta*. Considering the large size of *L. composita*, the small, rounded lobe of the prothorax, the enlarged apical segments of the abdomen, and the form of the vulvar lamina, the species should probably be placed in *Libellula* proper.

Habitat.—Yellowstone.

MESOTHEMIS.

M. collocata, Hagen, Synop., 171, 3.

I named this species after a fragment in very bad condition in the Yellowstone Report. The abdomen of a female was in one bottle and the remaining parts of the insect in another; besides this, the Yellowstone collection contained some pressed specimens not fitted for scientific use. I therefore consider my identification somewhat dubious, if I had not received in the mean time two pairs from San Diego, Cal., by Mr. Crotch, which, belonging probably to the same species, confirm my opinion. A full comparison is even now not possible, as the male type of *M. collocata* is a teneral one, and the two males from San Diego very mature; but the females agree exactly with the rudiment from Yellowstone. This species is very near to *M. simplicicollis*, but different in the black superior appendages of the male; the inferior one is yellow, a character not stated in my Synopsis. In the younger female, the appendages are yellowish, but the quadrangular, black, dorsal spot on the segments 4 to 10 is wanting; only the sutures and margins of all segments are black. Though convinced of the rights of the species, more material would be needed for a full scientific description.

M. simplicicollis, Hagen, Synop., 170, 1.

In my last report I mentioned a single female from Ogden, Utah; at present I am more doubtful, the specimen being very imperfect. Probably it belongs to the foregoing species. *M. simplicicollis* is very common everywhere in the Western Territories east of the Rocky Mountains from the northern border to Florida, Cuba, Texas, and Mexico.

No specimen is known from parts west of the Rocky Mountains.

M. illota, Hagen, Synop., 172, 4.

A female in my collection from the Yellowstone, but imperfect, without the head, belongs probably to this species, which is common in California from the Gulf of Georgia to Cape Mendocino and San Diego. The *L. gilva* from Columbia is very similar, perhaps identical.

M. corrupta, Hagen, Synop., 171, 3.

This species is very common in Texas, California, and is discovered in Illinois by Mr. Walsh. There are a few teneral specimens from the foot-hills of Colorado, June 25 to July 6.

M. longipennis, Hagen, Hayden's Report, 1872, 728.

Habitat.—Yellowstone (C. Thomas). A species common everywhere.

DIPLAX.

D. atripes, sp. nov.

Male.—Reddish-brown, subvillous; labium, labrum, and head reddish; front above near the eyes with a large, blackish, transverse band; vertex reddish, large, inflated, smaller at the tip, with the angles not well marked; occiput reddish-brown, villous; eyes behind reddish-brown, with transverse blackish spots. Prothorax reddish, black beneath, the posterior lobe with very long hairs; thorax clothed with brownish hairs, reddish-brown, the mesothoracic crest and the sutures on both sides blackish. Abdomen reddish; ventral margin of segments 7 to 9, with a large black band; appendages reddish, villous, the superiors cylindrical, straight, somewhat thicker for the tip, with about five small teeth; tip shortly-pointed; the inferior a little shorter, triangular, somewhat smaller toward the apex; the tip bent upward, with two small teeth; genital parts of the second segment with the hamule black, bifid, the branches not very widely separated, the external stouter, elongately triangular, a little decurved at the tip; the internal shorter, slender, strongly recurved, acute at the apex; genital lobe oblong, rounded at the tip, interiorly inflated; anterior lamina with a small tooth in the middle of the margin; feet black; the anterior femora pale-brown beneath; wings hyaline, with a faintly smoky tinge; the extreme base flavescent; membranula white; veins reddish-yellow; pterostigma oblong, reddish; 7–8 antecubitals; 7 postcubitals.

Female.—Similar to the male, paler; head yellow; dorsum of the thorax pale-brown, sides yellowish, with three wavy, blackish lines on the sutures; abdomen luteous; a large black band on the ventral margin, and another above it not reaching the apex; segments 7–9, with a black dorsal band in the middle; appendages yellowish, cylindrical; vulvar lamina short, truncated; feet as in ♂; trochanters yellowish; in teneral females all femora above in part yellowish; wings as in ♂, the base larger, flavescent; sometimes also the costal border to the pterostigma.

Length of the body, ♂, 30–38 millimeters; ♀, 31–35 millimeters; alar expansion, ♂, 43–60 millimeters; ♀, 52–58 millimeters; pterostigma $1\frac{1}{2}$–$2\frac{1}{2}$ millimeters.

Habitat.—Yellowstone; some pairs in copula (Mr. Carpenter). This species is nearly related to *D. costifera*, but different by the black color of the feet.

D. decisa, sp. nov.

Similar in shape and colors to *D. vicina*; labium luteous; labrum and head in front yellow; front above deeply canaliculated, discolored; a large black band before the eyes; antennæ black; vertex nearly globular, the anterior angles obtuse, luteous, black around the ocelli; occiput luteous; eyes behind luteous, with two transversal brownish bands; thorax reddish-brown; on the dorsum a brownish tinge, dilated triangularly to the prothorax; abdomen reddish-brown; sutures yellowish, a black, lateral band dilated behind on the ventral margin of segments 3 to 9 and two yellow dorsal spots, nearer to the base; abdomen beneath pale-brown; margin of segments 4 to 7 black; venter black;

appendages reddish, cylindrical, the apex acute, black, recurved beneath, in the middle with a stout triangular tooth, with the apical side straight, the basal side oblique, with 6 small teeth; inferior appendage shorter, ending just after the tooth of the superiors, triangular, but the apical half of equal breadth; the tip a little excised, nearly bifid; genital parts of the second segment with the hamules long, bent at the base, straight, rounded externally, the apex bifid; the external branch stout, triangularly-pointed; the internal of equal length, slender, unguiculated; anterior lamina excised; sheath of the penis orbicular, with a longitudinal impressed furrow; apical lobe of the second segment small, triangularly-pointed; feet black, all trochanters and the anterior femora beneath reddish-yellow; wings hyaline, the extreme base flavescent, membranula whitish, a little cinereous on the margin; veins reddish, the costa and some transversals near the base yellowish; pterostigma oblong, yellow, darker in the middle; 7 antecubitals; 7 postcubitals; 3 discoidal areolets.

Female similar to the male, paler, coloring more luteous; the lateral black bands of the abdomen more enlarged to the tip, no yellow dorsal spots; appendages yellow, slender, cylindrical, the apex acute; vulvar lamina triangular, bifid, the two branches pointed at tip and a little divergent; the femora of the anterior and intermediate feet yellowish beneath.

Length of the body, ♂, 34 millimeters; ♀, 32 millimeters: alar expansion, ♂, 52 millimeters; ♀, 53 millimeters; pterostigma 2 millimeters.

Habitat.—Foot-hills, Colorado; Colorado Mountains, Pacific slope, August 15 to September 6 (Lieutenant Carpenter), several pairs. The species is very similar to *D. vicina*, but differing in the black feet and the genital parts of both sexes. Some fragments of the male from the Yellowstone are a little larger, but probably the same species.

D. pallipes, sp. nov.

Male.—Very similar to *D. decisa*, but larger in size and paler in color, differs in the following characters: no transverse, black band before the eyes; vertex yellow in the middle, brownish on each side; the color of the dorsum of the thorax apparently changed by the alcohol, paler (perhaps greenish), with a triangular, brownish band in the middle, and on each side an ill-defined brownish line, not reaching the sinus; sides of the thorax red in the superior half, some ill-defined paler spots above the legs. Abdomen more slender, sutures brown; no black dorsal or ventral bands, except a dorsal brownish mark on the third and base of the second segment; however, these marks could be produced by the decaying process; on the third and fourth segment an indication of two yellow spots before the apex; venter pale; appendages similar, but the inferior middle tooth of the superiors with the interior surface not oblique, more perpendicular; the apex of the tooth yellow, with the small tooth more pronounced and black; genital parts similar, but the external branch of the hamule excavated exteriorly and cut on the tip; internal branch black; the apical lobe of the second segment narrower, more jointed. Feet more slender, reddish-yellow, a fine black line outside of the femora, not reaching the base, and a finer and shorter one on the tibia near the black spines; joints of the tarsi black at the tip. Wings similar, less flavescent at the base; 8–9 antecubitals; 7–8 postcubitals.

Length of the body, 40 millimeters; alar expansion, 61 millimeters; pterostigma, 2 millimeters.

Habitat.—Foot-hills, Colorado (Lieutenant Carpenter).

D. semicincta, Hagen, Synop., 176, 5.

A fragment of a female similar to my specimens, but the fuscescent color extending upon the anterior wings as far as on the posterior wings. I never saw similarly-colored specimens from the region east of the Rocky Mountains.

Habitat.—Foot hills, Colorado (Lieutenant Carpenter). The species is not rare in the States east of the Mississippi as far south as Maryland.

In the last report (1872, p. 728), I noticed from the Yellowstone region *D. assimilata*, *D. scotica*, and *D. vicina*. The first species is, as I now perceive, my *D. decisa;* the other two are no more at hand.

Subfamily CORDULINA.

EPITHECA.

E. semicircularis, De Selys, Synop. des cordulines, 61, 37.

Dark brassy-green; occiput and labium black; rhinarium and labium pale-yellowish; on each side of the front a large luteous spot, connected sometimes on the lower edge of the front in a narrow luteous band, interrupted in the middle by a small black interval; eyes black behind; thorax dark brassy-green, clothed with long grayish-brown pile before the sinus, sometimes transversally fulvous, sometimes not; the sides with two ill-defined luteous spots; feet entirely black; abdomen brassy-black, a large fulvous spot on each side of the second segment, a smaller one on the third segment (often wanting in the males); segments 4 to 8 with a small fulvous basal spot on each side (always wanting in the Colorado specimens); appendages of the male black, the superiors long, subcylindrical, carinate inferiorly and exteriorly; viewed from above, the basal half is convex, straight, tapering, divergent; the apical half is bent slightly outward, then inward, subexcavated before the pointed end; viewed laterally, the appendages are curved somewhat downward, the apex laminate, the lower edge with a small external basal tooth, beyond the middle a rounded lamella, and between them the internal edge produced in form of a larger rounded lamella. Both lamellae, viewed from above, appear as lateral projections; inferior appendage more than half the length of the superiors, triangular, bluntly-pointed, concave below, recurved, the tip minutely uncinate above; appendages of the female long, stout, cylindrical, black; vulvar lamina half the length of the segment, yellowish, quadrangular, somewhat erect; apical margin rounded, split in the middle; wings hyaline, or with a yellowish tinge (Vancouver Island specimens); costa lined with yellow; extreme base of the hind-wings subfumose; membranula blackish-gray, white at the base; antecubitals, 7–8; postcubitals, 6–7; triangle in some specimens with a transversal vein in one or both hind-wings.

Length of the body, 50–46 millimeters; alar expansion, 80–60 millimeters; pterostigma, $2\frac{1}{2}$ millimeters.

Habitat.—Gulf of Georgia (by Mr. A. Agassiz, the male type described by De Selys), Vancouver Island, in July (Mr. Crotch); Colorado, on Twin Lake and Arcade River, August 1 to 16; Pacific slope, August 16 to September 6 (Lieutenant Carpenter); Ogden, Utah (Mr. C. Thomas). A careful study of the male type in the collection of the museum shows the anterior femora entirely black, not "*presque noirâtre,*" as in De Selys's description. This character is very important as difference from *E. forcipata.* The words of the description, "*Je crois distinguer en dessous une sorte de dent submédiane analogue à ce que l'on voit chez E.*

arctica," are to be struck out, as this appearance was due to some dirt which stuck to the appendages of the typical specimen. The male type and the pair from Vancouver's Island are larger, most of the Colorado specimens show smaller dimensions, and differ as stated above by the abdomen being black, without fulvous basal spots on segments 4–8; this may be due, perhaps, to the action of the alcohol or of some substance added to the alcohol for the better preservation of the specimens. The difference of *E. forcipata* is no longer doubtful after the examination of more specimens, but this species is very nearly related, and differs by the labrum having a brownish spot on each side, by the anterior femora being partly fulvous, by the appendages of the male; the vulvar lamina of the female is the same, split on the apex. Having now carefully compared *E. arctica* of Europe with both species, I am very sure of the specific difference of this species. In *E. arctica*, the split at the apex and the appendages of the male are different.

Subfamily ÆSCHNINA.

ÆSCHNA.

Æ. constricta, Hagen, Synop., 123, 8 (Hayden's Report, 1872, 727).

Habitat.—Yellowstone, common (C. Thomas); foot-hills, Colorado, a male without head. This species is common everywhere east of the Mississippi from Canada to Maryland and west to Wisconsin and British Columbia.

Æ. multicolor, Hagen, Synop., 121, 4 (Hayden's Report, 1872, 727).

Habitat.—Yellowstone (C. Thomas); Vancouver's Island (Mr. Crotch); Upper Missouri, Pecos River, Western Texas, and Cordova, Mexico. A decidedly western species.

Æ. propinqua, Hayden's Report, 727.

Habitat.—Yellowstone, fragments of the male and female; Colorado plains, June 25 to July 5, female. The specimens are not in good condition, but I believe them to belong to the species described by Mr. Scudder from the White Mountains, New Hampshire. In the report of 1872, I did mention one female of the *Æ. eremitica* from Yellowstone; perhaps this female belongs also to *Æ. propinqua*.

Subfamily GOMPHINA.

OPHIOGOMPHUS.

O. severus, sp. nov.

Greenish-yellow; head and mouth parts greenish-yellow, labium and labrum paler; antennæ black; part between the eyes black, forming a transverse black band above the base of the front, excised in the middle; vertex greenish-yellow, flat, the front margin deeply notched, the sides of the vertex cariniform, curved in an exact semicircle around the lateral ocelli; occiput greenish-yellow, straight, fringed with black hairs, a small rounded inflation in the middle of the front side; eyes behind greenish-yellow, with a small, black band along the superior border, beginning near the occiput. Thorax greenish-yellow, an ill-defined, brownish spot on the dorsum each side near the wings; the crest of the sinus not exceeding the bifurcation, black, and an incomplete blackish band on the humeral suture beginning at the wings.

(Three males and two females from Colorado, in alcohol; a single male from Yellowstone, preserved dry, shows the following pattern): dorsum with a broad black band in the middle, following the sinus above and united with a complete black band on the humeral suture. Mesothoracic crest from the bifurcation to the prothorax yellow; a large, ovoid, black spot each side of the dorsum, not confluent with the bands; a black band on the second lateral suture, nearly united by a superior line at the base of the wings with the humeral band; an inferior, incomplete black band on the first suture, ending at the stigma. Abdomen cylindrical, enlarged at the base, and on the seventh to ninth segments greenish-yellow; all the segments each side on the apical half with a large blackish band; the bands are interiorly dilated at the tip, and converging (diverging on the first segment); venter black on segments 3 to 6, orange on the following; in the Yellowstone male, the bands are broader and confluent on the tip; the yellow part between the bands forming a basal hastiform spot; appendages yellow, the superiors about as long as the last segment, short, parallel, stout, trigonal, exteriorly rounded, subincurved, pointed on tip, which is bent outward, beneath somewhat thickened before tip, with numerous small black spines; inferior appendage a little shorter, triangular, bifid to the base, contiguous, the basal half forming an obtuse elevation, the apex recurved with a small black superior tooth; genital parts in the second segment with the first hamule forming a lobe interiorly hollowed; the tip with a semicircular excision, the hind angle of the tip prolonged in a strongly-bent slender black hook; second hamule longer, the tip suddenly narrowed, a little recurved, blackish, cut straight; penis with an inferior tooth on second joint, the last one with two long spines; sheath of the penis hollowed out, four-lobed, the two inner lobes cylindrical, divergent, the outer ones large, flat, semicircular; earlets yellow, large, rounded, on the hind band a series of small, black teeth. The female has the occiput exactly similar to the male, without any posterior teeth; appendages yellow, short, pointed; vulvar lobe triangular, a little shorter than the segment, bifid to the base, contiguous, indented short before the sharply-pointed black tip, which is bent outward; feet yellow, femora an apical superior black band, beginning on the knee, divided anteriorly; beneath with numerous very short black spines; tibiæ black beneath and interiorly or on both sides with a black line and long black spines; tarsi black, all or only the basal joint yellow above; wings hyaline, veins black; the costa and some transversals yellow; pterostigma oblong, a little dilated in the middle, yellowish, darker in the middle, covering nearly three areolets; 11–12 antecubitals, 7–10 postcubitals; 2 discoidal areolets; membranula whitish.

Length of the body, 51 millimeters; alar expansion, 64–68 millimeters; pterostigma, 2½ millimeters.

Habitat.—Colorado (Mr. James Ridings); foot-hills and plains of Colorado. End of September (Lieutenant Carpenter); Fort Garland, Colorado, June 27, South Montana and Yellowstone (Mr. C. Thomas). This is the species given in my last report (p. 726) doubtfully as *G. colubrinus*. This interesting species is very near *O. colubrinus* in the appendages and genital parts of the male, but different in the pattern of color on the head and abdomen and the structure of the occiput in both sexes. *O. colubrinus* is a species rarely to be found in collections; even the female is not yet described. To prevent doubts about the rights of *O. severus*, I give here a description of the female of *O. colubrinus*. I do not possess the male, and my manuscript description of it is still in Europe.

O. colubrinus, Hagen, Synop., 101, 7.

Female.—Greenish-yellow, marked with black; labium luteous, the margins clothed with pale-brownish hairs; median lobe with a broad black band on the anterior margin; lateral lobes and the palpus dusky-brownish; labrum yellow, with a black shining band on the anterior margin and a narrower one at the base; head yellow; rhinarium with a pale, slender, transverse, black line, interrupted in the middle near the base of the labrum; epistoma with an inferior transverse band, and another between the front and the epistoma, a little dilated on the sides, and united near the eyes with the black band above on the base of the front before the antennæ; this band is produced a little in the middle and before each antenna; antennæ and part between the eyes black; vertex black in front, brownish near the occiput, cariniform, excavated above, front margin rounded, notched in the middle, with a deep, curved impression on each side near the margin; the sides of the vertex curved in a semicircle around the lateral ocelli; occiput yellow, straight, with an anterior furrow in the middle, the border with long, black cilia; each side near the furrow a long, sharp spine, yellow at the base, blackish on tip, divergent, the tip gently recurved inside near the base with a sharp tooth, a smaller one after the middle, and a very small one just near the tip; each side behind the eyes just near the occiput and not to be seen in the front view, a stouter black process, cylindrical, somewhat rough and divided by two transverse furrows, blunt at tip; eyes behind yellow, with a large, superior, black band; thorax greenish-yellow, with a large blackish-brown band in the middle, narrowed toward the sinus, and a large blackish band, not reaching the wings, narrowed above and separated only by a slender yellow line from a similar band on the humeral suture, which is narrowed beneath; sinus and mesothoracic crest blackish-brown; sides of the thorax yellow, with a blackish band on the second suture, and an incomplete inferior one on the first suture, ending near the stigma; thorax beneath yellowish; abdomen (not in good condition) yellowish, each side with a dorsal blackish-brown band, and between them yellow, hastiform, large spots, not reaching the apex in segments 5 to 6; smaller, and only basal on segments 7 to 9; segment 10 yellowish, the apical margin blackish; the sides of the segments yellowish; on segment 2 a large blackish spot; venter brownish; appendages wanting; vulvar lobe a little shorter than the segment, triangular, bifid to the base, the lobes rounded, tapering to the tip and convergent, yellowish, the tip black; feet luteous; femora above brownish; tibiæ superiorly paler; femora with shorter, tibiæ with longer black spines; wings hyaline, a little smoky; veins black; pterostigma oblong, pale, brown, covering five areolets; 13–14 anticubitals; 11 postcubitals; 2 discoidal areolets, beginning with three.

Length of the body, 42 millimeters; alar expansion, 60 millimeters; pterostigma, 3 millimeters.

Habitat.—Portneuf, near Quebec, Canada (Mr. Uhler's collection). This female agrees well with the description given in the monograph of the Gomphines, p. 77. I figured in the same work (Pl. 5, No. 1) the occiput of the male, with two small spines behind the eyes. The figure is the same in my original drawings now before me, but in the description the spines, indeed quite extraordinary for a male, are not mentioned. As my manuscripts are still in Europe, I am unable to say more about it. To avoid further mistakes occurring, the very closely-related species *O. rupinsulensis* and *O. mainensis*, united by the latest monographer, Baron De Selys Longchamps, in 1873 and 1874, I prefer to give a full description of both, the more so as both sexes are now before me.

O. rupinsulensis.

Herpetogomphus rupinsulensis, Walsh, Acad. Nat. Sci. Phil., 1862, p. 388, male. Proc. Ent. Soc. Phil., 1863, p. 253.

Male.—Greenish-yellow; labium pale-livid (blue, Walsh), black on the anterior margin and the fore half of the side; lateral lobes pale; labrum pale, with a fuscous basal spot, but little marked on each side; head in front greenish-yellow; antennæ black, apical border of the first joint pale; part between the eyes and front black; the extreme base of the front between the antennæ black; vertex greenish-yellow, cariniform, excavated above, scarcely emarginate, the sides rounded off at the ends, and a smaller carina in a semicircle around the ocelli; occiput straight, scarcely elevated in the middle, yellow, densely ciliated with long, black hairs; eyes livid behind, paler beneath, with a blackish superior spot near the occiput. Thorax greenish-yellow, the mesothoracic crest black just where it bifurcates, and on the end of the sinus near the wings; a brownish band only indicated on each side near the humeral suture, not reaching the wings; a small brown band on the humeral suture; thorax otherwise immaculate except some brownish spots near the feet to the stigma. The colors of the abdomen not well preserved (pale-brown, clouded with brown, Walsh); on the dorsum of the segments a lanceolate, yellowish spot, two black apical spots, and two small transversal lines in the middle; last segment yellowish, rounded; ventral margins of the segments yellowish; venter black, on the four last segments rufous; the abdomen slender, cylindrical, somewhat dilated at the base and much more on segments 7–8; appendages greenish-yellow, with long, pale, dense hairs; superiors about as long as the last segment, very robust, directed downward, approximate at base, conical, a little bent, obtuse at tip, interiorly with a small basal tooth; viewed laterally, with an inferior carina, squarely truncate on tip, and on the terminal half below three irregular rows of small, short, black teeth; inferior about as long and exactly attaining the lower angle of the truncated tips of the superiors, broad, bifid on the apical half, viewed from below and each branch very robust, rounded, divaricate, squarely truncate on tip, viewed laterly strongly incurved, incrassate at base and still more so on tip, which is truncate; genital parts on the second segment with the first hamule black, with a deep, posterior, elliptic excision on tip, the superior angle forming a long, sharp, incurved hook, nearly meeting the opposite angle; the second hamule longer, the basal half thick, pale, cylindrical, the apical half suddenly thinner, black, cylindrical, incurved, and again recurved on tip; sheath of the penis hollowed, four-lobed, the two interior lobes divergent, short, conical, the outer lobes large, rounded on the margin; penis with two small, black, short, incurved spines on tip, and with an inferior tooth on the second joint; earlets yellowish-green, rounded, some small black spines on the inner angle; feet yellowish-green, femora with a broad, brown, anterior band, only near the knee on the four posterior feet, which are more brownish beneath; tibiæ black, with a superior yellow band; tarsi black, on the posterior pair yellow in part above; wings hyaline, slightly flavescent at base; veins black, the costa yellow; pterostigma brown, oblong, surmounting about five cells; membranula cinereous; antecubitals, 13–14; postcubitals, 9–12; two discoidal areolets.

Female.—Similar to the male. Occiput similar, but each side on the border nearer to the eye a short, small, cylindrical, yellow spine, smooth on the tip; a second female has the spine rudimentary; in a third specimen there is none; behind the eyes, each side, near the occiput, a brown, robust, conical process, both convergent. Thorax same as in the male; the brown bands on the dorsum darker, nearly confluent with the antehumeral band in one of the specimens. Abdomen less slender, a little dilated on the tip; colors same as in the male, the dorsal yellow spot on the second segment large; earlets small; appendages yellow, as long as the last segment, conical, sharp, convergent; tubercle between them darker; vulvar lamina yellow, nearly as long as the segment, triangular, bifid a little beyond the apical half, the branches contiguous, rounded, tapering toward the tip, which is bent outward, indented just before. Feet and wings as in the ♂; pterostigma larger.

Length of the body ♂, 52–54 millimeters; ♀ 51 millimeters; alar expansion, ♂, 65–68 millimeters; ♀, 68 millimeters; pterostigma, ♂, 3 millimeters; ♀, 4 millimeters.

Habitat.—Rock Island, Illinois (Mr. Walsh); Upper Wisconsin (Mr. Kennicott); Maine (Dr. Packard and Mr. Uhler). Mr. Walsh saw only one male; the type burned in Chicago was examined by me in 1868, but I took no notes. The description by Mr. Walsh agrees perfectly with the two males from Wisconsin described by me; Mr. Walsh stated (p. 389) that the male has no tooth on the second joint of the penis, but it certainly exists there, and, as I know that Mr. Walsh used lenses of low power only, he may have overlooked it. In the third addition to the *Synopsis des gomphines*, De Selys describes (p. 13) a male from Maine, communicated by Dr. A. S. Packard, and erroneously unites with it *O. mainensis*, as will be seen by the description of this species.

O. MAINENSIS.

O. mainensis, Walsh, Proceed. Ent. Soc. Phil., 1863, p. 255, female.

Male.—Yellowish-green, marked with black; labium paler, the margin black; labrum with a narrow, black, front margin; head before yellowish-green; part between the eyes black, and a large basal black band above on the front; antennæ black, tip of the first joint pale; vertex black, pale at the base and in the middle, cariniform, excavated above, scarcely emarginate, the sides rounded off at ends, and a smaller carina in a semicircle around the ocelli; occiput greenish-yellow, straight, densely ciliated with long black hairs; eyes behind livid, with a black transversal superior spot near the occiput; prothorax black, with small yellowish spots on the middle and each side; thorax greenish yellow, with blackish-brown bands; the middle ones narrowed to the wings, separated by the carina, yellowish to the bifurcation; the laterals large and confluent with the antehumeral, only near the wings divided by the paler suture; margin of the sinus blackish; sides of the thorax greenish-yellow, an incomplete, inferior blackish band, ending at the stigma, and a smaller complete one on the second suture; below pale; abdomen cylindrical, slender, at the base and before the apex dilated, black on all segments, with yellow dorsal spots, enlarged on 1 and 2, hastiform, not reaching the tip on 3 to 5, shorter, more triangular on 6 and 7, short basal and enlarged on tip on 8 and 9, large, transversal, separated from the base on 10; sides of all segments with large, elongated, yellow spots, divided by the suture, reaching the tip only on segments 2 and 8 to 10; ventral margins of segments 8–9 black; dorsal articulations after the sixth segment yellow; venter black, of the last three segments fulvous; appendages yellow; clothed with pale hairs; superiors as long as the last segment, robust, directed downward, approximate at base, with a basal tooth on the inner edge, conical, sharp on tip; viewed laterally very robust, with a basal inferior carina, the apical half dilated, rounded till short before the sharp-pointed tip, with two series of about seven stronger black teeth; the inferior appendage large, much broader than the superiors and of the same length, the apical half divided by a larger semicircular notch; viewed from below the two branches, large, quadrangular, obliquely truncate, the angles sharp; viewed laterally incurved, thicker before the recurved tip, the outer angles forming a large superior tooth; genital parts on the second segment with the first hamule black, a very long, flat lobe, incurved more on tip; indeed, they are similar to *O. rupinsulensis*, the base is broader, and the excision beginning at the base is so large that the superior angle alone exists; second hamule longer, brownish, broad, flat at base, the other part forming a slender, very long lobe, strongly recurved and suddenly again incurved, the apical part straight; sheath of the penis hollowed, ovoid, bifid on tip; the two branches conical, divergent; penis with two short black spines on tip, and an inferior tooth on 2d joint; earlets greenish-yellow, rounded, with a series of black spines on the posterior inner angle; feet black; femora somewhat villous, with very short spines, the four anteriors with a greenish band on the inner side; wings hyaline; veins black; costa yellow; pterostigma oblong, blackish-brown, covering 3 (or 5) cells; 2 discoidal areolets; 12–13 antecubitals; 9 postcubitals; membranula very small, whitish.

Female (type described by Mr. Walsh). More adult; the labium brownish-black, with a yellowish, basal spot; lateral lobes blackish on the inner border and tip; vertex blackish, with a rounded, yellow, middle spot and a yellow dot on each side; occiput inflated, ciliated above, emarginated behind, and on each side with a rounded tubercle; the superior edge rounded in the middle with two, but little separated, conical processes, ending in long, sharp, strongly incurved spines, converging so as almost to touch at their extreme black tips; eyes behind black, with a large, inferior, yellow spot, divided in the middle; thorax as in the male, the lateral bands on the dorsum separated from the antehumeral by a narrow, yellowish band, nearly confluent above; an accidental black spot on the left side near the sinus; abdomen stouter, more clavate on tip; dorsal spots as in male, none on the three last segments; appendages about as long as the tenth segment, yellow, conical, sharp; lobe between obtuse, yellow; vulvar lamina yellow, nearly as long as the segment, oblong, bifid on the apical half, a little broader before an apical exterior indention, the tips sharpened, bent outward; feet as in ♂, the posterior femora with a greenish spot before the tip; wings as in the male; costæ black, but near the base the formerly yellow color is visible; pterostigma a little longer, covering 5–6 areoles; 14–15 antecubitals; 13 postcubitals.

Length of body, 46 millimeters; alar expansion, 56–60 millimeters; pterostigma $2\frac{2}{3}$—3 millimeters.

Habitat.—Maine, by Dr. Packard; I have seen only one pair; the female is the type of Mr. Walsh, in the collection of the Peabody Academy, in Salem, Mass.; the male, in the collection of Mr. Uhler, Baltimore, Md. Both were collected by Dr. Packard at the same locality, and there is no doubt that both belong to the same species. A translation of Walsh's description is given by De Selys's in his second addition to *Synopsis of the Gomphines* (p. 45), but the vertex and occiput were not exactly accurate in Walsh's text. In the third addition (p. 14), De Selys unites the female with *O. rupinsulensis.* As I have described now both species in both sexes, this is apparently erroneous. *O. bison*, from California, is described by De Selys in the appendix to the third addition (1874, p. 51) after an incomplete female. I have not seen the type; the only difference from *O. mainensis* consists, according to the description, in the spines of the occiput being divergent instead of convergent. More specimens of both species are necessary to show the constancy of this character.

HERPETOGOMPHUS.

H. compositus, Hagen, Synop., 99, 1.

A teneral female, in very bad condition, quoted in my last report (p. 727) as probably belonging to *H. viperinus*, a species never seen by me, has again been carefully studied, and I am now of the opinion that it belongs to *H. compositus*, described by me after a single female from Texas. I received a male from Northern Texas, Dallas, by Mr. Boll, agreeing with De Selys's description in the third addition (p. 12), but the very abrupt and intensive yellow color at the base of the wings is not marked. The female from Yellowstone is larger; length, 54 millimeters; alar expansion, 68 millimeters; and the first lateral brown band of the thorax not well defined, ending shortly after the stigma. It will be more prudent to retain this female as *E. compositus* until the difference is better established by the comparison of more specimens, the more as the pair described by De Selys from Oregon is nearly as large as the Yellowstone one. De Selys adds: "*Je ne vois pas de renflement antérieur d'occiput chez la femelle*," but it exists not in the female type.

Habitat.—Western Texas, Pecos River, the female type in my collection; Dallas, Tex., Boll, one male; Yellowstone, a female from Hayden's expedition, 1872; a pair from Oregon by Lord Walsingham.

GOMPHUS.

G. olivaceus, De Selys's third addition Synop. des Gomphines, p. 22.

Female (in alcohol).—Pale greenish-yellow; head entirely greenish-yellow, labium paler; a transverse brownish band, interrupted in the middle above at the base of the front; antennæ blackish; the two basal joints greenish-yellow; part between the vertex and front black, with some yellowish dots; vertex flat, depressed, yellow, each side behind the ocelli somewhat inflated, carinated around the lateral ocelli; occiput yellow, straight, with short, black cilia, and with a series of fine, black teeth; eyes behind yellow, with a superior black spot near the occiput; prothorax yellow; on the disk each side with a larger brownish spot; thorax yellow; dorsum each side near the yellow crista with a brown band, narrowed above, not reaching the sinus; each side a large, incurved, brown band, separated by a smaller yellow band from the brown line on the humeral suture; sinus brownish to the bifurcation; sides and below yellow; abdomen large, cylindrical, yellowish, each side a dorsal, black, large band, indented inside, not reaching the base on segments 4–5 (the rest is lost by accident, but has been examined before; it was colored in a similar way, the appendages yellow, the vulvar lamina short, broad, notched in the middle); femora yellow, with a short, black, apical band above, and below with numerous very short, black spines; tibiæ and tarsi black; wings hyaline; veins black; costa yellow; pterostigma oblong, yellow, with 4 cells below; 14–15 antecubitals, 10–11 postcubitals; 2 discoidal areolets; membranula whitish.

Length of the body, 54 millimeters; alar expansion, 72 millimeters; pterostigma, 4 millimeters.

Habitat.—Humboldt River, Nebraska, Mr. Garman; California, Lord Walsingham, or perhaps, as the foregoing species, from Oregon.

The described female, besides being preserved in alcohol, is a teneral one; De Selys's specimen is more adult. After a careful comparison, I find his description agreeing very well with the female before me, except the "*point huméral supérior rond*," but such a spot is sometimes only occasional or perhaps belongs to the adult specimen. The length of the femur, 8 millimeters, is the same. In comparing the female with *G. plagiatus* male, I believe them to be different species.

Mr. Garman collected in Utah, Great Salt Lake, the nympha-skin of a *Gomphus*. The skin is 31 millimeters long, and similar to the species described by Mr. L. Cabot in his monograph (p. 3, No. 4).

Subfamily CALOPTERYGINA.

HÈTÆRINA.

H. Californica, Hagen, Syn., 59, 2.

In my last report (p. 729), I quoted some fragments of males from Yellowstone. It would be necessary to see more specimens in better condition, but the fragments belong, doubtless, to the genus *Hetærina*, and very probably to *H. Californica*. By some error in the report, the species is placed between the insects not belonging to the *Odonata*.

Subfamily AGRIONINA.

LESTES.

L. disjuncta, De Selys, Synop. lestes, 18, 10.

Specimens in bad condition from Yellowstone are quoted in my last report (p. 727). This is a decided northern species.

L. congener, Hag., Syn., 67, 5.

A male from Yellowstone is quoted in my last report (p. 727); another from foot-hill, Colorado, by Mr. Carpenter.

L. hamata, (*L. forcipata* Hagen, Syn., 71, 13).

Some specimens from Colorado Mountains, Pacific slope, belong probably here; but all the *Lestes*, as, in general, all *Agrionina* collected by the expedition, are in worse condition, and unfit to be determined with certainty. For this species I believe the determination sure, but males and females are present only in broken pieces.

ARGIA.

One species from Yellowstone and Snake River, Idaho, quoted in my last report, belonging to the group of *A. moësta*.

AGRION.

One species from foot-hills, Colorado, group of *A. prævarum*.

ISCHNURA.

One species from foot-hills, Colorado, group of *I. iners*. All the specimens being broken more or less, a scientific description would be impossible and even objectionable.

NEUROPTERA.

Family HEMEROBINA.

POLYSTŒCHOTES.

P. punctatus, Hagen, Syn., 206, 1.

The species is very common everywhere in the United States, from the Gulf of Mexico to British America and from the Atlantic to the Pacific. Curiously enough, the previous states of this beautiful and very interesting species are still unknown. From analogy, and even from the fact that the larva of this large and everywhere common species was not yet observed by American entomologists, it is safe to presume that the larva will be aquatic, with habits similar to the larva of *Osmylus*, and must be looked for in the months of April and May, perhaps even in June, as the imago appears in the middle of July, and continues until the arrival of the cold weather. I saw a large cluster of eggs on a leaf in the collection of Mr. A. Lintner in Albany, N. Y., probably belonging to this species.

Habitat.—Yellowstone (Mr. C. Thomas); Colorado Mountains, August 29, foot-hills, September (Lieutenant Carpenter); Twin Lake, August.

The following *Hemerobinæ* are unfit for scientific purposes, having been collected in alcohol or put together in papers with *Lepidoptera*, and covered throughout with lepidopterous scales; the last ones cannot be cleaned without being more or less spoiled.

MICROMUS.

One specimen, related to *M. sobrius*, from foot-hills, Colorado.

HEMEROBIUS.

One specimen, from Fair Play, July 11, related to *H. alternatus*, and two other species, Colorado Mountains, July; entirely unfit for determination, except to say that there are two different species.

CHRYSOPA.

There are three species, one from the Snake River, Idaho (Mr. C. Thomas), belonging to the group of *C. oculata*, probably new; and two from Colorado plains, belonging to the groups of *C. nigricornis* and *C. externa*. A description of new species based upon single specimens in this very difficult genus is scientifically objectionable, especially when the single specimens are imperfect.

MYRMELEON.

M. diversus, Hagen, Report for 1872, p. 729.

Habitat.—Yellowstone and Snake River, Idaho.

Family SIALINA.

CORYDALIS.

A not full-grown larva from Chiquili, Colo. (Professor Newberry). The larva differs from those of *C. cornuta* by a longer prothorax, luteous legs, and the mark of the head. There are now six species known from Texas and Mexico; of course, it is still impossible to ascertain the species of the larva from Colorado, but probably it may belong to one of the three Texan species.

RAPHIDIA.

The genus *Raphidia* belongs to the interesting class of genera which are represented largely in Europe and Asia, are entirely wanting in the fauna of North America east of the Rocky Mountains, but are represented again in California, and in the other vast tracts of land west of the Rocky Mountains. I have seen only two specimens, one from Ogden, Utah (C. Thomas), the other from Rio Grande, Colorado, June 13 (Lieutenant Wheeler's expedition). Both belong to different species, and to *Raphidia* proper (not to *Inocellia*); both being preserved in alcohol, I am not able to give any better information, the more so as the genus *Raphidia* contains the most difficult species for determination.

Family PHRYGANINA.

LEMNEPHILUS.

There is a species from Colorado Mountains, August, by Mr. Carpenter, in broken alcoholic specimens. It belongs to the group of *L. rhombicus*, and has nearly its size.

GONIOTAULIUS.

A very imperfect female from Colorado Mountains, August; it belongs to the group of *G. griseus*.

STENOPHYLAX.

St. divergens, Hagen, Syn., 255, 5.

Fragments only from the Colorado Mountains, August. Perhaps some of them belong to a different but related species.

PLATYPHYLAX.

P. designatus, Hagen, Syn., 269, 6.

Fragments sp. nov. from foot-hills, Colorado, September.

P. atripes, sp. nov.

SYN. *Stathmophorus*, spem., Hagen's Sixth Annual Report, by Professor Hayden, 1873, 729.

Pitchy-black above, orange-colored beneath; antennæ stout, the inner edge orange and serrate; head before the antennæ orange, clothed with orange hairs; palpi orange; head above clothed with black and orange hairs; ocelli very large and prominent; thorax and prothorax tightly clothed with pale hairs, and with longer black hairs, pale on tip; anterior wings large, the apex parabolic, cinereous, somewhat shining; the veins pitchy-black and very distinct; costal margin and thyridium pale; the membrane throughout, with the exception of the costal and dorsal margins, distinctly granulated, sparingly covered with very small orange hairs (perhaps the clothing is spoiled); apical cells large, the first and third longer and pointed as well as the fifth, the second and fourth cut straight; all spaces and cells paler in the middle; posterior wings of the same color, without granulations and orange hairs; first apical cell shorter than the third, the others similar; feet strong, pitchy-black; femora bright-orange; the four anterior tibiæ and tarsi brown interiorly; spurs 1, 2, 2, yellow, long; tibiæ and tarsi with strong black spines; abdomen pitchy-black above, orange beneath.

Male.—The upper margin of the last segment is cut off straight; appendages orange; the superiors small, flattened, straight, subconvergent lobes, rounded on tip, with some small yellow hairs beneath; between them a shorter triangular penis-cover, carinated above; intermediates very small, short, cylindrical, the tip suddenly enlarged, rounded; inferiors large, much longer than the superiors, broad, separated below by a short, ovoid, ventral lobe, concave inside; the margin after a small excision produced in a long, band-shaped, narrow process, incurved, and pointed on tip; perhaps the process is moveable; the base sparingly clothed with brown hairs; tip of penis visible; two thin penis-sheaths, with some bristles on tip.

Female.—Abdomen blunt on tip; anal valves triangular; vulvar lobe not well visible, perhaps trilobate.

Length, with the wings, 26 millimeters; expansion of the anterior wings, 51 millimeters.

Locality.—One pair from Colorado Mountains, in August. Here belongs the badly-preserved male from Yellowstone, referred to in the sixth report as *Stathmophorus* related to *St. Argus.*

This interesting species is the largest known for North America, differing from all others by the very large ocelli. The species is very similar to *St. Argus* in sp. nov. size and shape, and even more to *St. gilvipes.*

Stenophylax gilvipes, sp. nov.

This species recalls *Pl. atripes* in size, shape, and color in the most extraordinary manner. Nevertheless, it is to be recognized by the entirely yellow legs and 1, 3, 4 spurs; orange-colored, head and thorax pitchy-black above; head before the antennæ orange, clothed with orange hairs, palpi orange; antennæ stout, pitchy-black, serrated beneath, and there the tip of the joints brownish; basal joint orange beneath; head and thorax above clothed with grayish and some black hairs; ocelli large, prominent; thorax beneath tightly clothed with white hairs; anterior wings large, the apex parabolic, ash-gray, somewhat shining; the veins pitchy-black and margined everywhere with black, very distinct; costal margin pale in the middle, blackish at both ends; thyridium and arculus pale; the membranes, excepting the costal and dorsal margins, distinctly granulated; from each granulation springs a small, decumbent, orange hair; apical cells of the same breadth; the first, third, and fifth pointed, somewhat longer; posterior wings of the same color, without granulations and hairs; veins less distinct; the costal margin pale throughout; apical cells similar; feet dull-yellow; spurs 1, 3, 4, yellow, long; tibiæ and tarsi with long, black spines; abdomen orange.

Male.—The upper margin of the last abdominal segment cut off straight; appendages orange, sparingly clothed with longer yellow hairs; superiors short, flattened, straight, convergent lobes, rounded on tip, and visibly larger than in *Pl. atripes;* between them a shorter bifid penis-cover; intermediates just below the superiors, shorter, cylindrical; inferiors, large, longer than the superiors, broad, widely separated by a short, ovoid, ventral lobe, concave inside, produced externally in a long, triangular process, incurved, and pointed on tip; the interior part incurved in the same way and pointed on tip.

Length, with the wings, 27 millimeters; expansion of the anterior wings, 52 millimeters.

Locality.—Quesnel Lake, British Columbia, August 27 (Mr. Crotch). The extraordinary resemblance of *St. gilvipes* with *Pl. atripes* is mentioned above; the described characters prove nevertheless the difference of the two species.

RHYACOPHILA.

Two specimens in very poor condition from Long Peak and Divide, June 3, Colorado, belong to this genus. The species is probably new, but the specimens are not fit for a description.

Besides the described imagos, a number of Phryganid cases, sometimes with the larvæ in alcohol, were collected. The previous stages of the *Phryganidæ* not being well enough known to determine them specifically, I will only enumerate the groups to which they belong. There are from the plains, July 1 to September 19, cases belonging to *Limnephilidæ*, probably to *Limnephilus*, *Stenophylax*, *Goniotaulius*, *Hallesus*, and some to *Phryganea* proper.

From Little and Big Thompson, Este's Park, May, cases belonging to *Phryganea*, *Limnephilus*, *Hallesus*.

From foot-hills and mountains, July 1–19, cases belonging to *Phryganea*, *Limnephilus*, *Stenophylax*.

Besides those, I have before me from Colorado, from South Park, Roaring Fork, and Fair Play, cases belonging to *Limnephilidæ*, *Mystacidæ*, and *Rhyacophilidæ*.

List of the described species.

The species without numbers were introduced in the present report merely for the sake of comparison with other described species. The occurrence of some of them in the territory embraced by the present report is, however, very probable.

PSEUDONEUROPTERA.

Family TERMITINA.

TERMOPSIS.

1. *T. angusticollis*, var. *Nevadensis*, Truckee, Nevada; the typical species from British Columbia, through California and Louisiana.

—. *T. occidentis*, California; west coast of Central America.

Family PERLINA.

PTERONARCYS.

2. *Pt. californica*, Washington Territory; California; Utah; San Luis Valley, Colorado.
3. *Pt. regularis*, Truckee, Nevada.
4. *Pt. badia*, Bridger Basin, Wyoming; Cache Valley, Utah; Colorado Mountains.

ACRONEURIA.

5. A. *abnormis*, occurs from British America to Georgia, and perhaps Mexico; South Montana; Snake River, Idaho; Eagle River, Colorado.

DICTYOPTERYX.

6. *D. signata*, foot-hills of Colorado, and mountains on the Pacific slope.

ISOGENUS.

7. *I. elongátus*, foot-hills, Colorado; Ogden, Utah.
8. *I. colubrinus*, Snake River, Idaho.

PERLA.

9. *P. sobria*, Colorado Mountains, Pacific slope.
10. *P. ebria*, Colorado Mountains, Pacific slope.
11. *P.* (?) (species not described), from the same locality.

CHLOROPERLA.

12. *Chl.* (?) (species not recorded), foot-hills, Colorado.

Family EPHEMIRINA.

EPHEMERA.

13. *E. compar*, foot-hills, Colorado.
—. *E. decora*, west of the Mississippi down to Virginia.
—. *E. guttulata*, New York.
—. *E. natata*, Canada; Illinois; Maine.

HEPTAGENIA.

14. *H. brunnea*, Truckee, Nevada.
15. *H. pudica*, foot-hills, Colorado; Washington, D. C.

LEPTOPHLEBIA.

16. *L. pallipes*, Truckee, Nevada.

Family ODONATA.

Subfamily *Libellulina*.

LIBELLULA.

17. *L.* 4 4-*maculata*, Snake River, Idaho; Ogden, Utah; Bridger basin, Wyoming.
18. *L. nodisticta*, Yellowstone; Mexico.
19. *L. forensis*, Yellowstone; California; British Columbia.
20. *L. pulchella*, Ogden, Utah; common everywhere west of the Mississippi.
21. *L. saturata*, Yellowstone; Mexico; Arizona.
—. *L. croceipennis*, California; Mexico.
22. *L. flavida*, Yellowstone; Texas.
23. *L. composita*, Yellowstone.

MESOTHEMIS.

24. *M. collocata*, Yellowstone; California.
25. *M. simplicicollis*, Ogden, Utah; everywhere east of the Rocky Mountains.
26. *M. corrupta*, foot-hills, Colorado; California; Texas; Illinois.
27. *M. illota*, Yellowstone; California.

DIPLAX.

28. *D. atripes*, Yellowstone.
29. *D. decisa*, foot-hills of the Colorado mountains, Pacific slope.
30. *D. pallipes*, foot-hills of Colorado.
31. *D. semicincta*, foot-hills of Colorado; east of the Mississippi, not rare.

Subfamily *Cordulina.*

EPITHECA.

32. *E. semicircularis*, Twin Lake, Colorado; Arcade River and Pacific slope of mountains, Colorado; Ogden, Utah; Vancouver's Island and Gulf of Georgia.

Subfamily *Æschn.na.*

ÆSCHNA.

33. *Æ. constricta*, Yellowstone; foot-hills of Colorado; common everywhere east of the Mississippi.
34. *Æ. multicolor*, Yellowstone; Vancouver's Island; Upper Missouri; Texas; Mexico.
35. *Æ. propingus*, Yellowstone; Colorado plains.

Subfamily *Gomphina.*

OPHIOGOMPHUS.

36. *O. severus*, foot-hills and plains; Fort Garland, Col.
—. *O. colubrinus*, Canada, Quebec.
—. *O. rupinsulensis*, Illinois; Upper Wisconsin; Maine.
—. *O. mainensis*, Maine.

HERPETOGOMHUS.

37. *H. compositus*, Yellowstone; Oregon; Texas.

GOMPHUS.

38. *G. olivaceus*, Humboldt River, Nebraska; California.

Subfamily *Calopterygina.*

HETÆRINA.

39. *H. californica*, Yellowstone; California.

Subfamily *Agrionina.*

LESTES.

40. *L. disjuncta*, Yellowstone.
41. *L. congener*, Yellowstone; foot-hills of Colorado.
42. *L. hamata*, Pacific slope of Colorado Mountains.

ARGIA.

43. *A.*, spec. (?), (group of *A. moësta*), Yellowstone.

AGRION.

44. *A.*, spec. (?), (group of *A. prævarum*), foot-hills of Colorado.

ISCHNURA.

45. *I.*, spec. (?), (group of *I. iners*), foot-hills of Colorado.

NEUROPTERA.

Family HEMEROBINA.

POLYSTŒCHOTES.

46. *P. punctatus*, Yellowstone; foot-hills and Twin Lakes, Colorado.

MICROMUS.

47. *M.*, spec. (?), (group of *M. sobrius*), foot-hills of Colorado.

HEMEROBIUS.

48. *H.*, spec. (?), (group of *H. alternatus*), Fair Play, Col.

CHRYSOPA.

49. *Chr.*, spec. (?), (group of *Chr. oculata*), Snake River, Idaho.
50. *Chr.*, spec. (?), (group of *Chr. nigricornus*), Colorado plains.
51. *Chr.*, spec. (?), (group of *Chr. externa*), Colorado plains.

MYRMELEON.

52. *M. diversus*, Yellowstone.
53. *M. nigrocintus*, larva, Montana.

Family SIALINA.

CORYDALIS.

54. *C.*, spec. (?), larva, Chiquili, Col.

RAPHIDIA.

55. *R.*, spec. (?), Ogden, Utah.
56. *R.*, spec. (?), Rio Grande, Colorado.

Family PHRYGANINA.

LIMNEPHILUS.

57. *L.* spec. (?), (group of *L. rhombicus*), Colorado mountains.

GONIOTAULIUS.

58. *G.* spec. (?), (group of *G. griseus*), Colorado mountains.

STENOPHYLAX.

59. *St. divergens*, Colorado mountains.
—. *St. gilvipes*, British Columbia.

PLATYPHYLAX.

61. *P. designatus*, foot-hills of Colorado.
62. *P. atripes*, Colorado mountains; Yellowstone.

RHYAROPHILA.

63. *R.*, spec. (?), Long Peak and divide, Colorado.

FAUNA OF COLORADO.

The fauna of Colorado is represented by 36 species.

PERLINA.

Pteronarcys californica.
badia.
Acroneuria abnormis.
Dictyopteryx signata.
Isogenus elongatus.
Perla sobria.
ebria.
spec.
Chloroperla, spec.

EPHEMERINA.

Ephemera compar.
Heptagenia pudica.

ODONATA.

Mesothemis corrupta.
Diplax decisa.
pallipes.
semicincta.
Epitheca semicircularis.
Æschna constricta.
Æschna propinqua.
Ophiogomphus severus.
Lestes congener.
hamata.
Agrion, spec.
Ischnura, spec.

HEMEROBINA.

Polystœchotes punctatus.	Chrysopa, spec.
Micromus, spec.	spec. (?)
Hemerobius, spec.	

SIALINA.

Corydalis, spec.	Raphidia, spec.

PHRYGANINA.

Limnephilus, spec.	Platyphylax atripes.
Goniotaulius, spec.	designatus.
Stenophylax, divergens.	Rhyacophila, spec.

About the geographical distribution of the 36 species from Colorado, only a few general remarks may be here given. Of the enumerated species, 13 are represented by specimens in poor condition, only fit for the determination of the genus, and even the whole number of 36 species is evidently only a small fragment of the fauna.

There are 11 species, with a decided alpine character, from the mountains, Twin Lakes, and Fair Play, viz: *Pter. badia*, *Perla sobria*, *ebria*, sp. n., *Epith. semicircularis*, *Polyst. punctatus*, *Hemerob.* (spec.,) *Limneph.* (spec.,) *Goniot.* (spec.,) *Rhyac.* (spec.,) *Stenoph. divergens.* One of them, *Polyst. punctatus*, occurs everywhere in the United States, the previous stages probably living in the water; *Epith. semicircularis* is a decided alpine species, imitating the *Epith. arctica* from Europe, occurring in Lapland and Switzerland; *Stenoph. divergens* is a northern species, and perhaps the only one to be found also east of the Rocky Mountains.

From the Pacific slope there are 8 species, viz: *P. californica*, *Dictyopt. signata*, *Dipl. decisa*, *Epith. semicircularis*, *Lest. hamata*, *Coryd. larva*, *Raphidia* (spec). Only *Lest. hamata* lives also east of the Rocky Mountains. The genus *Raphidia* is decidedly a western genus, reaching as eastern limit Colorado. *Epithec. semicircularis* goes to Vancouver's Island, and perhaps more to the north. It is interesting to remark that this species is imitated in the northeast by *Epith. forcipata*, going not farther to the south than the White Mountains, New Hampshire.

The eastern slope foot-hills, Fort Garland, and plains give 20 species; only one of them, *Mesoth. corrupta*, is a decidedly western species, but going east of the Rocky Mountains as far as the Mississippi. Some of them, *Æschna constricta* and *propinqua*, seem to have their western limits much farther than in Colorado.

The species mentioned in my last report about the Yellowstone fauna were again examined by me, and some species better determined. So far as known, the fauna has a decidedly western character. From Utah, Wyoming, Idaho, and Nevada there are only a few species, which do not allow any general conclusions. Except some common everywhere, they seem all to belong to the western fauna.

REPORT ON THE MYRIOPODS COLLECTED BY LIEUT. W. L. CARPENTER, IN 1873, IN COLORADO.

By A. S. Packard, Jr., M. D.

MYRIOPODA.

Lithobius, n. sp. (?)—Five specimens from Colorado, collected by Lieutenant Carpenter, indicate a new species, differing from *L. Americanus*, Newport, in the antennæ being longer, though with fewer joints, averaging between 24 and 25; the joints being long and gradually diminishing in length to the end, while in *L. Americanus* the three basal segments are long (though shorter than in the Colorado form), and the segments beyond are very short and crowded; they are much less finely pilose. The labium is much narrower, with from four (young) to twelve teeth (adult). The entire head is slightly longer and narrower, while the body has the same proportions as in *L. Americanus*; the pits on the coxæ are much the same, and the spines on the legs not different. Length, 0.88 inch. It is very different from a Californian species received from Goose Lake, Siskiyou County, through Mr. Holleman, but agrees perfectly with an undescribed species (not *L. paucidens*, Wood) from San Francisco, Cal. (H. Edwards), in the Museum of the Peabody Academy of Science.

I forbear to name it, until more specimens are received both from the Rocky Mountains and the Pacific States. It occurred at Camp 1, May 23, and Elbert Peak, above 12,000 feet elevation, and on the route from Fair Play to Twin Lakes (Lieutenant Carpenter).

Geophilus, n. sp. (?)—Two specimens of a species probably allied to *G. brevicornis*, Wood, were collected by Lieutenant Carpenter between Long's and James's Peaks and between Fair Play and Twin Lakes, Colorado. It is certainly neither of the other species noticed by Wood. It is closely allied to an undescribed species from Goose Lake, Cal. (J. Holleman), but differs chiefly in the longer antennæ.

Julus, n. sp.—Several specimens of a new species were collected by Lieutenant Carpenter on the foot-hills and plains of Colorado, September 20 to October 4. It has 53 segments, exclusive of the head and anal segment; chestnut-brown, with the lateral spots unusually well marked, the dorsal stripe well marked, and the antennæ scarcely clavate. The mucro is very short and blunt. In color and general appearance, it is closely allied to *J. impressus*, Say. I should not however feel justified in naming and describing it until larger collections of the *Juli* of the Rocky Mountains and California have been received, as it is also closely allied to a Californian species received from Mr. H. Edwards, and may prove identical.

It seems probable, from the facts presented above, that the myriopodous fauna of Colorado is nearly identical with that of the Pacific States, and it is useless to study the fauna of Colorado without extensive material from California and Oregon in a group where there is so much specific variation as in the Myriopods.

REPORT ON THE AMPHIPOD CRUSTACEANS.

By S. I. Smith.

HYALELLA, *genus nov.*

First pair of maxillæ with rudimentary, very short, and uniarticulate palpi. Palpus of the maxillipeds (Fig. 5) composed of five segments, the terminal segment being slender and styliform, and the penultimate longer than broad. Antennulæ, antennæ, and thoracic legs much as in *Hyale*. Telson short, stout, and entire.

HYALELLA DENTATA, *sp. nov.* (Plate I, Figs. 3–6.)

Body slightly compressed. First and second segments of the abdomen with the dorsal margin produced posteriorly into a well-marked spiniform tooth. Eyes nearly round, about equal in diameter to the thickness of the proximal segment of the peduncle of the antennula. Peduncle of the antennula about as long as the head; the flagellum a little longer than the peduncle, and composed of about seven to nine segments. Antenna somewhat longer than the antennula; the two distal segments of the peduncle elongated and nearly equal; the flagellum usually but little longer than the flagellum of the antennula, and composed of about eight to twelve segments.

First pair of thoracic legs (Fig. 6) small and slender; the palmary margin of the propodus transverse, nearly straight, and armed with a small tooth at the inferior posterior angle; the dactylus very strongly curved, and its tip closing behind the inferior posterior angle of the propodus. Second pair of legs, in the male (Fig. 3, terminal portion), very large; carpus projecting into a process along the posterior side of the propodus; propodus very stout, about as long as the epimeron, and a little longer than broad, its palmary margin strongly oblique, a little arcuate, with an abrupt notch near the middle, and two slight emarginations near the posterior inferior angle; the dactylus stout and strongly curved. In the young males, the palmary margin of the propodus of the second pair of legs (Fig. 4) is less oblique, and the emarginations of the edge nearly obsolete, and the dactylus is much less curved. In the female, the second pair of legs is weak and slender, and the carpus and hand elongated and narrow; the propodus not broader than the merus, more than twice as long as broad, the posterior inferior angle produced distally, so that the nearly straight prehensile portion of the palmary margin forms less than a right angle with the posterior margin; the dactylus slightly curved and fitting closely the palmary margin. Seventh pair of legs only slightly longer than the sixth, and with the basis broad and its posterior margin serrate, as it is also in the fifth and sixth pairs.

The inferior posterior angles of the first three segments of the abdomen a little less than right-angled, but not produced. First pair of caudal stylets considerably longer than the second. Third pair short, the basal segment not reaching by the basal segments of the second pair, nearly as broad as long, and armed on the outside, at the distal extremity, with three or four stout spines; the terminal segment nearly as long as the basal, slender, tapering, and furnished with a few slender setæ at the tip. Telson stout, as long as broad; the posterior margin rounded and furnished each side with a slender seta.

Length from front of head to tip of telson, 3.5^{mm} to 5.8^{mm}.

Colorado, 1873; Carpenter, collector.

It also occurs in Norway, Maine (S. I. Smith); Salem, Mass. (Caleb Cooke); New Haven, Conn., in small ponds of stagnant water (Professor Verrill, S. I. Smith); Madison, Wis. (Professor Verrill); Madeline Island, Lake Superior (J. W. Milner); West Fork of the Desmoines River, Humboldt, Iowa (Caleb Cooke); Lake Raymond, Nebraska (T. M. Prudden and O. Harger); Birdwood Creek, Nebraska (O. Harger); The Dalles, Oregon (O. Harger).

HYALELLA INERMIS, *sp. nov.* (Plate I, Figs. 1–2.)

Closely allied to the last species, but wholly without teeth upon the dorsal margin of any of the abdominal segments. Two specimens, male and female, give the following additional characters:

Male: Antennula reaching to the middle of the flagellum of the antenna; ultimate segment of the peduncle fully as long as the penultimate; flagellum considerably longer than the peduncle, and composed of eight articulations. Flagellum of the antenna much longer than the peduncle, or than the flagellum of the antennula. First pair of thoracic legs almost exactly as in the last species. The second pair of thoracic legs (Fig. 2, terminal portion) are much smaller in proportion than in the last species; the palmary margin is transverse, nearly straight, and wholly without an emargination in the middle; the dactylus slightly curved and terminating in an acute horny tip. The remaining thoracic legs, the caudal stylets, and telson as in the last species, or, if differing at all, only very slightly.

The second pair of thoracic legs are very different from those of the adult males of *H. dentata*, but resemble much more those of the young males of that species (Fig. 4), and it is possible that, in our single specimen, they are reproduced appendages, and not fully developed. This seems quite improbable, however. The proportional size and other differences are well shown in Figs. 2, 3, and 4, which are all enlarged the same amount.

The female (Fig. 1) differs very little from the female of *H. dentata*, except in the absence of dorsal teeth upon the abdomen and in the same, or nearly the same, slight differences in the antennulæ and antennæ, which seem to characterize the male.

Length from front of head to tip of telson, male, 5.5^{mm}; female, 6.0^{mm}.

Colorado, 1873; Carpenter, collector.

GAMMARUS LIMNÆUS. (Plate II, Figs. 13–14.)

Gammarus lacustris Smith, American Journal of Science, III, vol. ii, p. 453, 1871; and Preliminary Report on Dredging in Lake Superior, in Report of the Chief of Engineers, 1871, p. 1023, 1871.

Colorado, 1873; Carpenter, collector. Cool Spring, Fire-Hole Basin (No. 224). Lake near Long's Peak; elevation, 9,000 feet; June 1, 1873.

The first and second pairs of thoracic legs are quite characteristic of this species. The palmary margin of the first pair, in the male (Fig. 13), is slightly convex and continuous with the posterior margin; has a narrow lamellar edge, and is armed with a few long hairs and usually two long, obtuse spines near the middle of the margin, and three or four smaller ones near the tip of the closed dactylus. In the female, the propodus is considerably smaller and shorter in proportion than in the male;

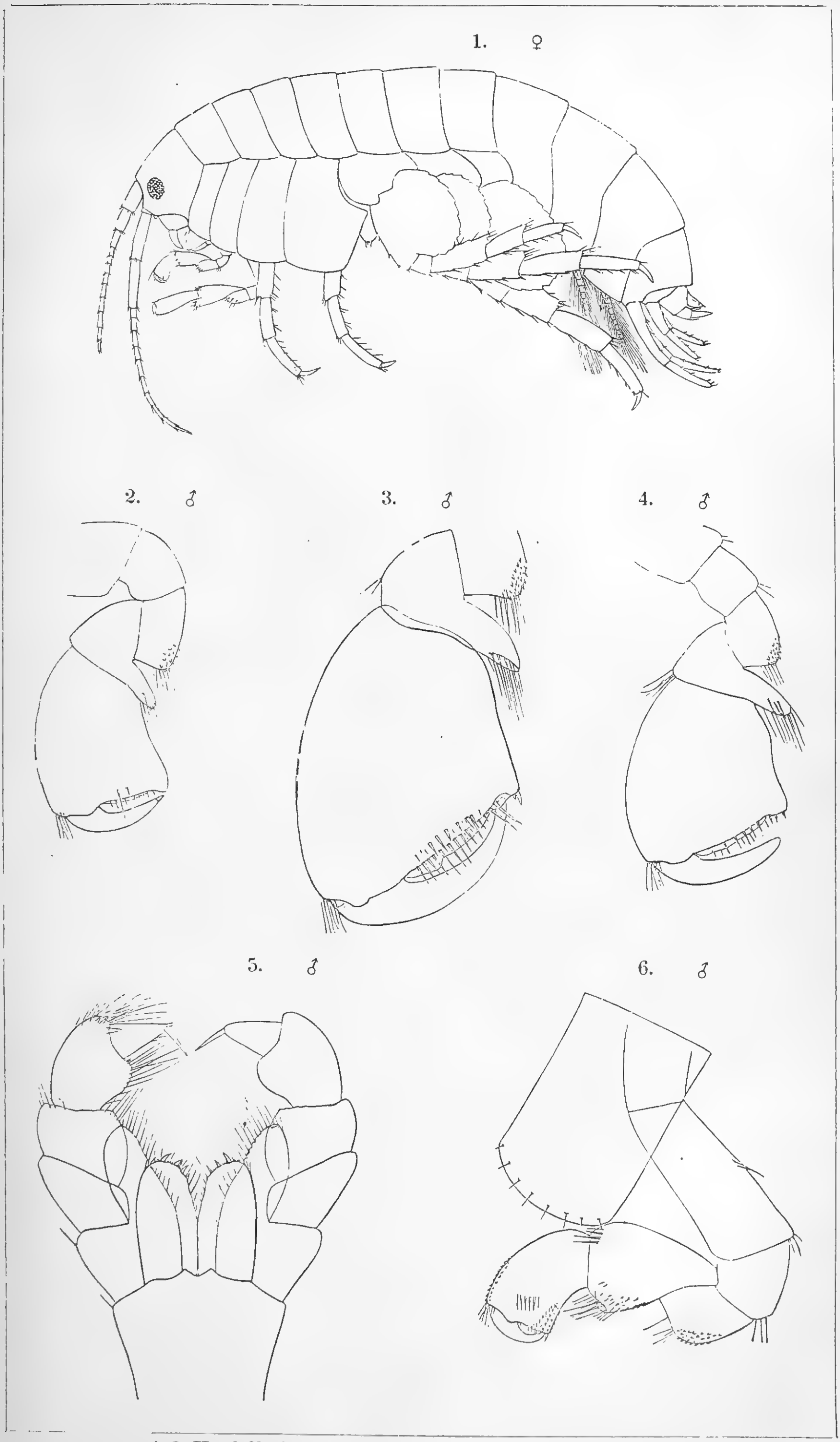
the palmary margin is without the lamellar edge and without spines, except two or three small ones at the tip of the closed dactylus. The palmary margin of the second pair, in the male (Fig. 14), is only a little oblique, is convex in the middle, has a broader lamellar edge than in the first pair, and is armed on the outside with one, or very rarely two, long, stout, and obtuse spines near the middle, and with two, three, or very rarely four, successively smaller ones near the tip of the closed dactylus. There are also two or three still smaller obtuse spines on the inner side of the palmary margin near the tip of the dactylus. In the female, the palmary margin of the propodus in the second pair of legs is without the lamellar edge and the spines in the middle, and is straight and nearly transverse.

The name *lacustris* is preoccupied.

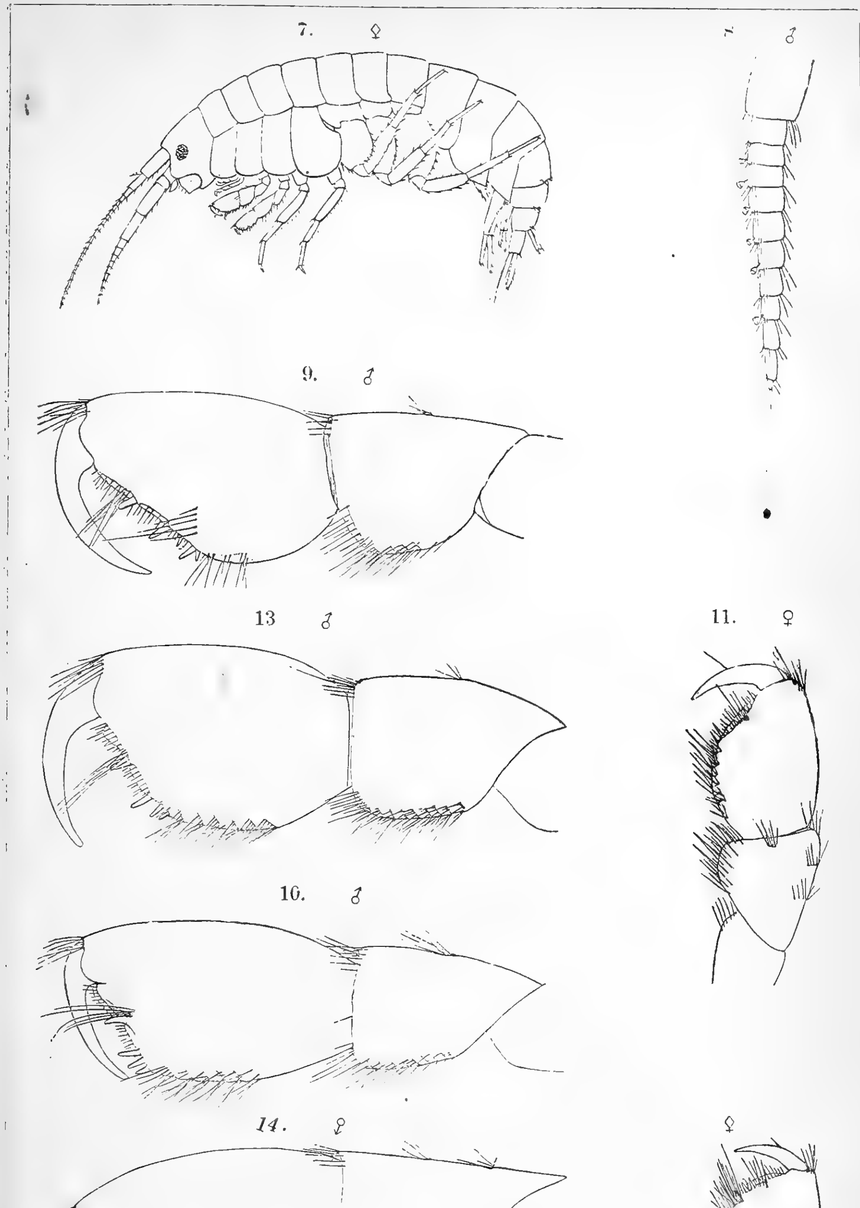
GAMMARUS ROBUSTUS, *sp. nov.* (Plate II, Figs. 7–12.)

Eyes small, nearly round, about equal in diameter to the thickness of the proximal segment of the peduncle of the antennula. Antennula much longer than the antenna; second and third segments of the peduncle together but little longer than the first; flagellum about twice as long as the peduncle, and composed of twenty-five to thirty segments in fully grown males, and of twenty to twenty-five in the females; secondary flagellum short, composed of three segments, of which the terminal one is very small. Peduncle of the antenna long and stout; the ultimate and penultimate segments subequal in length, and each but little shorter than the flagellum; flagellum (Fig. 8) stout, composed of eight to eleven segments, and in nearly all adult specimens having several of the segments furnished on the upper side with peculiar cup-shaped appendages. First pair of thoracic legs in the male (Fig. 9) with the propodus short and stout; the palmary margin very oblique, nearly straight, with a very narrow lamellar edge, and armed on the outside with three large obtuse spines, and on the inside with quite a number of small ones. In the second pair of legs (Fig. 10), the propodus is very broad and stout, the palmary margin slightly oblique, sinuous in outline, with a much broader lamellar edge than in the first pair, and armed on the outside with a stout spine near the middle, and two or three smaller ones near the posterior margin, and on the inside with two or three small teeth near the posterior margin. In the female, the first and second thoracic legs are much smaller and slenderer than in the male. In the first pair (Fig. 11), the palmary margin of the propodus is less oblique than in the male, slightly convex in outline, with a prominent lamellar edge, but without spines except near the posterior margin, which is itself armed with several small spines partially obscured by numerous hairs. In the second pair (Fig. 12), the propodus is proportionally much narrower than in the male, and has the palmary margin very slightly oblique, quite convex in outline, with a broad lamellar edge, and armed with two or three small spines near the posterior margin, but without any median spine.

Second and third segments of the abdomen with the infero-lateral angles acute. In all the specimens examined, there are four dorsal spines upon the fourth segment of the abdomen, two median and one lateral each side; six upon the fifth segment, two median and two lateral each side; and upon the sixth, a lateral each side and no median. The number of these spines is, however, very likely subject to some variation as in the *G. limnæus*. Outer ramus of the posterior caudal stylets about five times as long as broad, and with only a few and small marginal spines; the terminal segment short and stout. Inner ramus consider-



1–2. *Hyalella inermis.* 3–6. *Hyalella dentata.*



7-12. *Gammarus robustus.* 13-14. *Grammarus limnaeus.*

ably shorter than the basal portion of the outer. Divisions of the telson with two or three terminal spines each, and a single spine about the middle of the outer margin.

Length from front of head to tip of telson, 10^{mm} to 15^{mm}.

Wahsatch Mountains, Utah; L. E. Ricksecker, collector (collection Peabody Academy of Science).

EXPLANATION OF PLATES.

PLATE I.

Fig. 1.—*Hyalella inermis*, female; lateral view, enlarged 16 diameters.

2.—The same, male; terminal portion of one of the second pair of thoracic legs, seen from the outside, enlarged 50 diameters.

3.—*Hyalella dentata*, adult male; terminal portion of one of the second pair of thoracic legs, seen from the outside, enlarged 50 diameters.

4.—The same, young male; 3.7^{mm} long; terminal portion of the corresponding leg, enlarged 50 diameters.

5.—The same, adult male; maxillipeds, seen from above, enlarged 80 diameters. The hairs are omitted from the palpus on one side.

6.—The same, adult male; one of the first pair of thoracic legs with its epimeron, seen from the outside, enlarged 50 diameters.

PLATE II.

Fig. 7.—*Gammarus robustus*, female; lateral view, enlarged 5 diameters. (The secondary flagellum is figured upon the first instead of the last segment of the peduncle of the antennula by a mistake of the engraver.)

8.—The same, male; flagellum of one of the antennæ, enlarged 25 diameters.

9.—The same, male; terminal portion of one of the first pair of thoracic legs, seen from the outside, enlarged 25 diameters.

10.—The same, male; same portion of one of the second pair of thoracic legs, enlarged 25 diameters.

11.—The same, female; terminal portion of one of the first pair of thoracic legs, seen from the outside, enlarged 25 diameters.

12.—The same, female; same portion of one of the second pair of thoracic legs, enlarged 25 diameters.

13.—*Gammarus limnæus*, male, from lake near Long's Peak; terminal portion of one of the first pair of thoracic legs, seen from the outside, enlarged 20 diameters.

14.—The same, male from the same locality; same portion of one of the second pair of thoracic legs, enlarged 20 diameters.

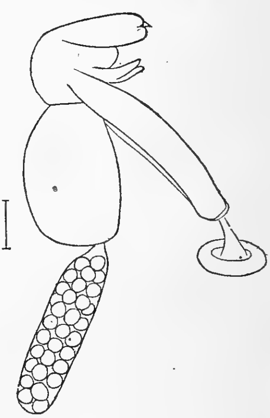
(All the figures drawn by S. I. Smith.)

DESCRIPTION OF A LERNÆAN CRUSTACEAN (ACHTHERES CARPENTERI) OBTAINED BY LIEUT. W. L. CARPENTER, IN 1873, IN COLORADO.

By A. S. Packard, Jr., M. D.

CRUSTACEA.

Achtheres Carpenteri, n. sp. (Fig. 1.)—Head about half as long as the body, with very minute conical antennæ; the antennal region forming a large rounded lobe. The jaws large, finger-shaped. Anchor, or jaw-feet, large, widely separate; the space between them being narrow-oval, and united by the sucker, which is of the general shape of *Achtheres*. Abdomen rounded-oval, one-half longer than thick, with indications of three segments; the sutures nearly obsolete, however. Egg-sacs a little longer than the abdomen, regularly cylindrical, containing from about forty to sixty eggs, the eggs nearly one-half the diameter of the arms of the anchor-feet. Uniformly pale-white.


Achtheres Carpenteri.

Length of body without egg-sacs, 0.15 inch; with egg-sacs, 0.25 inch. This should perhaps be regarded as the type of a subgenus of *Achtheres*, which it resembles more nearly than *Lernæocera*. The segments of the abdomen are very faintly indicated, and in the form of the head and appendages, and their degree of development, it seems intermediate between *Achtheres percarum* and *Cauloxenus stygius*, Cope, from Wyandotte Cave, Indiana.

Taken from trout, East River, August 29 (W. L. Carpenter).

SYNOPSIS OF THE FRESH-WATER PHYLLOPOD CRUSTACEA OF NORTH AMERICA.

By A. S. Packard, Jr., M. D

That group of *Crustacea* (crabs, lobster, shrimps, water-fleas) known as *Phyllopoda*,* is so called from the leaf-like nature of the feet, which are broad, flat, two or three lobed, and adapted for swimming and for purposes of respiration rather than for walking. While the number of feet in the lobster and crabs (*Decapoda*) is limited to five, in the phyllopods the number ranges from ten to sixty, exclusive of the antennæ and jaws. The thoracic and abdominal regions are merged into each other, and there is no special distinction in form of the appendages. One of the most distinctive characters, however, in all except the highest family, *Branchipodidæ*, is the large, loose carapace, which is attached by a muscle to the head, and elsewhere loosely covers the thorax and the base of the abdomen; in the lower forms (*Estheriadæ*), this carapace becomes enlarged, double, and folded on the side of the compressed body of the animal, protecting it as completely as a clam-shell its occupant; and so striking is the resemblance to the bivalve-shells, especially the small fresh water forms, such as *Cyclas*, that they are often mistaken for them by collectors of shells.

The lower forms, such as *Lymnetis*, have only ten pairs of swimming-feet, with the body entirely enclosed by the shell, and are not much higher in structure than the water-fleas (*Cladocera*), such as *Dapnia* and *Sida* (Fig. 1), and are scarcely larger, being about a line in length.

The eggs of the phyllopods are round, and protected by a hard shell, sometimes, as in *Limnadia*, rough and polygonal. Why the egg-shells are so dense and tough will be seen below, when we speak of the singular mode of life of these animals. The eggs are borne about by the females. In *Branchipus* and *Artemia*, they are carried in special egg-sacs, usually long and slender, attached to the base of the abdomen. In *Apus*, the eggs are few in number, and contained in an orbicular sac, formed by the adhesion of two of the circular lamellæ of the eleventh pair of feet. In the *Limnadiadæ* there is no egg-sac, but the eggs are situated loosely on top of the back, under the shell, and held in place by little filaments arising from the legs.

The young, when hatched, are more or less oval in form, and with but two or three pairs of feet; the first two pairs of these feet representing the antennæ of the adult. The young is called a *Nauplius*, from its resemblance to the young (*Nauplius*) of the copepodous Crustacea (*Entomostraca*). Fig. 2 *a* represents the Nauplius of *Branchipus* (*Artemia* has a similar larva), and *b* that of *Apus*. The young of *Limnadia* has but two pairs of appendages, with an enormous hypostoma, or upper lip.

The difference between the sexes is always well marked. In *Branchipus* and *Artemia*, the second antennæ are converted into large-clasping

* From the Greek φύλλον, leaf; πούς, ποδός, foot.

appendages, sometimes branched, as in *Streptocephalus* (Fig. 13), while in the female they are simple and end in a mucronate point. In *Apus*, the sexual differences consist in the rounded egg-sacs of the female on the eleventh feet; in the family of which *Limnadia* is the type, the first pair of swimming-feet in the male end in large, clumsy hooks, adapted as clasping-organs.

Now, besides the ordinary, normal mode of reproduction, several genera of the phyllopods are known to reproduce by what is termed by Professor Owen *parthenogenesis*, or virgin reproduction; *i. e.*, the eggs arise from the ovary by a budding process, like the budding of leaves on a tree, through the simple multiplication of cells, without fertilization by the male spermatic cell. This occurs in several insects, as in the *Aphis*, the honey-bee, the silk-moth, &c., and in *Daphnia*, the water-flea, which is closely allied to *Sida* (Fig. 1), and in other *Entomostraca*,

A Russian naturalist, Schmankiewitsch, in 1872, discovered a variety of "*Branchipus*" (*Artemia*) *Arietinus*, near Odessa. In the summer and autumn of the year before, he noticed that this *Artemia* changed its form, corresponding to the greater or less saltness of the water. In summer, when the water was most salt, there was a retardation in growth; and this retardation was the more evident the higher the temperature and the more concentrated the solution of salt. Toward the end of the summer, when heavy rains set in and the temperature decreases, the *Artemia* becomes larger, loses its red and gray color, and becomes clear and transparent, so that the July generation has important differences from that which appears in November. In order to observe this phenomenon carefully, he undertook the artificial breeding of the *Artemia* in two different ways. In one vessel, he increased the saltness of the water up to 18° Baumé; in another, he reduced the solution to 3°, and thus reared several generations. In both cases, he remarked that each new generation easily lived in such a concentrated solution as the previous generation could scarcely live in. By raising them in so different solutions (18° and 3° Baumé), very differerent forms of *Artemia* were obtained, which were not to be found in their original pond.

"While carrying on these observations, he at the same time proved that a parthenogenetic reproduction exists in *Artemia*. Each time, both in the great increase of the weak solution as well as in the greatly increased saltness of the water, the females produced new generations, despite the absence of the males. Under these relations of the solutions, in warm weather, only females were produced. These females produced in similar breeding-jars only female offspring. Only in water of medium strength were produced males."

As a further illustration of the influence of physico-chemical surroundings on the organization of these animals I will again quote from the abstract of the remarks of our author. "In the salt-pools in the neighborhood of Limans (near Odessa), he found in the spring, together with *Branchipus* (*Artemia*) *ferox*, Gr., a very peculiar *Artemia*, which he thought was undescribed. He thought from certain characters that this species belonged to the higher group of *Branchipus*. In this form, he observed some strange differences in the structure of the sexual organs, changes which could scarcely be regarded as pathological. Usually, the horns (lower antennæ) of the females are small, but in the old females they are clearly elongated, and are very much like the claspers of the males. Still earlier appears a striking change in the structure of the genital organs, when in some, characteristics of the male organs appear. In like manner, the sexual organs are clearly changed in the old males; and, in the sacs in which the outer sexual organs lie, we find a space which is very similar to the ovisac of the young *Branchipus ferox*, Gr. In such old males, the spermatic particles are very clearly enlarged. How far these changes could go on, he could not say, since this *Branchipus* is short-lived. These changes in the sexual organs are especially marked in old individuals; and he further remarks that such misshapen forms often occurred in the salt-pools after heavy rains." (Siebold and Kölliker's Zeitschrift, 1872, p. 293.)

Such facts as these show how desirable collections in very large numbers, at different seasons of the year, and from different localities, are for the proper study of these animals. Moreover, they are among the most important facts showing how new generic and specific forms, as well as an unusual mode of a sexual reproduction, arise in consequence of changes in the physical surroundngs of animals.

Von Siebold, in his second work on parthenogenesis, has ascertained that *Apus* also reproduces by this virgin reproduction. Already, in 1856, Siebold had stated his supposition that *Apus cancriformis*, *Limnadia gigas*, and *Polyphemus oculus*, in which species no males had been observed, presented examples of true parthenogenesis, and were not to be regarded as bud-producing "nurses" in a so-called alternation of generations. Leuckart subsequently expressed the same opinion with regard to the reproduction, independent of males, observed in *Daphnia*, *Apus*, and *Limnadia*. Ever since that period, Siebold has continually kept an eye upon *Apus*. In 1858, the males of *Apus* were discovered by Kozubowski, and Siebold received specimens from various localities. He thus learned to distinguish with perfect facility the two sexes, and was enabled now to convince himself that, as with the *Lepidoptera* above spoken of, so with *Apus*, broods occur which are entirely destitute of males, and go on reproducing parthenogenetically, while other broods occur in which both sexes are present. The number of *Apus* of two species—*Apus cancriformis* and *Apus productus*—examined by Siebold amounts actually to some thousands. He received quantities taken from various ponds in Middle Europe (*Apus* occurs in shallow pools which dry up during parts of the year, and it can be taken in immense quantities), and had the opportunity of studying one pond—that at Gossberg, near Munich—with minuteness, from the year 1864 to the year 1869, inclusive, besides casual examinations of the same pond in 1857 and 1858. Time after time, taking several hundreds of the *Apus* from the pond, he never found a single male among them. On one occasion, he had the whole contents of the little pond removed with the greatest care, so as to feel sure that he had obtained every *Apus* present. He obtained on this occasion 5,796 specimens of *Apus*, *every one of which, being carefully examined*, proved to be a female. At the same time, 2,576 specimens of *Branchipus* were obtained from the pond, which were, as usual, of both sexes. In those cases where ponds afforded both males and females of *Apus*, it is remarkable that the proportion of the sexes was very variable. The highest proportion of males appears to be in a case recorded by Sir John Lubbock, who found 33 male and 39 female *Apus productus* in a pond near Rouen; while among 193 specimens of *Apus cancriformis*, from a locality near Krakou, only one male occurred. What is most important about this variation in the proportion of males to females is that in two or three localities, furnishing mixed generations of *Apus*, from which he has received, year after year, numbers of specimens, Siebold has observed an apparent constantly augmenting disproportion of males to females, and he is led to the supposition that, in these cases, the males will at last cease altogether, and thus a female generation be produced, which will continue to reproduce itself parthenogenetically, as in the Gossberg and a great number of other ponds. This is, however, by no means proved; and we have no idea at present as to how the males may make their appearance again, or what are the conditions affecting their development and extinction. It occurred to Siebold that an objection might be urged against parthenogenesis in *Apus*, in that, although he examined consecutive generations, and found them always female, he could not be sure that males had not been present before he took his specimens, and had not died and decomposed after having fertilized the females. To meet such an objection, he first made himself thoroughly acquainted with the male generative organs and the spermatozoa, and secondly with the ovaries and their development. He found the spermatozoa to be motionless like those of other *Crustacea*, and he never succeeded in detecting any of them in the female genitalia among the specimens belonging to supposed female generations. But he equally failed to find spermatozoa, or a receptacle for them, in the female genitalia of the specimens of mixed generations, and therefore no conclusion could be drawn from the observation. The structure and development of the ovum, however, made this observation decisive, since it was found that an egg-shell forms round the ovum in the uterus, and, in the absence of a micropyle, fertilization, if it takes place at all, must be accomplished before this shell is hardened. A further proof of another kind was obtained by experiment. Having removed eggs from females which certainly at the time contained no spermatozoa, Siebold placed them in a small tank, and from these obtained *Apus* embryos. Others were reared to maturity from eggs taken in the pond.

The relative size of male and female is a question about which there is some interest; differences which have been observed seem to depend on the fact that *Apus* continues growing as long as the pond in which it lives does not dry up. And hence the eggs which hatch soonest give the largest-sized progeny. In his tabular statements, Siebold gives measurements of the specimens examined by him at different times from various localities.

As to the other crustaceans named, which are *Artemia salina* and *Limnadia Hermanni*, the occurrence of parthenogenetic broods is inferred from the descriptions of other writers whose works are criticised at some length, and also from examination of specimens. It seems not impossible, from an observation of Zenker, that in *Artemia salina* parthenogenetic alternate with digenetic broods. In the beginning of the year 1851, this observer found th ee males among one hundred females; later, in July, the same pond furnished thousands of females, but not one male.

It seems that males and females in this country have occurred in *Apus longicaudatus* and *Apus Lucasanus*, but the males occurred in a lot of *A. æqualis* from Kansas. It would appear as if the males from Kansas must be those of *A. æqualis;* but they were undistinguishable in form from *A. Lucasanus* from Cape Saint Lucus. Further observations are needed to clear up the matter. More material from the Western States is greatly needed; and as much has been already contributed by Dr. Hayden, it is to be hoped that the surveying parties sent out under his direction may collect largely of them.

This leads to the subject of the geographical distribution of the fresh-water phyllopods of North America. Thus far no species of *Apus* has been found in the United States east of the Mississippi nor in British America. In Greenland and Arctic America, the *Lepidurus glacialis* occurs. In the West Indies, *Apus Domingensis* occurs at San Domingo.

West of the Mississippi, three species are known to inhabit the region east of the Rocky Mountains, and a fourth has occurred on the Pacific slope at Cape Saint Lucas.

Of the family *Branchipodidæ*, species occur scattered over the whole country, though no *Branchipus* has yet been discovered in the Pacific States. An *Artemia* occurs in Mono Lake, California, and the Great Salt Lake. The genus *Branchinectes*, with one species in Greenland and another in Labrador, is also represented by an interesting form in Colorado, at an elevation of 12,500 feet.

Of the family *Limnadiadæ*, species occur scattered over the whole country, east and west of the Rocky Mountains, in British America, and the West Indies. In the Pacific States, but one species (*Estheria Californica*, Pack.) has occurred, and that is very unlike any eastern species as yet discovered, and closely resembles an Italian species, thus bearing out the analogy of the Pacific coast fauna to that of Europe.

The geological distribution of the fresh-water phyllopods is exceedingly interesting. The oldest forms are the *Estheriæ*, which occur as low down as the Devonian formation in Europe, while certain forms in the Mesozoic beds of this country have been described as bivalve mollusks. The genus *Apus* occurs in European Triassic rocks. The fresh-water strata of Mesozoic and Tertiary age, especially in the West, will undoubtedly, when thoroughly explored, reveal some of these forms, and the attention of paleontologists and collectors is hereby drawn to them.

The habits of these crustaceans are exceedingly interesting from their unusual dependence on physical surroundings. They usually abound in pools and puddles that dry up in warm weather; when the pools are filled, after a series of heavy rains, they suddenly appear. They are very local, rarely met with, but when they do occur, exist in large numbers. This singular appearance after rains, in the beds of pools that have dried up, is due to the wonderful vitality of the eggs, which are surrounded by a dense outer shell, enabling them to resist great changes in temperature, and to be dried up for months without injury. Thus the eggs dropped in the bottom of pools and left there during the hot summer-months, when the pool is dried up, survive the exposure to the sun and the cold of winter to hatch out in the spring. Dr. Brauer, of Vienna, believes, as he has informed me, from certain experiments on *Estheria*, that the eggs would live and hatch if kept in dry mud for several years. *Artemia*, which lives in salt-water, can be reared by putting the eggs in fresh water. And here I would ask any one who is so situated to send me a quantity of mud from the banks of Salt Lake, Utah, containing their eggs; the mud taken from the edge of the lake, at any season, must teem with their eggs, and it could be dried and sent east by express. On receiving it, and placing the mud in fresh water, this interesting animal can be reared and studied at leisure. We have seen that these creatures, in one species, at least, like the plant-lice, reproduces parthenogenetically at one season, and by the normal mode at another, and thus some of the most interesting questions in biology may be studied, and perhaps settled by a thorough study of the mode of life of these interesting creatures.

I append a brief synopsis of the fresh-water species of America north of Mexico, beginning with the lowest forms, so that they may be readily identified; and I hope, by drawing the attention of individuals and government surveying parties, especially in the Far West, to these interesting animals, to have their co-operation in the preparation of a monograph of the group. Specimens should be collected by hundreds, as they always occur in great abundance when found at all, and placed in strong alcohol for permanent preservation.

SYNOPSIS OF THE FRESH-WATER PHYLLOPODA NORTH OF MEXICO.

Order PHYLLOPODA.

Family 1, ESTHERIADÆ.—Body compressed, with from 10 to 27 feet, inclosed in a bivalve-shell.

Limnetis.—Shell small, less than two lines in length, round, globose, without lines of growth or umbones; feet-bearing segments from 10 to 12. (Fig. 3.)

L. Gouldii, Baird (Annals and Mag. Nat. Hist., 1862, p. 393).—Shell with numerous deep punctures scattered over the surface, with the place of insertion of the adductor muscle very smooth and shining. Canada and Massachusetts.

L. gracilicornis, Pack. (Amer. Journ. Sc., 1871).—Differs from *L. Gouldii* in the long, slender, second antennæ, which have about 20 joints. The keel on the front of the head does not reach to the front edge, while in *L. Gouldii* it does; shell of the same form, but much larger than in *L. Gouldii.* Length of shell, 0.17 inch; breadth, 0.16 inch. Texas. In fresh-water pools.

Limnadia.—Shell large, with few (4 or 5) lines of growth, subtriangular or broadly ovate; animal with a knob-like projection ("*Haftorgan*") above the eyes; second antennæ with 9 or 10 joints to the flagella; from 18 to 26 feet. Males (only known in an Australian species, Claus.) with large, clumsy hooks on the ends of the first pair of swimming-feet; body much smaller than in *Estheria.*

L. Americana, Morse (Proc. Bost. Soc. Nat. Hist.), (Fig. 4).—Shell large broad-oval, with 18 lines of growth, smooth and shining; allied to *L. gigas* of Europe. Length of shell, 0.55 inch. Massachusetts.

L. (*Eulimnadia*) *Agassizii*, Pack. (Sixth Rep. Peab. Acad., 1874), (Fig. 5).—Shell narrow-ovate, rather prominent behind the umbones, with 4 lines of growth. Animal with 18 feet, and antennæ with 9-jointed flagella. Length of shell, 0.25 inch. Penikese Island, Massachusetts.

L. (*Eulimnadia*) *Texana*, Pack. (Amer. Journ. Sc., 1871).—Shell narrower than in *L. Agassizii*, more oblong, with 5 lines of growth. Animal with 10 joints in the flagella; 18 pairs of feet; and with a larger telson than in *L. Agassizii.* Length of shell, 0.27 inch. Texas. "Quite common in many places in Western Texas in the early spring. It occurs in muddy pools made after rains, and totally disappears with the first drying of the pools; occurred with *Limnetis* and *Streptocephalus.*"—(Belfrage.)

Limnadella coriacea (Haldeman).—This genus was founded by Girard (Proc. Phil. Acad. N. S., 1854, p. 3) under the name *Limnadella Kitei.* It was previously described by Haldeman as *Limnadia coriacea* in the same proceedings (vol. 1, p. 184, 1842). It is said to have the eyes united into one, with 24 pairs of feet. Shell elliptical; light or dark-brown, spotted with black, three lines in length. Ohio and Pennsylvania. Grube thinks this may possibly be a species of *Estheria.* It is very desirable to rediscover this species.

Estheria.—Shell oval, more or less globose, *Cyclas*-like, with numerous lines of growth, amber-colored. Animal without a haftorgan; second antennæ with from 11 to 17 joints to the flagella; from 25 to 27 segments in the body behind the head, and 24 to 28 feet; anterior feet in the males with clumsy hooks.

E. Californica, Pack. (Sixth Rep. Peab. Acad. Sc., 1874), (Fig. 6).—Shell remarkably thin, so that at first sight it would be mistaken for a *Limnadia*, subtriangular; umbones very small, situated much nearer than usual to the anterior edge; 18 lines of growth, with very fine granulations between them. Length, 0.45 inch. California.

E. Clarkii, Pack. (Sixth Rep. Peab. Acad. Sc., 1874), (Fig. 7).—Shell oblong-oval, thin, about two-thirds as broad as long, with the umbones rather prominent, oblique, situated on the anterior fourth of the shell. About 20 lines of growth. Unusually fine microscopic punctures between the lines. Length, 0.45 inch. Male shell narrower, and with rather more prominent umbones than in the female. Animal with 14 joints in antennal flagella; each joint along the middle with 6 or 7 spines above, and 3 or 4 stout hairs beneath; 22 pairs of swimming-feet; telson with 20 pairs of unequal spines; claws of male long and much curved; telson larger than in the other sex. Ohio, Kentucky, Kansas. May and later. Differs from *E. Caldwelli* in the flatter shell, and smaller umbones, while the interstices between the lines are much less coarsely punctate.

E. Caldwelli, Baird (Proc. Zool. Soc. London, 1862, p. 148).—Umbones situated almost in the middle third of the shell, broad, and directed a good deal anteriorly; shell very globose; lines of growth numerous, thickly punctured between them; 0.40 inch. Lake Winnepeg, Grube.

E. Morsei, Pack. (Amer. Journ. Sc., 1871).—Shell intermediate in form between *E. Caldwelli* and *E. Dunkeri*, Baird, from Zimapan, Mexico. Much swollen; oblong-oval, pale horn-color, umbones large, prominent, larger than in *E. Caldwelli*, much less oblique, and situated near the anterior end of the shell. Dorsal margin shorter than in *E. Caldwelli*, and in front of the umbones, instead of being straight and suddenly curved downward, is regularly rounded, as in *E. Dunkeri*. Punctures between the lines of growth on an average, in the middle of the shell, from 5 to 10 in number. Length, 0.50 inch. Six specimens from "Grindstone Creek, half-way from Fort Pierre to the Bad Lands," Dakota. Collected by Dr. Hayden (Mus. Chicago Acad. Sc.),—Iowa.

E. Belfragei, Pack (Amer. Journ. Sc., 1871), (Fig. 8).—Shell thick, very globose, with the umbones prominent, situated at the anterior third of the shell; dorsal edge straight behind the umbones, bent rather suddenly downward at two-thirds of the distance from the umbones to the posterior end, the end being full and rounded, 22 lines of growth, between which the shell is coarsely punctuate, from 5 to 8 dots (when placed in a straight line) between the lines. Length, 0.30 inch; flagella with 16 joints; 15 pairs of spines on the telson. Texas.

E. Jonesii, Baird (Proc. Zool. Soc. London, 1862, p. 147).—A number of individuals of this species, which do not differ from specimens from Cuba, received from Dr. von Martens, of the Berlin museum, belong to the Chicago Academy, and are marked in Dr. Stimpson's handwriting "Locality lost." As no other specimens from the West Indies occur in the collection received from Dr. Stimpson, it indicates that *E. Jonesii* may possibly occur in the Southern States or Central America. The only habitat as yet known is Cuba.

Family 2, APODIDÆ.—Of large size, with a rounded carapace, partially covering the base of the abdomen, which is elongated, and ends in two long, many-jointed, caudal filaments. About 60 pairs of swimming-feet. Antennæ rudimentary. First maxillipeds antenniform.

Lepidurus—Body much shorter than in *Apus*. First maxillipeds shorter, and a long, spatulate, keeled telson, projecting out beyond the insertion of the caudal filaments.

L. glacialis, Kroyer (Fig. 9, enlarged).—A dark-greenish species, which differs from *L. productus*, Leach, in the distance from the front edge of the carapace to base of hypostoma being nearly one-half less than in *productus*. Supraanal plate with fewer larger teeth. Carapace shorter. Length, exclusive of caudal filaments, 1 inch. Greenland and Cape Krusenstern (Richardson).

Apus.—Antenniform maxillipeds long; telson squarish.

A. æqualis, Pack. (Amer. Jour. Sc., 1871), (Fig. 10).—♂. Carapace longer than in any of the other species; eyes larger. Number of segments behind the posterior edge of the shield, 23. Length of body (excluding caudal filaments), 1.15 inches.

♀. The telson has 5 median spines, and is shorter, while the caudal filaments have more numerous and shorter spines than in *A. Newberryi*. The under side of the telson is much smoother than in *A. longicaudatus*, and the outer gill of the first maxilliped is a little longer and more acute. Number of segments beyond the hind edge of carapace, 25. Length of body alone, 1.07 inches. Plains of Rocky Mountains, Kansas (?), and Matamoras.

Apus Newberryi, Pack (Amer. Journ. Sc., 1871).—♀. Differs chiefly from *A. longicaudatus* in the shorter maxillipeds, and much longer, smooth telson, with 3 instead of 4 median spines, and in the smooth, finely-spinulated caudal stylets, while the carapace is longer. Number of segments behind the posterior edge of carapace, 29. Length of body (excluding caudal filaments), 1.78 inches. Utah.

Apus Lucasanus, Pack. (Amer. Journ. Sc., 1871).—♂. Closely allied to *A. longicaudatus*. Maxillipeds shorter and smaller; telson longer, with 3 median spines. Anal stylets less spiny than in *A. longicaudatus*. Number of segments behind the posterior edge of the carapace, 33. Length of body alone, 0.94 inch.

♀. Carapace longer than in ♂, and caudal filaments not so heavily spined. Number of segments behind posterior edge of shield, 29. Length of body alone, 0.80 inch. Cape Saint Lucas. Males from Kansas.

Apus longicaudatus, Leconte, ♂ and ♀ (Annals N. Y. Lyceum, IV 155, 1846).—In this species, the body is larger and carapace is shorter than in any of the others. James's *A. obtusatus* (Long's expedition) is probably this species. The ♀ differs from males in the shield being longer, with 28 segments beyond the end of the shield, and the under side of the telson is smoother, but above, as in ♂; ovisac, 0.10 inch in diameter. Length of body, 1.50 inches; of carapace, 0.60 inch. The caudal filaments are smaller and more coarsely spined than usual. Rocky Mountains, near Long's Peak (Mus. Yale Coll.); Texas. Pools near Yellowstone River, Dr. Hayden. "Found in immense numbers in a small shallow lake on the high plateau between Lodgepole Creek and Crow Creek, northeast of Long's Peak."—(Leconte.)

Family BRANCHIPODIDÆ.—Body long and slender, with no carapace; eyes stalked; second pair of antennæ adapted for clasping; 11 pairs of branchial (respiratory) feet. Female with a large egg-pouch attached at the base of the abdomen. Prof. A. E. Verrill, in his valuable "Observations on the Phyllopod Crustacea of the Family Branchipidæ" (Proc. Amer. Assoc. Adv. Sc., July, 1870), has given the characters of the genera and species, and I give abstracts of his diagnoses of the generic and specific characters, with the addition, however, of descriptions of *Streptocephalus Texensis* and *Branchinectes Coloradensis*, which have been described since the publication of his paper.

Artemia. Clasping organs (second antennæ) three-jointed; egg-sac short, broad; living in saline or alkaline waters.

Artemia gracilis, Verrill (Fig. 11, enlarged).—Body slender; in the male about 0.3 inch long; in the female, 0.4 inch. Claspers of the male relatively long and powerful; first joint thickened, with a distinct angle at the articulation on the outside, and a short, rounded, nearly semicircular process on the inside near the base, about its own diameter from the base; second joint broad, flattened, continuous with the third joint, strongly curved; outline nearly regularly convex on the outside, until near the middle it suddenly bends inward, forming an obtuse angle, beyond which the outline is concave to the last articulation, where it becomes again convex, forming on the last joint a slight, rounded angle; the inner edge is nearly straight, or but slightly concave, to the last articulation, where there is a slight but distinct angle; last joint triangular, longer than broad, tapering to the acute, slightly-excurved point. Ovigerous pouch of the female, when seen from below, flask-shaped. "In tubs of salt-water on railroad-bridges, New Haven, Conn., and Boston."—(Verrill.)

A. Monica, Verrill.—"A little larger and stouter than *A. gracilis*. Male-claspers relatively stouter; the hook, or outer two joints, being much broader, more triangular, and less elongated. Caudal appendages smaller, and sides of egg-pouch less angulated on the sides than in *A. gracilis*." Mono Lake, California.

A. fertilis, Verrill.—" Larger than either of the others, some of the specimens being three-quarters of an inch in length. Male-claspers stout, with the second joint broader and more triangular than in either of the preceding species. Great Salt Lake, Utah."—(Verrill.)

Branchinecta.—Form rather slender, with the median appendages longest, so as to somewhat resemble *Artemia* in outline, but larger. Male with rather slender, rounded, two-jointed claspers. Egg-pouch much elongated.

B. arctica, Verrill.—" Male-claspers rather long and slender; basal joint but little swollen, elongated, regularly curved, with a small tooth or prominent angle at the articulation on the inside, and on the inner side a row of numerous small, distinct, sharp teeth, extending from the articulation about half-way to the base, and arranged somewhat obliquely; second joint slender, regularly curved, tapering to a blunt point, the inner edge minutely serrulate. Egg-pouch of female much elongated, slender, subcylindrical."—(Verrill.) In a small pool, north shore of Hamilton Bay, or Invuctoke Inlet, Northern Labrador (Packard.)

B. Grœnlandica, Verrill.—"A little stouter than *B. arctica;* the largest male 17 millimeters long. Claspers similar to those of *B. arctica*, but more elongated; the basal joint less curved, and the second joint longer, less regularly curved, tapering more quickly at base, and, consequently more attenuated beyond the middle, with more slender tips, which are nearly straight. The tooth on the inside of the first joint is rather more prominent, but the row of teeth along the inside is similar. Caudal appendages stouter, tapering more rapidly. Greenland."—(Verrill.)

B. Coloradensis, Pack. (Fig. 12, male, female, and head of female).—Differs from *B. Grœnlandica*, its nearest ally, in the basal joint of the claspers being less curved, slightly shorter, this and the second joint being entirely unarmed. The second joint is sinuous, not tapering, swollen, and bent in slightly at the tip when seen in outline, but seen in front broad and flat, subspatulate. Caudal appendages rather stout, broader at base, and not contracting as in *B. Grœnlandica*. Length, 0.57 inch. Colorado, one ♀ from a " pond on a mountain near Twin Lake Creek, Colorado; elevation, 12,500 feet."—(Hayden's Survey of Colorado, 1873; collected by Lieut. W. L. Carpenter, U. S. A.) About a hundred males, and females, with eggs, Colorado, Dr. Viele (Mus. Comp. Zool. Cambridge). No date.

It will be interesting to determine whether these three forms are really of specific value. For this purpose, large numbers of specimens from different localities at different dates are necessary. After the observations made at Odessa on the wonderful degree of variation in *Artemia* at different seasons of the year and density of the water, we are led to think, from the fact that the females of the above three species of *Branchinectes* are almost undistinguishable, that the forms are possibly conspecific, and the differences which have been indicated are the result of climatic and other physical causes. At present, however, it will be, perhaps, wisest to regard them as distinct.

Eubranchipus, Verrill.—"Body robust; male with large head and very stout claspers; first joint of clasper much swollen, capable of retracting the basal portion of the second joint into their cavity; second joint stout at base, in the typical species with a large tooth on the inside, the outer portion tapering, rather obtuse. Front of head between the claspers bears two thin, flat, tapering appendages, serrated on the edges and transversely striated or jointed. Caudal appendages long. Egg-pouch short and thick."—(Verrill.)

E. vernalis, Verrill.—"Claspers very large and strong; the basal joint much swollen; second joint long, broad, with an angle on the outside, from which it rapidly narrows by strongly concave outlines on each edge, bearing at the constricted portion, not far from the base, a large, strong, very prominent, crooked, bluntly-pointed tooth, which is directed inward and backward. Massachusetts and New Haven, Conn. Very early in spring in quiet pools."—(Verrill.)

Streptocephalus, Baird.—Male-claspers long, three-jointed, tortuous; the terminal joint subdivided more or less into two or more branches, or bearing slender appendages. Male organs long, slender. Egg-pouch elongated or conical.

S. Texanus, Pack. (Amer. Journ. Sc., 1871), (Fig. 13, male enlarged).—Male differs from *S. similis*, Baird, from San Domingo, in the longer branch of the inferior antennæ being much longer and slenderer at tip, while the shorter branch is much narrower. Length of male, 0.65 inch; female 0.55 inch. Texas, in pools, in summer, formed by the summer-rains, which had dried up early in the season; and also in April.—(Belfrage.)

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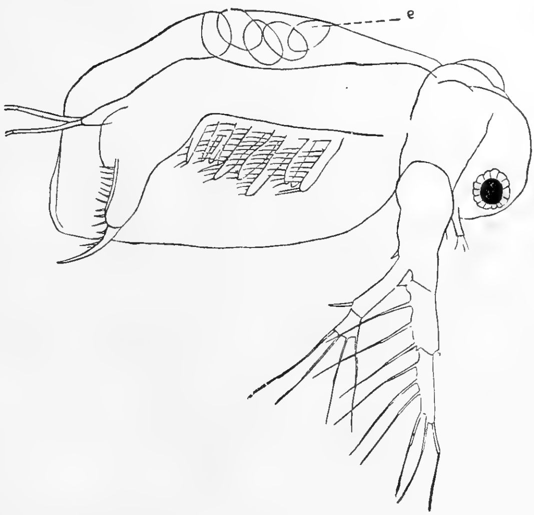

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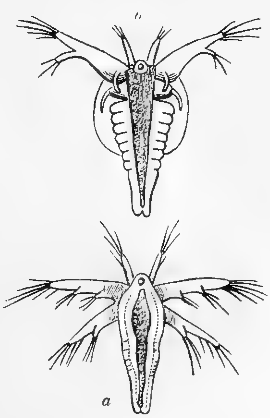

1. Sida. 2 *a*. Nauplius of Branchipus. 2 *b*. Nauplius of Apus.

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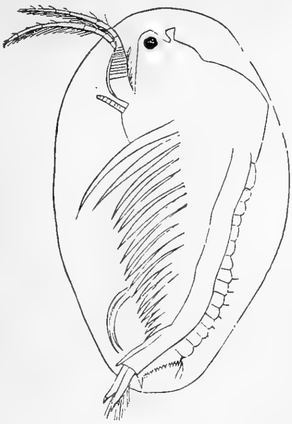

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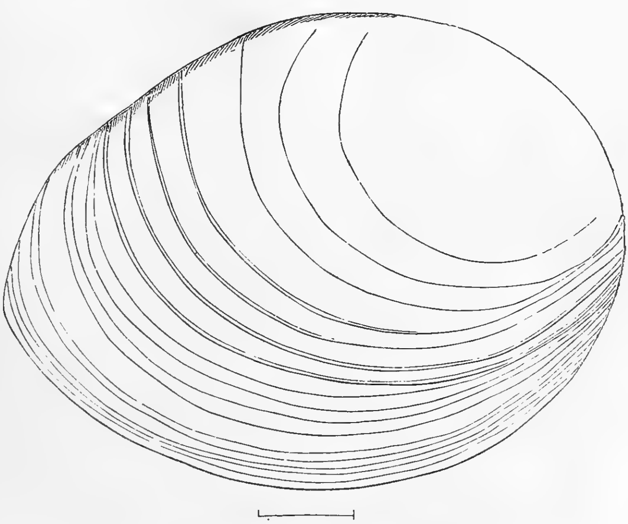

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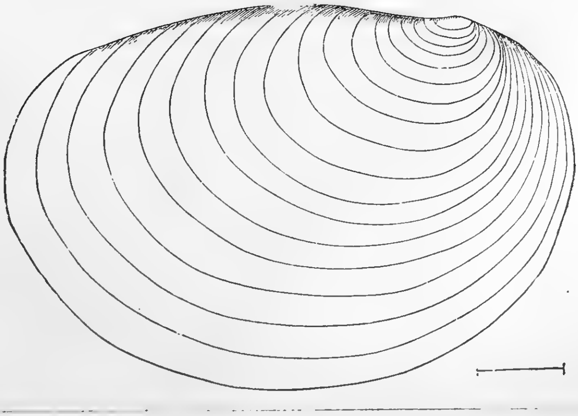

3. Limnetis.
5. Limnadia Agassizii.
4. Limnadia americana.
6. Estheria californica.

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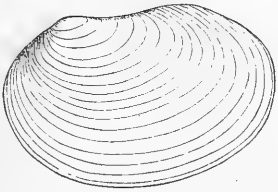

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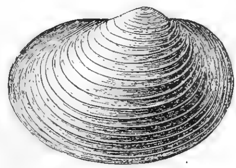

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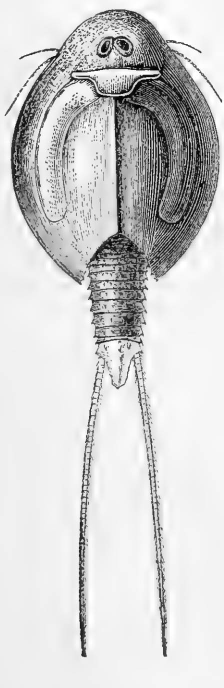

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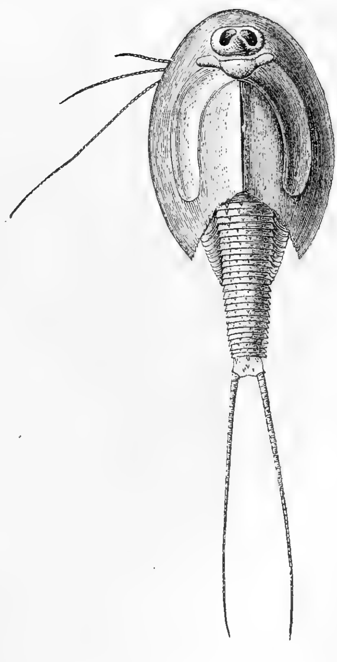
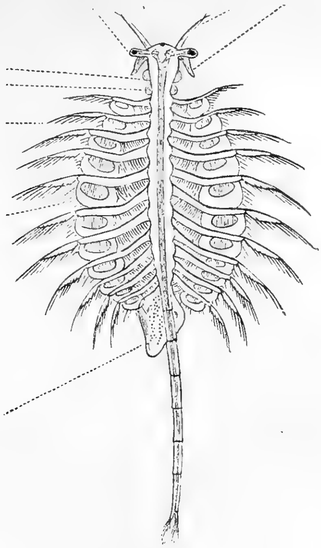


7. Estheria Clarkii. 8. Estheria Balfragei.
9. Lepidurus glacialis. 10. Apus æqualis.

11.



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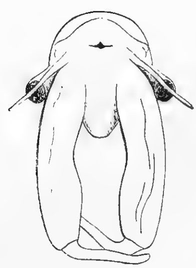
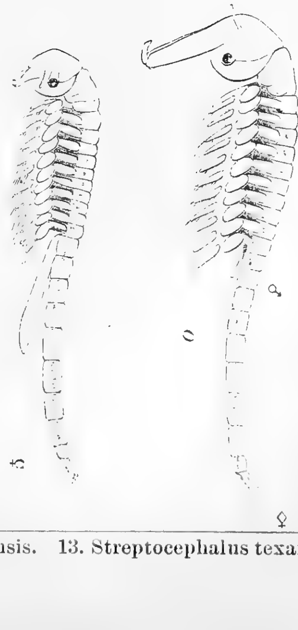


Branchinectes Coloradensis Pack.



11. Artemia gracilis. 12. Branchipus coloradoensis. 13. Streptocephalus texanus.

LIST OF LEECHES COLLECTED BY HAYDEN'S EXPEDITION, 1873.

BY A. E. VERRILL.

Nephelis lateralis Verrill (Say, sp.)

A plain, dark brown variety, Clear Lake, Col. (Lieutenant Carpenter).

Clepsine ornata Verrill, var. *b*.

In this large variety, the back is covered with numerous prominent papillæ, arranged in transverse rows. The two ocelli are united into one. Clear Lake, Col. (Lieutenant Carpenter).

Aulastomum lacustre Leidy, var. *fuliginosum* Verrill.

In this variety, the color is nearly uniform dark brown. From a lake, elevated 9,000 feet, near Long's Peak (Lieutenant Carpenter). It occurs also in pools near New Haven, Connecticut.

Nephelopsis obscura Verrill, dark variety.

The preserved specimens from this locality are dark olive, with blackish mottlings. Found with the *Aulastomum*, from a lake, at 9,000 feet elevation, near Long's Peak, (Carpenter.)

Nephelis quadristriata Verrill.

One specimen is nearly uniform obscure dark brown; another has two broad, blackish, dorsal bands, with a narrow, light, median stripe. Little and Big Thompson, Estes Park, Col. (Lieutenant Carpenter).

Clepsine pallida Verrill, var. *b*.

The back is smooth, with narrow, dark stripes; six distinct ocelli. Occurred with the two preceding.

Clepsine pallida Verrill.

The preserved specimens are brownish, with six small ocelli. Colorado (Lieutenant Carpenter).

LIST OF TERRESTRIAL MOLLUSKS COLLECTED BY LIEUT. W. L. CARPENTER, U. S. A., FOR THE UNITED STATES GEOLOGICAL SURVEY OF COLORADO, 1873.

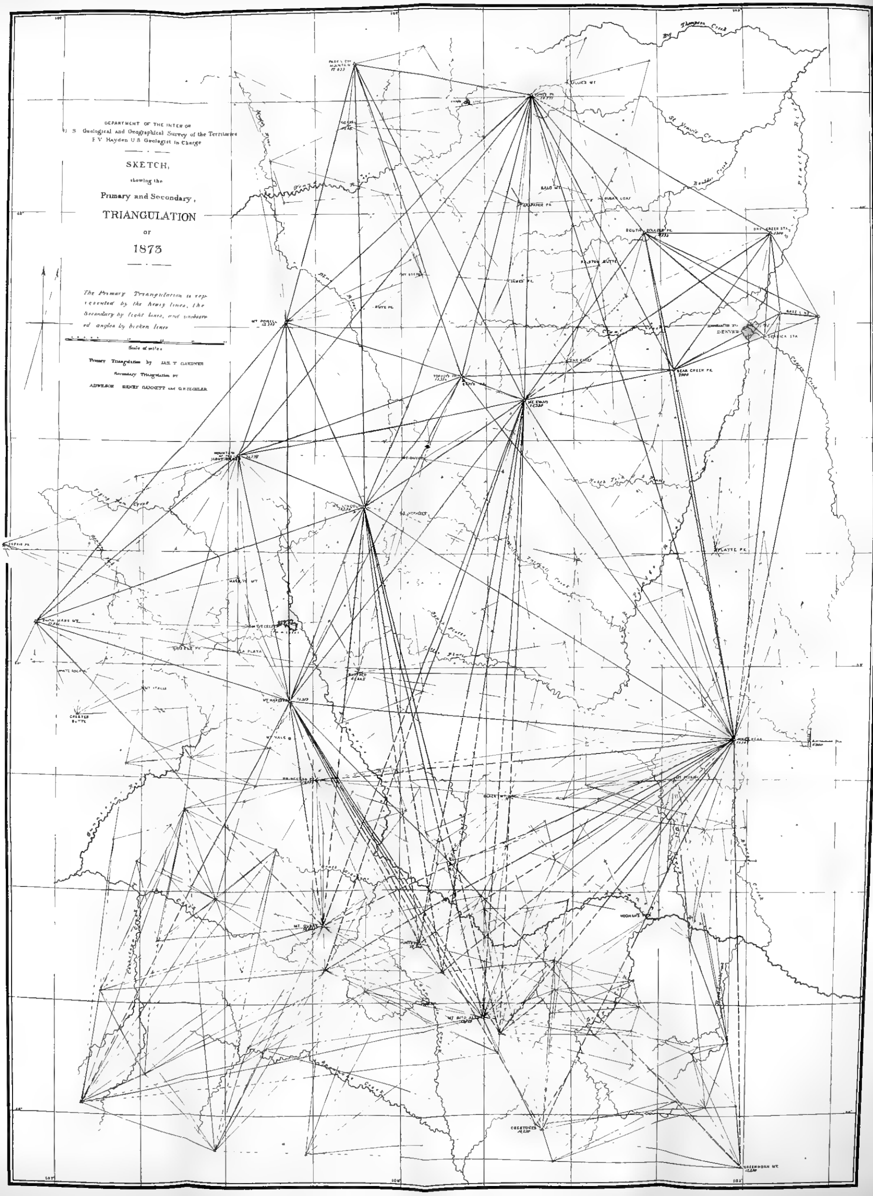
BY WILLIAM G. BINNEY.

HELICIDÆ.

Helix pulchella, Müll., Este's Park.
Vitrina Pfeifferi, Newc., head of Gunnison River.
Patula striatella, Anth., Este's Park.
Succinea lineata, W. G. B., Este's Park.
Patula Cooperi, W. G. B., Grand River.
Patula strigosa, Lea., Grand River.

PART IV.

GEOGRAPHY AND TOPOGRAPHY.


DEPARTMENT OF THE INTERIOR
U. S. Geological and Geographical Survey of the Territories
F. V. Hayden U. S. Geologist in Charge
SKETCH,
showing the
Primary and Secondary,
TRIANGULATION
OF
1873
The Primary Triangulation is represented by the heavy lines, the Secondary by light lines, and unobserved angles by broken lines
Scale of miles
Primary Triangulation by JAS. T. GARDNER
Secondary Triangulation by
A. D. WILSON HENRY GANNETT and G. R. BECHLER
DENVER
MT. EVANS
BEAR CREEK PK.
PLATTE PK.
SOUTH BOULDER PK.
Big Thompson Creek
St Vrain Cr.
Boulder Creek
LA PLATA
MT. YALE
CRESTONES

SKETCH OF THE METHODS OF SURVEY IN THE GEOGRAPHICAL DEPARTMENT.

BY JAMES T. GARDNER, GEOGRAPHER.

WASHINGTON, *July* 18, 1874.

SIR: I have the honor to inclose a sketch of the methods upon which the work is based in the geographical department of this survey, and also the results of my investigations to determine the true elevation of Denver; regretting that the latter has occupied so much time that full reports of other branches of my work must be delayed till next year.

Very respectfully,

JAS. T. GARDNER,
Geographer.

F. V. HAYDEN, *Geologist-in-Charge,*
U. S. Geological and Geographical Survey of the Territories.

The horizontal measurements of this survey are made by a connected system of large and small triangles, developed from a measured base near Denver. I have endeavored to bring the trigonometric work to such a grade of accuracy that its errors will not be appreciable within the limits of the Territory on maps of a scale of four miles to one inch. With this purpose, the primary triangulation was expanded by me from the Denver base, four miles of which are on the track of the K. P. R. R. and two more are over very level ground. The termini are, however, so much higher than the central part that the line of sight between them is never less than 20 feet above the surface and generally 40 feet. Its length was twice measured with a steel tape, compared before and after measurement with the United States Coast-Survey standard. The tape was under 20 pounds strain, and temperature-observations were taken every five minutes. The profile was determined by leveling, and results of the measurements corrected for level and temperature. Triangular pyramids 30 feet high were erected at the stations on the plains, by which the triangles were expanded to the mountains, where roughly-built stone monuments were used to sight at, except in the very long lines, where they became invisible, and the exact summit of the peak was taken. The angles were measured with an 8-inch circle graduated to 10″, and reading to 5″, constructed by Wm. Würdemann for the United States Coast-Survey. The measurements were generally repeated six times on different parts of the circle. The plan of the triangulation is shown on the accompanying map.

Azimuths were observed at five of the principal trigonometric stations by repeated observations between Polaris and an illuminated signal on one of the lines of the triangulation.

At Denver and Colorado Springs, the triangles are connected with very accurate astronomical stations, located for us by the kind co-operation of the United States Coast-Survey. Geodetic latitudes and longitudes of forty-eight stations were reduced trigonometrically from Denver, and plotted on a projection. From these points, the secondary triangulation and topography was plotted with protractors by the topographers. The accuracy of the triangulation is determined by the closure of the triangles, whose observed angles should sum up to 180° plus the spherical excess. The forty-seven triangles, completed in 1873 and used in the final adjustment of the scheme, have a mean error of closure of 10″.3. During the season of 1874, a check-base will be measured in the San Luis Valley, and we shall then be able to judge more closely of the probable errors of measurement by this triangulation. At present it appears as if they would not exceed two feet per mile. Twelve thousand square miles were completed last summer, and more than twice that amount partially finished.

The secondary triangulation is done by the topographers with the gradienter, whose circle is small, but its telescope powerful. The error of closure of these triangles is about 2′. As they rest for their bases upon the primary triangulation, the errors do not accumulate over any large area. The topography is sketched from the trigonometric stations, and the principal points of the sketch located by triangulation. The important roads are meandered. The magnetic needle is not used for angular measurement, except for minor details.

The vertical measurements of the survey are based on determinations of the height of the trigonometric stations above Denver on the following plan:

The D. & S. P. R. R. had run a line of levels from Denver, whose elevation is about 5,000 feet, up to Fairplay, at about 10,000 feet, and I had these levels extended at our expense to the summit of Mount Lincoln, about 14,000 feet high. These points are about sixty miles west of Denver. On Mount Lincoln and at Fairplay we established barometric stations, and at Denver the station of the United States signal-office was used for reference. Ninety miles to the south, at Cañon City, on the D. & R. G. R. W., we had another barometric station at an elevation of about 5,000 feet. The heights of the base-barometers above Denver being thus known by railroad-levels, the surveying-parties, using mercurial barometers (Green's mountain-barometer) observed at their stations and camps synchronously with the observations at the permanent stations.

The height of any point where observations were taken was determined by referring them to the permanent station nearest in altitude. From the trigonometric stations, angles of elevation and depression were taken to a great number of points to assist the topographer in sketching the contours of the ground. These are, of course, referred to the elevation of the trigonometric station, as determined barometrically.

As it was impossible to proceed with our final maps until the elevation of Denver was known, I have undertaken to put together into connected chains all the various lines of railroad-levels that unite Denver with the sea. It has been a labor of many months. The details and results of the investigation are given in a separate report.

THE ELEVATIONS OF CERTAIN DATUM-POINTS ON THE GREAT LAKES AND RIVERS AND IN THE ROCKY MOUNTAINS.

BY JAMES T. GARDNER, GEOGRAPHER.

INTRODUCTION.

As the field of labor of the United States geological and geographical surveys of the Territories now lies in Colorado, the following work was undertaken for the purpose of determining the elevation of Denver, which is at present the base from which all altitudes in the Territory are measured. The height of Denver above the sea had been variously reported at from 5,043 feet to 5,303 feet, and the spirit-level lines of the K. P. and U. P. R. R.s seemed to differ nearly 200 feet. Believing that any such large discrepancies between spirit-level lines must be due to false reports and errors in joining the different links of these long chains to the sea, I determined to reconstruct all possible lines of levels from the ocean to the Rocky Mountains, using only official reports by engineers, and checking them by personal examination of their note-books and working profiles wherever practicable. For this purpose I visited the railroad-engineer offices at Denver, Omaha, Lawrence, Kansas City, Saint Louis, Chicago, Cleveland, New York, and Philadelphia, examining not only the completed profiles and the original notes from which they were made, but making, also, such corrections as then seemed necessary to unite the lines of different companies. Several of the most important profiles were lost in the Chicago fire, and of one of these, that of the C., A., & St. L. R. R., no record is left. Profiles of the C. & N. W. and of the C., R. I., & P. R. R.s had been sent to the geological survey of Iowa, and had been published; these have now to be used instead of the originals.

For many years, various Departments in Washington have been gathering railroad and canal profiles. Mr. Nicholson, the topographer of the Post-Office Department, deserves especial mention for his long-continued activity in this important work under the Smithsonian Institution. Lately, the office of the Chief Signal-Officer of the United States Army has compiled all of this material, with a large collection of their own from original sources, and carefully arranged and indexed it. In the 1871 and 1872 reports of the Chief Signal-Officer, Gen. Albert J. Myer, he speaks of Lieut. Henry Jackson, acting signal-officer and assistant, as having vigorously prosecuted this department of the work. The collection comprises over one thousand profiles and reports from original sources; and efforts are being made to render it so complete, as to the profiles and their connections, that the elevation of every town on railroad or canal shall be well determined. The civil engineers of this country cannot render a greater service to geographical science than to send to the United States Signal-Office copies of railroad and canal profiles. Some of the most important problems in the meteorology of the country are dependent for their solution upon our exact knowledge of the elevations of the observing-stations; and these must be determined independently of the barometer. The elevations should be known to within five feet to satisfy the present needs of meteorology.

The use of this large and admirably-arranged collection was kindly offered me, and to its assistance I am largely indebted for the completeness of this investigation.

The principal difficulties encountered in the present work were: the discrepancies between the different official reports of the profiles of the same railroad or canal; the difficulty of finding the points referred to at the ends of the profiles; the difficulty of connecting them with the mean surface of the ocean; and the clerical errors or mistakes in figures evidently due to copying.

The differences between the reports of the profile of a railroad or canal seem to arise from want of care in computing from the level-notes, and from the fact that they are actually reports of different levelings which do not agree. Generally, a preliminary line of levels is first run over the whole line of the railroad, and bench-marks established; then, when construction is commenced, the different divisions of the line each take one of these bench-marks as the datum for their levels, and build their part of the work from this point. Thus, the line as a whole is really built from many separate datum-planes. Where the different divisions join, they connect their levels so that the relative height of the different datum-planes may be calculated, and all may be reduced to one base. The notes of these connections are generally correct; but, in the first calculations of them, many errors almost always occur, incident upon the hurry and confusion of closing the work and dismissing the engineers for the sake of economy. After the railroad is running, and the chief engineer has leisure to examine the records of his office, errors are found in the calculations of his profiles, and the whole is reviewed and a new profile constructed. It often happens that, after a number of years, either a part or the whole of line is releveled, and a new profile is the result.

Among the profiles which I have examined are representatives of all these classes:

First. Profiles of preliminary lines of survey.

Second. Profiles from first calculation of constructed lines.

Third. Profiles of final calculation of constructed lines.

Fourth. Profiles of final releveling of constructed lines.

Fifth. Profiles made up in the offices by mixing the results of two or more of the above classes.

It is evident that these classes must differ very much in accuracy; and necessarily the first step in this examination was to determine upon methods of testing the profiles so as to fix their proper relative weights. This was a very complicated and difficult process on account of the number of factors to be considered. Some of the principles may, however, be stated.

If two points were connected by several independent lines of railroad or canal, the agreement of these lines as to the difference of altitude of the termini was considered one of the best tests of accuracy.

If one of these lines was a canal which had been releveled many times, and the termini carefully connected with the other lines, and of which we had a final official report, this was taken as true and used as a standard of comparison for the accuracy of the other lines.

If the lines were all canal-levels, their relative weight was determined by the number of times they had been releveled, the recentness of the work, the recentness of the official report, and its detailed character.

If the lines were all railroad-levels, the following points were considered as favorable to the character of any line or connection of lines:

First. That the official reports should be recent and detailed.

Second. That they should be reports of the final computation of the construction-levels, or a releveling of the completed line, or, best of all, that we should have both of these reports agreeing closely.

Third. That there should be few connections of lines formerly independent to make up the present through-line.

Fourth. That, where the line was made up by joining several parts formerly independent, the connection between them should not be open to any doubt.

If, of several lines between two points, one disagreed largely from the others of apparent equal weight, it was considered as probably in error.

If several railroads, running from a common point, cross an important river, the fall of the stream was determined by the very best lines, and those were rejected which made it run up hill or gave an improbable fall.

If several parallel railroads were cut by a cross-line, well connected, their agreement upon this common line was considered as an important test.

If several lines of levels between two points start from a common datum or directrix, and end also at a common datum, the connection for comparison is far more reliable than when the ends of the lines merely came into the same city, and then have to be joined by connecting the depots by city-levels.

The results of the application of these standards of accuracy showed that recent official reports of the final computation of the construction-levels were generally reliable so far as any one line is concerned. The Pa. R. R. may be given as one of the best examples. It has been recently releveled, and though there was a discrepancy between the new and old elevations of Pittsburgh of 11 feet, it was found on a third leveling of a part of the line that this was due to erroneous connection of two leveling-parties, and all occurred at one point. And now, when a final computation of the old construction-levels, and of the new and corrected line, is made, the elevation of Pittsburgh by the new line is within a foot of the old. Great credit is due to Mr. Wilson, the consulting engineer of this road, for the interest he has taken in investigating the discrepancies of the Pa. R. R. profiles, and through his exertions we have at last a correct report of the profile of that important railroad so many years after the levels were run. The profiles that seemed from their dates to be first calculations of constructed lines were often found unreliable, and do not generally agree with the final calculation of the levels when we have reports of both. The profiles of preliminary lines of survey were, of course, found very unreliable. The elevations of Cairo, Ill., and Columbus, Ky., have hitherto rested on a preliminary survey of the M. & O. R. R. from Mobile Bay, and seem to be 10 to 15 feet below the better determinations.

The worst of all the profiles, and the most perplexing to the geographer, are those made up in the offices of some of the railroads by putting together data from old and new printed reports and from all the manuscript profiles in the office, and treating them as if the same datum of levels was referred to in all these sources of information. The mixture thus produced generally defies the most ingenious power of analysis in the searcher after truth.

In general, I am satisfied that *the important errors in our railroad and* *canal profiles are not so much due to imperfect instrumental work as to hasty computation and careless combination of the results.*

The difficulties of making connection between the end of one profile and the beginning of another have been very great. Most cities have now a datum or base-point from which all the city-levels date, often called the city directrix. The United States Signal-Office has taken great pains to get reports from most of the city-engineers of the heights of the railroad-depots above these city-directrices; but the difficulties of using this connection between railroads is that in many cases the present depots are not the ones referred to on the profiles of the roads; and even when the present depots are the same as the old ones, the grade at the depot has been changed since the railroad-profile was made, and no note of the present grade made on the profile. This seems to be the case in Chicago, where the railroad-profiles almost all indicate a lower grade for the depots than those reported by the city-engineer.

By visiting the ground, and making connections with old benches, I have gotten rid of many of these errors, and, fortunately, in many cities the railroad-engineers have connected their datum with that of the city. If the engineers of this country will adopt this as a rule, the value of their work for general and scientific purposes will be very much increased.

The railroad-lines from Philadelphia, and the railroad and canal lines from Albany, had reported the elevations along their lines above tides of various stages at these points, and the G. T. R. W. of Ca. had reported their elevations as referred to tide at Three Rivers, the head of tide-water in the Saint Lawrence. These datum-points differ from each other, and from the mean surface of the ocean, which is the only proper plane of reference for our elevations. The errors due to this cause have entered into all previous reports of elevations in Pennsylvania and the regions about the great lakes. By the assistance of the United States Coast Survey, and of Mr. Smedley, city engineer and surveyor of Philadelphia, the datum-planes of the Erie Canal and N. Y. C. R. R. levels and of the Pa. R. R. have been connected with the mean surface of the ocean.

Important changes are made as the result of this investigation. The elevation of the great lakes and surrounding country is found to be about 9 feet more than previously reported by the State geologist of Ohio, and that of Saint Louis about 23 feet higher than reported by Humphreys and Abbot. While Kansas City, and all the surrounding country for many hundred miles south and west, has heretofore been reported more than 100 feet too low, Omaha is raised about 31 feet, and Indianapolis about 100 feet. The fall of the Mississippi above Memphis, and of the Ohio, and of the Missouri River, is also changed. The amounts of these changes are so great, and the accuracy of the results of such importance to science and to our work of internal improvements, that I publish the evidence upon which they rest, and a statement of the evidence upon which previous reports were made where such could be found.

The checking at Denver of the levels brought through by the U. P. and D. P. R. R., and by the K. P. R. R. is so close that I believe the error of elevation of this point cannot exceed 10 feet, exclusive of that due to deflection of the plumb-line by attraction of mountain-masses. The result by the K. P. R. R. is 5198.97; and by the U. P. and D. P. R. R.s, 5194.20 feet above mean sea. My determinations of the elevation of Ogden, above the Atlantic Ocean, by the U. P. R. R., and above the Pacific Ocean, by the C. P. R. R., differ only 25 feet. When it is considered that the line of levels from the Atlantic to Ogden, Utah, is about two thousand miles long, this discrepancy is small. It is not improbable that a large part of this error lies between Cheyenne and Ogden, where the work on the U. P. R. R. was driven at an unprecedented speed, and where the line lies over mountains. The accompanying map shows the lines of levels that have entered into this discussion.

Discussion of evidence of the altitudes of various points in the United States and Canada.

THE ELEVATION OF LAKE ONTARIO.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
First determination.			
Mean tide at Albany, by United States Coast Survey leveling.	4.84	Above mean tide west end of Eighteenth street, New York.	4.84
Mean surface of Lake Ontario, by report of final levelings of Erie Canal, (see profiles accompanying annual report of State engineer and surveyor of New York, January 1, 1868, by J. P. Goodsell.)	245.15	Above M. T., Albany ...	....
Mean surface of Lake Ontario..........	....	....	249.99
Second determination.			
Mean tide in St. Lawrence River at Three Rivers, datum of levels of G. T. R. W. of Canada.	6.77	Above M. H. T., at Portland, Me.	....
Surface of Lake Ontario..........	235.00	Above M. T., Three Rivers.	....
Do	241.77	Above M. H. T., Portland	....
(These figures are from a report of the chief engineer of the G. T. R. W. of Canada, dated March, 1872.)			
Mean high-tide at Portland, Me., by United States Coast Survey report.	4.5	Above M. T., Portland..	....
Surface of Lake Ontario..........	....	....	246.27
Final results.			
Surface of Lake Ontario:			
First determination	....	....	249.99
Second determination	....	....	246.27
Adopted as correct..........	....	....	249.99
Error of second determination	− 3.72	....	....

The first determination is adopted, because it is the final result of many years' leveling over the line of the Erie Canal, as against the result of a long and broken line of railroad-levels; and because the canal-engineers have undoubtedly taken greater pains to get the mean surface of the lake than the railroad-engineers, to whom such knowledge was of no practical importance.

At Montreal, the levels of the G. T. R. W. are checked approximately by levels run by the Montreal and Champlain R. R. Co., Montreal, summer, water in river is 30 feet above mean sea by the G. T. R. W.; by the M. & C. levels L. W. at Montreal is 69.7 feet below L. W. Champlain. The surface of the lake is 100.84 feet by canal from Albany; hence L. W. Montreal about 31 feet. Considered with reference to Lake Champlain, we have its height above mean sea 100.84 feet by Hudson River and Whitehall Canal, and 99.7 feet by G. T. R. W. from Portland.

ELEVATION OF BUFFALO, CLEVELAND DIRECTRIX, AND MEAN SURFACE OF LAKE ERIE.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
First determination.			
Mean tide at Albany, N. Y., by United States Coast Survey leveling.	4. 84	Above M. T. foot of Eighteenth street, New York.	....
Surface of water in Erie Canal at Buffalo, by report of final levelings of Erie Canal, (see profiles accompanying annual report of State engineer and surveyor of New York, January 1, 1868, by J. P. Goodsell.)	568. 42	Above M. T. Albany	....
Water-prism of this section 9 feet deep; hence, bottom of canal at Buffalo.	559. 42	......do	....
Surface of Erie Canal, Buffalo	....	....	573. 26
Bottom of Erie Canal, Buffalo	....	....	564. 26
Surface of Lake Erie, by observations at Cleveland and Buffalo from 1844 to 1857, and published in Smithsonian Contributions, by C. Whittlesey, 1860.	8. 82	Above bottom of Erie Canal.	....
Mean surface of Lake Erie at Buffalo	568. 24	Above M. T. Albany	....
Do	....	....	573. 08
Cleveland directrix, by mean of a very favorable month of synchronous observations at Buffalo and Cleveland on surface of lake, by Mr. C. Whittlesey and Mr. J. Lathrop.	11. 42	Above bottom of Erie Canal, Buffalo.	....
Cleveland directrix	....	....	575. 68
Do	2. 60	Above M. S. of Lake Erie from 1844 to 1857.	....
Mean surface of Lake Erie from 1844 to 1857	....	....	573. 08
Second determination.			
Permanent United States Coast Survey bench on granite block at Gloucester Ferry, N. J., by United States Coast Survey Report of 1871.	8. 10	Above M. T. Raritan Bay, equal mean surface of Atlantic.	....
Mean tide in Delaware River at Philadelphia, by United States Coast Survey Report.	4. 751	Below U. S. C. S. bench	....
Mean tide at Philadelphia	....	....	3. 34
Philadelphia city datum, by leveling of Mr. S. L. Smedley, city-engineer and surveyor, and his assistant, Mr. Herring, January 11, 1874.	0. 632	Above U. S. C. S. bench	....
Philadelphia city datum	....	....	8. 732
Pennsylvania R. R. datum, by report of Mr. Wilson, consulting-engineer of P. R. R., 1874.	1. 819	Below Philadelphia city datum.	....
Pennsylvania R. R. datum or base of levels, called H. T. at Philadelphia.	....	....	6. 913
Harrisburgh, Market street depot track	313. 00	Above P. R. R. datum	....
Do	....	....	319. 913
Pittsburgh, Union depot track	738. 00	Above P. R. R. datum	....
Do	....	....	744. 913
(The above elevations are from a profile of the last computations from releveling the whole line, agreeing within one foot with the old construction-levels at Pittsburgh. Report by Mr. Wilson, consulting-engineer, April 29, 1874.)			
Alliance, by P. F. W. & C. R. R. profile, 1872	336. 70	Above Union depot, Pittsburgh.	....
Alliance, (track)	....	....	1, 081. 613
Cleveland directrix, by profile of C. & P. R. R., reported by Mr. I. Pillsbury, February 11, 1858.	507. 55	Below Alliance	....
Cleveland directrix	....	....	574. 063
Crestline, (track,) by profile of P. F. W. & C. R. R. ...	407. 60	Above Union depot, Pittsburgh.	....
Crestline	....	....	1, 152. 51
Cleveland directrix, by profile of C. C. C. & I. R. R., reported by Mr. I. Pillsbury, February 11, 1858.	577. 30	Below Crestline	....
Cleveland directrix	....	....	575. 21
Cleveland directrix, mean of Crestline and Alliance routes.	....	....	574. 637
Mean surface of Lake Erie	....	....	572. 037
Third determination.			
Mean tide Albany, by United States Coast Survey	4. 84	Above M. T. New York ..	....
Buffalo, N. Y. C. & L. S. R. R. depot track, by profile of N. Y. C. R. R.	578. 23	Above tide at Albany, assumed to be M. T.	....
Buffalo, N. Y. C. depot track	....	....	583. 07

Elevation of Buffalo, Cleveland directrix, and mean surface of Lake Erie—Continued.

	Feet.	Various datam-planes.	Elevation in feet above mean surface of Atlantic Ocean.
Third determination—Continued.			
Cleveland, L. S. depot track, by profile of L. S. & M. S. R. R.	0.70	Above Buffalo depot track.	....
Cleveland, L. S. R. R. depot track	....	....	583.77
Cleveland, L. S. R. R. depot track, by city-engineer report.	8.5	Above city-directrix	....
Cleveland directrix	....	....	575.27
Mean surface of Lake Erie	....	....	572.67
Fourth determination.			
Junction of the N. C. & Pa. R. Rs., on main line of Pa. R. R., west of Harrisburgh, by profile of N. C. R. R.	350.00	Above M. T. Baltimore	....
Harrisburgh, Market street depot track	30.25	Below junction of N. C.	....
Do	....	....	319.75
Surface of Lake Erie, (year not given,) by P. & E. R. R.	251.00	Above Harrisburgh	....
Surface of Lake Erie, (year unknown)	....	....	570.75
Fifth determination.			
Erie Railway depot at Dunkirk	606.80	Above M. T. New York	....
Surface of Lake Erie at Dunkirk, by profile supposed to be from construction-levels.	582.20	......do	....
(The present chief engineer reports that the line has been rerun, and that the old and new lines differ over 20 feet in some places. After examining the old and new levels, he gives preference to the old, but considers both incorrect.)			
Cleveland, L. S. depot, by L. S. & M. S. R. R	14.5	Below Dunkirk	....
City directrix	8.5	Below Cleveland depot	....
Cleveland directrix	23.00	Below Dunkirk	....
Do	....	....	583.80
Mean surface of Lake Erie	....	....	581.20
(This result is rejected in making up the means, because the levels are condemned by the chief engineer of the road.)			
Sixth determination.			
Surface of Lake Ontario, by G. T. R. W. of Canada	....	....	246.27
Surface of water in Detroit River opposite Detroit, by G. W. R. W. of Canada.	328.40	Above mean surface of Lake Ontario.	....
Surface of Lake Erie by State geological survey report.	3.00	Below river at Detroit	....
Surface of Lake Erie	....	....	571.67
Final results.			
Lake Erie:			
First determination	....	Mean surface	573.08
Second determination	....	......do	572.037
Third determination	....	......do	572.670
Fourth determination	....	......do	570.750
Fifth determination	....	......do	[581.20]
Sixth determination	....	......do	571.67
Adopted result.			
Surface of Lake Erie, mean of observations from 1844 to 1857.	....	....	573.08
Differences of other results from the one adopted.			
Second determination differs	− 1.04	....	....
Third determination differs	− 0.41	....	....
Fourth determination differs	− 2.33	Year unknown	....
Sixth determination differs	− 1.41	......do	....
(The first determination is adopted, because it is the final result of many years' leveling on the Erie Canal, connected with the mean of thirteen years' observations on the surface of the lake.)			
Cleveland directrix:			
First determination	....	....	575.68
Second determination	....	....	574.637
Third determination	....	....	575.270

Elevation of Buffalo, Cleveland directrix, and mean surface of Lake Erie—Continued.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
Adopted result.			
Cleveland directrix, (this is high-water mark of 1838 on pier.)	....	....	575. 68
Differences of the other results from the one adopted.			
Second determination differs...........................	− 1. 04	....	....
Third determination differs.............................	− 0. 41	....	....

The first determination is adopted, because it is the result of many years' leveling over the Erie Canal, connected with Cleveland by a very favorable month of observations on the lake surface, and connected with mean sea by the levels of the United States Coast Survey.

The United States Coast-Survey line from their tide-gauge at New York to that at Albany was run for scientific purposes, and is undoubtedly leveling of the first quality. The Erie Canal has been in process of construction and enlargement for over fifty years. During this time the levels must have been rerun many times, and the benches and computations checked by a succession of different engineers. Their final report should be of the highest authority. The mean surface of Lake Erie, during a month with light winds, when the fluctuations of the lake were small, is considered a level plane for connecting the west end of the canal with Cleveland. I think these reasons sufficient to justify me in accepting the first determination as against those by the railroad-lines.

The result may then be considered as showing great accuracy in the railroad-surveys, which are from 480 to 600 miles long, and yet differ but about one foot from the canal-levels.

At Harrisburgh, where the lines of the second and fourth determinations cross, the checking is very close. The height, as brought by the U. S. C. S. and Pa. R. R. from Raritan Bay, one hundred and seventy-five miles, is 319.91, while that brought from Baltimore by the N. C. R. R. is 319.75; the two differing only $\frac{16}{100}$ of a foot. The elevation of this same Market-street depot at Harrisburgh by the P. & R. R. R., reported to me by the chief engineer May, 1874, is 308.03 above M. T. Philadelphia, which would be 311.38 above M. T. Atlantic Ocean. This line is evidently in error about 8 feet between Philadelphia and Harrisburgh, but I believe it to be mostly in their computation, and not in the instrumental work.

At Pittsburgh the Pa. R. R. is again checked by the B. & O. R. R., which, in a number of reports, give the elevation of their depot as 735 feet above mean tide at Baltimore. By the report of the city-engineer, the B. & O. R. R. depot track is 7.75 feet below that of the Union depot; hence the elevation of the track in the Union depot at Pittsburgh, by the B. & O. R. R. above M. T. Baltimore, is 742.75 feet. That by the Pa. R. R. was 744.91 feet above M. T. Raritan Bay. As it is not known to me how this mean tide was determined at Baltimore, nor is it known whether mean tide at Baltimore is the same as the mean ocean-surface, and as the B. & O. R. R. levels have not been subject to as many revisions as those of the Pa. R. R., and the connection of the Pittsburgh depot is not known to be with the same grade given in the profiles of the railroad, I consider the Pa. R. R. result as being the more reliable for the present elevation of the track in the Union depot.

The line of levels from Baltimore, by the N. C. R. R. to Harrisburgh, and thence, by the P. & E. R. R. to Lake Erie, at Erie, a distance of four hundred and twenty-six miles, reaches the lake with an error that does not exceed 2 feet.

ELEVATIONS OF LAKE HURON, LAKE MICHIGAN, AND THE CHICAGO DIRECTRIX.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
First determination.			
Lake Ontario at Oswego, by United States Coast Survey and Erie Canal.	....	....	249.99
Surface of Georgian Bay, Lake Huron, at Collingwood, by N. R. R. of Canada.	340.00	Above Lake Ontario	....
Surface of Lake Huron in Georgian Bay	....	....	589.99
Second determination.			
Surface of Lake Huron at Sarnia, south end of lake, by G. T. R. W. of Canada.	341.00	Above Lake Ontario	....
Surface of Lake Huron	....	....	590.99
Third determination.			
Mean surface of Lake Huron at Sarnia, by G. W. R. W. of Canada.	340.00	Above Lake Ontario	....
Mean surface of Lake Huron	....	....	589.99
Fourth determination.			
Mean surface of Lake Erie, by United States Coast Survey and Erie Canal.	....	....	573.08
Surface of Detroit River at Detroit, by State geological survey report.	3.00	Above Lake Erie	....
Mean Surface of Lake Huron, by G. W. R. W. of Canada.	11.60	Above surface of river at Detroit.	....
Difference of Lake Erie and Lake Huron, mean surfaces.	14.60	....	....
Mean surface of Lake Huron	....	....	587.68
Fifth determination.			
Surface of Detroit River at Detroit, by State geological survey report.	3.00	Above Lake Erie	....
Junction of D. & M. R. R. and G. T. R. R., by D. & M. R. R.	55.60	Above water in Detroit River, Sept. 24, 1868.	....
Surface of Lake Huron, by G. T. R. W. of Canada	43.00	Below Milwaukee junction	....
Lake Huron	12.6	Above river at Detroit, September 24, 1868.	....
Do	15.6	Above Lake Erie	....
Surface of Lake Huron	....	....	588.68
Sixth determination.			
Surface of Detroit River at Detroit	3.00	Above Lake Erie	....
Surface of Lake Michigan at Grand Haven, by D. & M. R. R.	10.74	Above river at Detroit, September 24, 1868.	....
Lake Michigan	13.74	Above Lake Erie	....
Surface of Lake Michigan	....	....	586.82
Seventh determination.			
Cleveland directrix	....	....	575.68
Crestline, by C. C. C. & I. R. R	577.30	Above Cleveland directrix.	....
Crestline	....	....	1,152.98
Chicago depot of P. F. W. & C. R. R. track, by P. F. W. & C. R. R. report, 1872.	558.6	Below Crestline	....
Chicago, P. F. W. & C. depot track	....	....	594.38
Chicago city directrix, by city-engineer, 1872	8.5	Below top of rail in P. F. W. & C. depot.	....
Chicago directrix	....	....	585.88
Mean surface of Lake Michigan for past twenty years, by city-engineer's report.	2.00	Above city-directrix	....

ELEVATIONS OF LAKE HURON, ETC.—Continued.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
Surface of Lake Michigan, mean of twenty years			587.88
Alliance, by C. & P. R. R	507.55	Above Cleveland directrix.	
Alliance			1,083.23
Chicago depot, track of P. F. W. & C. R. R., by P. F. W. & C., 1872, report.	487.7	Below Alliance	
Chicago depot, track P. F. W. & C. R. R			595.53
Chicago directrix, by city-engineers, 1872	8.50	Below depot track	
Chicago directrix			587.03
Surface of Lake Michigan, mean of past twenty years			589.03
Chicago directrix, by P. F. W. & C. R. R., mean of Alliance and Crestline connection with Cleveland.			586.46
Surface of Lake Michigan			588.46
Eighth determination.			
Cleveland directrix			575.68
Cleveland, L. S. & M. S. depot, by city-engineer	8.50	Above directrix	
Chicago, L. S. & M. S. depot track, by profile procured at the office of chief engineer, October, 1873.	16.6	Above Cleveland depot	
Chicago, L. S. & M. S. R. R. depot track			600.78
Chicago directrix, by city-engineer, 1872	12.80	Below track of L. S. & M. S. depot.	
Chicago directrix			587.98
Surface of Lake Michigan, mean of past twenty years.			589.98
Ninth determination.			
Mean surface of Lake Erie			573.08
Mean surface of river at Detroit, by State geological survey report.	3.00	Above Lake Erie	
Usual height of water in river on June 1	1.00	Above mean surface of river.	
Chicago depot of M. C. R. R., by M. C. R. R. report	13.20	Above river at Detroit, June 1, 1869.	
Chicago depot of M. C. R. R. & I. C. R. R			590.28
Chicago directrix, by chief engineer of I. C. R. R	6.5	Below I. C. & M. C. R. R. depot.	
Chicago directrix			583.78
Mean surface of Lake Michigan			585.78
Final results.			
Surface of Lake Michigan and Lake Huron:			
(2) First determination	Huron	State of water unknown	589.99
(2) Second determination	do	do	590.99
(2) Third determination	do	Mean surface	589.99
(1) Fourth determination	do	do	587.68
(1) Fifth determination	do	State of water unknown	588.68
(1) Sixth determination	Michigan	do	586.82
(4) Seventh determination	do	Mean surface	588.46
(4) Eighth determination	do	do	589.98
(1) Ninth determination	Michigan	do	585.78
(The figures in parentheses indicate the relative weights with which the different determinations enter into the mean.)			
Adopted result.			
Mean of nine determinations			589.15
Mean surface of Lake Michigan for past twenty years.			589.15
The extreme range among the nine results is	4.21		
(This amount does not exceed the known fluctuations of the lakes.)			
Chicago directrix:			
Seventh determination			586.46
Eighth determination			587.98
Mean			587.22
Result by subtracting 2 feet from adopted result for mean surface of the lake.			587.15
Adopted result.			
Chicago city-directrix			587.15
The observations at Chicago make the city-directrix	2.00	Below mean surface of Lake Michigan for past twenty years.	

Hence, if the height 589.15 feet is adopted as the mean surface, 587.15 feet must be the elevation of the city-directrix. I have given their respective relative weights to the different determinations for the following reason: The fourth, fifth, sixth, and ninth are of least value, because they depend on the height of the water at Detroit, being 3 feet above Lake Erie, as reported by the State geological survey. The original data upon which this report depends cannot be found, and I therefore consider it open to much doubt. The first, second, and third determinations are given the value (2) because they are first-class railroad-lines, run from a base at Toronto, called surface of Lake Ontario, but which I do not *know* to be the mean surface, but simply *assume* it to be so. They run directly to Lake Huron, but only in one case is the state of the water given; and then I do not know of how many years it is the mean. These results should, of course, be far better than the fourth, fifth, sixth, and ninth, but are not nearly so probable as the seventh and eighth, which depend on railroad-lines run directly from the Cleveland directrix to the Chicago depots, which in this case seem well connected with the Chicago directrix. The height of the Cleveland directrix, as brought through on these same railroad-lines, the L. S. & M. S., the P. F. W. & C., C. & P., and C. C. C. & I. R. Rs. had checked so closely with the canal and lake surface result that they are entitled to great weight in their westward extension to Chicago. In connection with these directrices of Cleveland and Chicago, the fluctuations of the lakes have been observed, and the mean surfaces determined. For accounts of these fluctuations see Smithsonian Contributions, 1860: Fluctuations of Level in the North American Lakes, by Charles Whittlesey; also a recent report from the Dudley observatory, Albany, N. Y.

Determinations 1, 2, 3, 7, and 8 are the only ones which rest upon sufficient evidence to make them of much value, and it will be noticed that the range among these five is only 2.53 feet, with the lake at an unknown stage of the water. The range among those three that refer to the mean surface of Lakes Huron and Michigan is only 1.53 feet. I think therefore that the elevations of the mean surface of Lake Michigan and of the Chicago directrix will probably not be open to a change of over one foot. We have here at the Chicago directrix an opportunity for comparing the results of two very long and independent lines of railroad-levels, those of the N. Y. C. and L. S. & M. S. R. Rs., and of the Pa. R. R. and P. F. W. & C. R. R. I give the results in detail:

From mean tide New York Bay to the Chicago directrix.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
By the N. Y. C. R. R.:			
Mean tide Albany, by United States Coast Survey.	4. 84	Above M. T. New York	
Buffalo depot, by N. Y. C. R. R.	578. 23	Above T. at Albany	
Chicago depot, by L. S. & M. S. R. R	17. 30	Above Buffalo depot	
Chicago directrix	12. 80	Below Chicago, L. S. & M. S. depot.	
Do			587. 57
Total distance from New York Bay, 980 miles.			
By the Pa. R. R.:			
Pa. R. R. datum, by United States Coast Survey	6. 913	Above M. T. Raritan Bay	
Pittsburgh Union depot, by Pa. R. R.	738. 00	Above Pa. R. R. datum	
Chicago depot, by P. F. W. & C. R. R	151. 00	Below Pittsburgh depot	
Chicago directrix	8. 50	Below Chicago depot	
Do			585. 41
Total distance, about 900 miles.			
Chicago directrix, by N. Y. C. & L. S. & M. S. R. R., 980 miles.	587. 57	Above M. T. New York	
Chicago directrix, by Pa. R. R. & P. F. W. & C. R. R., 900 miles.	585. 41	Above M. T. Raritan Bay	
Difference	2. 16		

These lines are about one hundred and fifty miles apart through the first half of their course and about fifty miles in the western part. The Pa. R. R. crosses the Appalachian-mountain system in a difficult place, rising to a height of 2,290 feet, among ridges that must exert considerable attraction upon the level, while the N. Y. C. and L. S. & M. S. Railroads are through comparatively level country; and yet, after this long course of about nine hundred miles, they reach Chicago with only two feet difference in their levels. The result seems truly remarkable. The height by the Pa. R. R. differs—1.74 feet, and by the N. Y. C., L. S. & M. S. R. R. +0.42 feet from the adopted elevation.

The N. Y. C. R. R. is checked at Buffalo, three hundred miles from Albany, by a connection with surface of Lake Erie, state of water unknown, but assumed to be mean surface. The railroad-levels are 0.7 foot too high. At Cleveland, four hundred and eighty miles from Albany, the railroad-levels are 0.41 feet too high, and at Chicago 0.42 feet too high. The Pa. R. R. is checked at Harrisburgh, one hundred miles from Philadelphia, where it is intersected by the N. C. R. R., bringing its levels from mean tide at Baltimore, eighty-four miles. The two lines of levels differ but 0.16 feet. It is checked again at Pittsburgh, three hundred and fifty miles from Philadelphia, where the B. & O. R. R. intersects, bringing its levels from mean tide at Baltimore about three hundred miles. The levels by the Pa. R. R. are 2.16 feet higher than by the B. & O. R. R., but the connection of the profiles of the two is not exactly certain. It is, however, not improbable that mean tide at Baltimore is a little above the mean level of the ocean. At Alliance, the P. F. W. & C., the extension of the Pa. R. R. line of levels to Chicago, is checked by the C. & P. R. R. from the Cleveland directrix. The elevation of Alliance by the Pa. R. R. and P. F. W. & C. R. R. is 1081.61 feet; that by the C. & P. R. R. is 1083.23 feet; the P. F. W. & C. being probably too low.

At Crestline it is checked again from the Cleveland directrix, the elevation by the P. F. W. & C. R. R. being 1152.51, and that by the C.

C. C. & I. R. R. 1152.98; the P. F. W. & C. being probably too low. At Chicago, the P. F. W. & C. R. R. levels are 1.74 feet too low. The mean of these checks at Alliance, Crestline, and Chicago would make the whole of the western part of this line 1.27 feet too low. I therefore think it not improbable that the elevation of Pittsburgh by the Pa. R. R. may be about 1 foot too low. Considering all the evidence, I should be inclined to adopt 746 feet as the elevation of Pittsburgh Union-depot track instead of the Pa. R. R. result of 744.913.

The longest connected line of railroad-levels that we have an opportunity to check at Chicago is that of the G. T. R. W. of Canada, from Portland, Me., to Detroit, Mich., and thence to Chicago by the M. C. R. R. The details of the line and its results are as follows:

Elevation of Chicago directrix by G. T. R. W. of Canada and M. C. R. R.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
Mean high tide at Portland	4.5	Above M. T. Portland	
Mean tide, G. T. R. R. datum at Three Rivers	6.77	Above M. H. T. Portland	
Toronto	239.78	Above G. T. R. W. datum	
Detroit junction	340.22	Above Toronto	
Chicago depot	4.70	Below Detroit junction	
Chicago directrix	6.50	Below depot of M. C. R. R.	
Do			580.07
Distance from Portland to Chicago 1,142 miles.			

My adopted elevation is 587.15 feet; therefore, this line of levels, eleven hundred and forty-two miles long, appears to be in error only 7.08 feet, and the greater part of this error is in the M. C. R. R. line in the last three hundred miles. The quality of the line in different parts is shown by the checks at various points. The first check is at Toronto, six hundred and thirty miles from Portland, where the line is connected with the surface of Lake Ontario, the state of the water unknown, but assuming it to be the mean surface, the levels are 3.72 feet too low. The next check is at Sarnia, on Lake Huron, eight hundred miles from Portland, where the line is connected with the surface of this lake; the state of the water is again unknown, but, if assumed it to be the mean surface, the levels are 1.88 feet too low. At Detroit junction we have an approximate check by the height of that point, by the M. C. R. R., above H. W. in river at Detroit, June 1, 1869. The M. C. R. R. gives the height of Grand Trunk junction at 17.90 feet above H. W. 1869. This point we have supposed, by the geological-survey report, to be about 4 feet above the mean surface of Lake Erie; hence the junction would be 21.90 above Lake Erie, or 594.98 feet above M. T. The elevation of this point by the G. T. R. W. is 591.27, a discrepancy of 3.71 feet. From this, and from the ninth determination of elevation of Lake Michigan, it appears that there is an error of about 4 feet in the M. C. R. R. profile, in the difference of elevation in its termini. The length of this line is two hundred and eighty-four miles.

Establishing the elevation of the Chicago directrix gives us the means of checking another very long line of levels, extending from M. T. at New Orleans to Chicago, a distance of nine hundred and sixty miles. The details of the line are as follows:

From mean tide at New Orleans to Chicago, by N. O. J. & Gt. N. R. R., Miss. C. R. R., M. & T. R. R., M. & L. R. R., N. & N. W. R R., H. W. slope of Mississippi River fourteen miles, M. & O. R. R., and Ill. C. R. R.

ELEVATION OF MEMPHIS, TENN.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
Canton, Miss., by N. O. J. & Gt. N. R. R	240.00	Above M. T. New Orleans.	
Grenada, Miss., by Miss. C. R. R	56.00	Below Canton	
Memphis, L. W. in Mississippi River	0.00	Above Grenada	
Memphis, (supposed to be depot,) by M. & T. R. R	75.00	do	
Memphis, depot			259.00
Memphis, L. W			184.00
Memphis City datum + 100 feet = H. W. previous to 1858, by city-engineer report.	41.00	Below M. & T. R. R. depot.	218.00
Grand Junction, Tenn., by M. C. R. R	334.44	Above Canton	
Grand Junction	574.44	Above New Orleans, M. T.	574.44
Memphis, by M. & C. R. R	329.47	Below Grand Junction	
Memphis, depot M. & C. R. R			244.97
Memphis, H. W. of railroad reports, 1844	25.00	Below M. & C. depot	219.97
Memphis City datum + 100 feet = H. W. previous to 1858.	27.00	Below M. & C. depot	217.97
(This city datum + 100 feet = H. W. is either the H. W. of 1844 or of 1850; but they differed only 0.4 foot. The elevation of this H. W. mark in several reports of the M. & C. R. R. is given as 220.44 above tide in Mobile Bay. As the only records that I have of the M. & C. R. R. are above L. T., Mobile Bay, this 220.44 may be above L. T. In this case Memphis H. W. would be 218.74 above Mobile Bay M. T., but in either case the results from New Orleans and Mobile differ very little.)			
Final results.			
Memphis H. W. previous to 1858, 100 feet above city-datum.		Above New Orleans M. T.	218.00
Do		do	219.97
Do		do	217.97
Mean of the above adopted result.			
Memphis H. W. 100 feet above city-datum		Above New Orleans, M. T.	218.65
Memphis H. W. 100 feet above city-datum	220.44	Above Mobile Bay	
Do	218.74	Above Mobile Bay, M. T	

MEMPHIS TO CHICAGO.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
Memphis, Tenn., City datum + 100 feet = H. W. previous to 1858, by N. O. J. & G. N., M. C., M. & T. R. Rs.	218.65	Above M. T. New Orleans.	
McKenzie Junction, by M. &. L. R. R	269.56	Above city-datum of Memphis + 100 feet = H. W.	
L. W. Mississippi River, Sept. 30, 1858, at Hickman, Ky.	213.00	Below McKenzie	
H. W., 1858, at Columbus, by Humphreys and Abbot's report.	37.80	Above L. W. 1858	
(This makes the H. W. slope of the river, from Hickman to Memphis, 0.49 feet per mile, supposing the distance to be 190 miles.)			
H. W. 1858, at Columbus, Ky., 14 miles up the Mississippi by slope of river.	7.00	Above H. W. Hickman	
H. W. at Cairo, by preliminary survey for M. & O. R. R.	11.50	Above H. W. at Columbus.	
Chicago directrix, by chief engineer I. C. R. R., October, 1873.	258.50	Above H. W. at Cairo	

MEMPHIS TO CHICAGO—Continued.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
Chicago directrix	....	Above M. T. New Orleans.	590. 01
From the figures given above we have also Memphis, Tenn., H. W. = city datum + 100 feet.	....	Above New Orleans M. T.	218. 65
Memphis, H. W. 1858	1. 00	Above previous extreme H. W.	....
Do	....	Above New Orleans M. T.	219. 65
Hickman, Ky., H. W. 1858	....	....	313. 01
Columbus, Ky., H. W. 1858	....	....	320. 01
Cairo, H. W. 1858	....	....	331. 51
Cairo City datum=ordinary L. W	40. 38	Below H. W. 1858	291. 13

The adopted elevation of the Chicago directrix being 587.15, this line of levels, nine hundred and sixty miles long, reaches Chicago with an error of only 2.86 feet. The error of connection, due to using the H. W. slope of the Mississippi River for fourteen miles, would not probably exceed a foot or two. At Memphis, the line is checked to within 1.8 feet with the levels from Mobile Bay. At Columbus and at Cairo, the line is checked by the M. & O. R. R.; but the only reports of this line which I can find give the elevations as determined by an experimental survey, the results of which were reported to the second meeting of stockholders, in 1850. The character of reconnaissance-surveys is such, and the results have proved so inaccurate when I have been able to compare them with the construction-levels, that I have not felt justified in giving the results of the M. & O. R. R. preliminary survey to Columbus and Cairo any weight as compared with the profiles of constructed lines. It is, however, upon this preliminary survey that Humphreys and Abbot, in their Hydraulics of the Mississippi River, base their elevations of Saint Louis, Cairo and Columbus, and consequently their slope of the river from Cairo to Memphis.

RESULTS BY M. & O. R. R., PRELIMINARY, COMPARED WITH ADOPTED LEVELS.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
H. W. at Columbus, by M. & O. preliminary survey	308. 50	Above M. L. W. Mobile Bay	....
M. T. Mobile Bay	1. 70	Above M. L. T	....
H. W. Columbus, by M. & O. preliminary	306. 80	Above M. T. Mobile Bay	306. 80
H. W. 1858, Columbus, by N. O. J. & G. N., M. C., M. & T., M. & L., N. & N. W. R. R.	320. 01	Above M. T. New Orleans.	320. 01
H. W. Cairo, by M. & O. preliminary	320.	Above L. T. Mobile Bay	....
Do	....	Above M. T. Mobile Bay	318. 30
H. W. 1858, Cairo, by N. O. J. & G. N., M. C., M. & T., M. & L., N. & N. W. R. R.	....	....	331. 51

It will be seen further on that the elevation of the Cairo City datum, as brought from New Orleans, is within a foot of that brought from the Cleveland directrix, via Cincinnati and Indianapolis. In summing up all evidence on the elevation of the Cairo City datum, on page 647, it will be shown why I reject the levels of the M. & O. R. R.

If we consider now the line from Portland to Chicago and from Chicago to New Orleans as one, we have a connected chain of railroad-levels twenty-one hundred miles long, starting from mean tide at Portland, Me., and reaching New Orleans, La., with an error of −9.9 feet.

If we join the N. Y. C. and L. S. & M. S. R. Rs. with the line from Chicago to New Orleans, we have a connected chain of railroad-levels, eighteen hundred miles long, starting from mean tide in New York Bay and ending at mean tide New Orleans, with an error of only −2.44 feet.

Using the Pa. R. R. and P. F. W. & C. R. R. for a through-connection in the same way between mean tide Raritan Bay and New Orleans mean tide, a distance of about eighteen hundred miles, the levels reach New Orleans with an error of —4.61 feet.

These results will give some idea of the accuracy of extended lines of railroad-levels when properly connected.

ELEVATION OF CINCINNATI CITY BASE, WHICH IS STANDARD LOW WATER IN OHIO RIVER, 62.50FEET BELOW H. W. 1832.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
First determination.			
L. W. Ohio River at Cincinnati, by Miami and Erie Canal.	133.00	Below Lake Erie	
Mean surface of Lake Erie			573.08
L. W. at Cincinnati			440.08
Second determination.			
Columbus, Ohio, by C. C. C. & I. R. R	167.33	Above Cleveland directrix.	
Cleveland directrix			575.68
Columbus, Ohio			743.01
L. W. in Ohio River at Cincinnati water-works, by Col. & X. and L. M. R. R.	307.58	Below Columbus depot	
L. W. Cincinnati			435.43
Third determination.			
Columbus, Ohio, depot track, by C. C. C. & I. from Cleveland directrix.			743.01
Athens, Ohio, junction of M. & C., by C. & H. V. R. R	96.00	Below Columbus depot	
Athens at junction of M. & C			647.01
L. W. at Cincinnati point, 62.5 feet below H. W. 1832, = city base, by M. & C. R. R.	207.00	Below Athens	
City base L. W. Cincinnati			440.01
Fourth determination.			
Dayton, by D. & M. R. R	180.00	Above Lake Erie at Toledo.	
L. W. at Cincinnati, by C. H. & D. R. R	313.00	Below Dayton	
Mean surface of Lake Erie			573.08
L. W. Cincinnati			440.08
Fifth determination.			
L. W. Ohio River at Parkersburgh, by report of a line of levels run from Cincinnati to Parkersburgh, (not the M. & C. R. R.)		Above M. T. Baltimore	573.50
L. W. in Ohio at Cincinnati, by same report		do	440.00
Final results.			
L. W. in Ohio River at Cincinnati, city directrix:			
(10) First determination			440.08
(1) Second determination			435.43
(1) Third determination			440.01
(1) Fourth determination			440.08
(1) Fifth determination			440.00
Mean with weights			439.74
Adopted result			439.74
(The first determination is given a weight of (10) because it is a canal-line. The second and third determinations are well checked at Columbus by the P. C. &. St. L. R. R. from Pittsburgh.)			
Adopted elevation of Pittsburgh			746.00
Columbus depot track, by P. C. & St. L. R. R	3.80	Below Pittsburgh	
Columbus depot track			742.20

This result differs but 0.8 feet from that by the C. C. C. & I. R. R. from Cleveland directrix.

If we consider the depot track at Columbus, Ohio, as the point of junction of two long, connected lines of levels from the sea, one being from New York by the Erie Canal, surface of Lake Erie, C. C. C. & I. R. R., and the other by the Pa. R. R. and the P. C. & St. L. R. R., we should have the elevation of Columbus by the former as 743.01 feet above the sea, and by the latter as 741.11 feet. The difference between the two is only 1.9 feet, though the shorter line of the two is over six hundred miles in length.

ELEVATION OF INDIANAPOLIS.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
Cincinnati L. W., city-base			439.74
First determination.			
Cambridge, by W. W. Val. R. R.	508.00	Above city-base	
Cambridge			947.74
Indianapolis union depot, by P. C. & St. L. R. R.	227.00	Below Cambridge	
Indianapolis union depot			720.74
Second determination.			
Indianapolis union depot, by I. C. & L. R. R.	283.01	Above point supposed to be city-base because H. W. 1858 is 58 feet in profile.	
Indianapolis union depot track			722.75
Third determination.			
City-datum of Fort Wayne, by report of city-engineer, who says it was brought by canal. As this elevation of the city-datum is not from original canal-reports, I do not dare to accept it, and prefer the following, as previous results have shown the C. C. C. & I. and P. F. W. & C. to be so reliable.	196.00	Above Lake Erie	769.08
Crestline, by C. C. C. & I. R. R.	577.33	Above Cleveland directrix.	
Fort Wayne depot	348.00	Below Crestline	
Do	229.33	Above Cleveland directrix.	
Cleveland directrix			575.68
Fort Wayne depot of P. F. W. & C.			805.01
City-datum, by city-engineer	15.31	Below P. F. W. & C. depot.	
Fort Wayne, city-datum			789.70
Fort Wayne, F. W. J. & S. R. R. depot	8.1	Below city-datum	
Junction of F. W. M. & C. R. R.	6.0	Above F. W. J. & S. depot.	
Do			787.60
Cambridge, by F. W. M. & C. R. R.	173.88	Above junction	
Cambridge			961.48
Indianapolis union depot, by P. C. & St. L.	227.00	Below Cambridge	
Indianapolis union depot			734.48
(As it is not known that the depots at Fort Wayne, referred to by the railroad-profiles, are the same as those of the city-engineer's report, I do not feel certain of the connections by this line. I, therefore, reject this determination, and use only the first and second in the final result.)			
Final results.			
Indianapolis union depot:			
First determination	720.74		
Second determination	722.75		
Mean adopted			721.75
City-base Indianapolis is L. W. in White River	33.08	Below union depot	
Indianapolis city-base			688.67

ELEVATION OF THE SAINT LOUIS DIRECTRIX.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
First determination.			
Indianapolis union depot track			721.75
Terre Haute, by T. H. and Ind. R. R	217.00	Below union depot Indianapolis.	
Terre Haute, T. H. & Ind. depot			504.75
Terre Haute, H. W. in Wabash River	19.3	Below depot	
Do			485.45
Terre Haute, river-bed Wabash River	50.8	Below depot	
Do			453.95
Terre Haute, ordinary water Wabash River			467.45
Saint Louis directrix, by St. L. V. & T. H. R. R	71.60	Below Terre Haute depot.	
Saint Louis directrix			433.15
Second determination.			
Indianapolis union depot			721.75
Vincennes, by Ind. & V. R. R	287.36	Below Indianapolis union depot.	
Vincennes			434.39
Saint Louis directrix, by C. & V. and St. L. & S. E. R. Rs.	3.60	Below Vincennes	
Saint Louis directrix			430.79
Third determination.			
Cincinnati directrix			339.74
Present depot of O. & M. R. R., by city-engineer	54.94	Above city-directrix	
Vincennes, by O. & M. R. R. report in 1857	68.00	Below O. & M. Cincinnati depot.	
(It is not known whether the present depot is referred to in this old profile. If not the present one, it is probably the one at the north edge of the city, which is a few feet higher. Assuming it to be the same depot as at present:)			
Vincennes			326.68
(On account of the uncertainty above mentioned, this result is not used, but merely introduced to show how small the probable error is of the elevations of Indianapolis, and Vincennes as determined through Indianapolis.)			
Fourth determination.			
Chicago directrix			587.15
Effingham, by Ill. Cent. R. R., (Chicago branch,) reported to me by chief engineer, October, 1873.	10.50	Above Chicago directrix	
Saint Louis directrix, by St. L. V. & T. H. R. R	170.80	Below Effingham	
Saint Louis directrix			426.85
Fifth determination.			
Chicago directrix			587.15
Mendota, (Ill. C. R. R. crossing,) by C. B. & Q. R. R	169.07	Above Chicago directrix	
Vandalia, (exact crossing of St. L. V. & T. H. R. R.,) by Ill. C. R. R.	249.00	Below Mendota	
Saint Louis directrix, by St. L. V. & T. H. R. R	83.6	Below Vandalia	
Saint Louis directrix			423.62
Sixth determination.			
H. W. 1858, Columbus, Ky., by N. O. J. & Gt. N., M. C., M. & T., M. & L., N. & N. W. R. Rs. to Hickman, thence fourteen miles by river-slope.	320.01	Above M. T. New Orleans	
H. W. 1844, probably	319.11	do	
Saint Louis directrix, by St. L. & I. M. R. R	100.3	Above end of track at Belmont.	
(Belmont depot is certainly not below H. W. at Columbus, on the opposite side of the Mississippi River:)			
Hence by this route the Saint Louis directrix could not be less than.			419.41
Seventh determination.			
Memphis, H. W., city-base + 100 feet	218.65	Above M. T. New Orleans.	
Argenta, (opposite Little Rock,) by M. & L. R. R. R	86.00	Above city-datum + 100 feet.	

ELEVATION OF THE SAINT LOUIS DIRECTRIX—Continued.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
Argenta			304.65
Saint Louis directrix, by C. & F. and St. L. & Q. M. R. Rs.	119.00	Above Little Rock	
(Assuming that the tracks are same height on both sides of the river at Little Rock:)			
Saint Louis directrix			423.65
Eighth determination.			
Cairo city-datum, ordinary L. W	291.13	Above New Orleans M. T.	
Carmi, by C. & V. R. R. and city-engineer	123.70	Above Cairo city-datum	
Saint Louis directrix, by St. L. & S. E. R. R	12.2	Above Carmi	
Saint Louis directrix		Above New Orleans M. T.	427.03
Ninth determination.			
Cairo H. W., by M. & O. R. R., preliminary line	318.30	Above M. T. Mobile Bay	
Saint Louis directrix, by C. & V. and St. L. & S. E. R. Rs	93.4	Above H. W. Cairo	
Saint Louis directrix			411.70
Saint Louis directrix, by Ill. Cent. to Vandalia, thence by St. L. & T. H. R. Rs.	96.6	Above Cairo H. W	
Saint Louis directrix			414.90
Final results.			
Saint Louis directrix:			
(1) First determination	433.15		
(1) Second determination	430.79		
Third determination			
(1) Fourth determination	426.85		
(1) Fifth determination	423.62		
(0) Sixth determination	[419.41]	Above New Orleans M. T.	
(0) Seventh determination	[423.65]	do	
(1) Eighth determination	427.03	do	
(0) Ninth determination	{ [411.70] [414.90]	} Above Mobile M. T.	
Mean of five	428.29		
Adopted results.			
Saint Louis directrix			428.29
Saint Louis H. W. 1844			435.87
Saint Louis H. W. 1858			431.57
Saint Louis H. W. 1851			431.17
Saint Louis L. W., extreme			394.48

I have rejected the sixth determination because of the uncertainty of the connection at Belmont, and the seventh from the uncertainty of the connection at Little Rock. The two results of the ninth are rejected because they are the results of a mere preliminary survey on a line about five hundred miles long. The remainder are given equal weight because Cincinnati and Chicago are about equally distant from Saint Louis, and the connections equally good. The best result on the elevation of Saint Louis will be obtained when the C. A. & St. L. R. R. rerun their levels; their own engineer making the connection with the city-directrixes at both termini. If these levels are run with care, the elevation of Saint Louis, as deduced by them from the Chicago directrix, should, I think, supersede the one I have adopted. The elevation of the Saint Louis directrix, as given in Humphreys and Abbot's Report on the Hydraulics of the Mississippi River, is 405 feet. The causes of their error were the adoption of the elevation of Cairo H. W. above Mobile Bay, as determined by the preliminary line of the M. & O. R. R., and of the elevation of Saint Louis above Cairo, as reported by Gen. G. B. McClellan. His report was based on a connection of the I. C. R. R., and the O. & M. R. R. This part of the O. & M. R. R. profile cannot now be had.

His elevation of Saint Louis directrix above H. W. Cairo is 82.9 feet. By connecting the Ill. Cent. with the St. L. V. & T. H. R. R. at Vandalia, my result for the difference of elevation of these points is 96.6 feet; by Ill. Cent. R. R. to Decatur, and T. W. & W. R. R. to Saint Louis, 96 feet; by Ill. Cent. to Effingham and St. L. V. & T. H. R. R. to Saint Louis, 98.2 feet; by C. & V. and St. L. & S. E. R. R.s, 93.4 feet; and by a preliminary survey for railroad from Saint Louis to Ca ro, 102 feet. The mean of my four determinations by constructed lines, the preliminary-survey result of 102 feet being excluded, is 96.05 feet for the elevation of Saint Louis directrix above H. W. at Cairo.

I hope the evidence that I have presented will be considered as warranting this important change of 23.3 feet that I have made in the elevation of Saint Louis and the fall of the Mississippi River.*

ELEVATION OF OMAHA.

	Feet.	Various datum planes.	Elevation in feet above mean surface of Atlantic Ocean.
First determination.			
Dubuque, Mississippi River, by a report from Mr. J. A. Lapham, Milwaukee.	10.00	Above Lake Michigan	
Dubuque, L. W. Mississippi River, by Galena & Chi. R. R.	13.00	do	
Dubuque, adopted L. W.	12.00	do	
Lake Michigan, mean surface			589.15
Dubuque, L. W. Mississippi River			601.15
Sioux City, track on levee, by Ill. Cent. R. R., Iowa division.	522.50	Above L. W. at Dubuque	
Sioux City, track on levee	534.20	Above Lake Michigan	
Do			1,123.35
Mo. Valley junction with C. & N. W. R. R., by S. C. & P. R. R.	90.6	Below S. C. track on levee.	
Mo. Valley junction			1,032.75
Council Bluffs station, by C. &N. W. R. R.	20.00	Below M. V. junction	
Council Bluffs station			1,012.75
Missouri River	31.00	Below M. V. junction	
Do			1,001.75
Council Bluffs, Missouri River L. W., by two other reports of C. & N. W. R. R.	31.00	Below M. V. junction	
Council Bluffs, L. W. Missouri River			1,001.75
Check upon first determination.			
Frémont, by S. C. & P. R. R.	190.3	Above M. V. junction	
Frémont			1,223.05
Omaha, L. W. mark base of U. P., by U. P. R. R.	236.00	Below Frémont	
Do			987.05

This latter result is evidently the correct one; for if L. W. was only 11 feet below the Council Bluffs station, as is reported by the C. & N. W. R. R., then their station would be overflowed 8 feet in time of high water. By the careful leveling of the bridge-company at Omaha, the flat alluvial regions on both sides of the Missouri River were shown to be about twenty feet above L. W. Hence, I reject the report of low water by the C. & N. W. R. R., and by levels from Council Bluffs station across to the U. P. R. R. L. W. base at Omaha. The various old and new datums on the Council Bluffs side of the river cannot differ over 2 feet in height.

* Since the above was written, I have found a report of the Saint Louis and Iron Mt. R. R. surveys, signed by J. H. Morley, chief engineer, giving H. W. in Mississippi River, at Ohio City, opposite Cairo, as 97 feet below the Saint Louis directrix, and H. W., Mississippi River, New Madrid, as 126 feet below Saint Louis directrix.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
Omaha, L. W. base of U. P. R. R. surveys, by leveling of bridge-engineers.	21.80	Below Council Bluffs station.	
Council Bluffs station			1,012.72
Omaha, L. W. base of U. P. R. R			990.95
Second determination.			
Council Bluffs station, by C. & N. W. R. R	420.9	Above Lake Michigan	
Lake Michigan mean surface			589.15
Council Bluffs station			1,010.05
Omaha, L. W. base of U. P. R. R	21.80	Below Council Bluffs	
Do			988.25
Third determination.			
Rock Island depot track, by C. R. I. & P. R. R	(8) 20.00	Below Lake Michigan	
Rock Island depot track, by C. B. & Q. to Monmouth, thence by R. R. I. & St. L. R. R.	(1) 20.03	Below Chicago directrix	
Rock Island depot track, by C. R. I. & P. to Peoria, and P. & R. I. R. R.	(1) 22.70	Below Lake Michigan	
(Assuming the above as referring to mean surface of Lake Michigan, I adopt the mean with weights as marked, giving much the greater weight to the direct through-line.)			
Adopted result for Rock Island depot track	20.47	Below mean, Lake Michigan.	
Do	18.47	Below Chicago directrix	
Do			568.68
Davenport depot track, corner of Fifth and Perry streets, by line of levels run for United States Weather-Bureau, 1872.	23.20	Above Rock Island depot track.	
Davenport, old depot track			591.88
Davenport, L. W. datum of C. R. I. & P. and P. & S. W. R. R.	32.00	Below depot at Davenport	
Davenport, C. R. I. & P. R. R datum			559.88
Council Bluffs station-grounds	432.00	Above Davenport datum	
Do			991.88
Omaha, L. W. base of U. P. R. R	21.80	Below Council Bluffs station.	
Do			970.08
Fourth determination.			
Burlington, L. W. datum of B. & M. R. R., by C. B. & Q. R. R.	75.26	Below Chicago directrix	
Burlington L. W., B. & M. R. R. datum			511.89
East Plattsmouth, H. W. Missouri River	438.30	Above datum at Burlington	
East Plattsmouth, L. W. Missouri River	421.30	do	
East Plattsmouth, H. W. Missouri River			950.19
East Plattsmouth, L. W. Missouri River, by B. & M. R. R.			933.19
Kearney junction, by B. & M. and P. R. Rs	1,629.00	Above L. W. datum at Burlington.	
Do			2,140.89
Omaha, L. W. base of U. P. R. R., by U. P. R. R	1,179.00	Below Kearney junction	
Omaha, L. W. base of U. P. R. R			961.89
Fifth determination.			
Moberly, by St. L. K. C. & N. R. R	454.37	Above Saint Louis directrix.	
Saint Louis directrix			428.29
Hannibal H. W. 1851	397.50	Below Moberly	
Do	56.87	Above Saint Louis directrix.	
Do			485.16
Quincy, L. W. 1854, by C. B. & Q. R. R	114.76	Below Chicago directrix	
Quincy, H. W. 1851	94.04	do	
Hannibal, H. W. 1851, by slope of river at one-half foot per mile.	8.00	Below Quincy H. W	
Hannibal, H. W. 1851	102.04	Below Chicago directrix	
Do			485.11
Saint Joseph, H. W. Missouri River, by H. & St. J. R. R.	335.00	Above H. W. Hannibal	
Do			820.11

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
Kearney junction, by St. J. & D. R. R.	1,343.00	Above H. W. at Saint Joe	
Kearney junction			2,163.11
Omaha, L. W. base of U. P. R. R.	1,179.00	Below Kearney junction	
Do			984.11
Final results.			
L. W. base of U. P. R. R. at Omaha:			
(2) First determination	987.05	By S. C. & P., by Fremont	
(3) Second determination	988.25	By C. & N. W. R. R	
(3) Third determination	970.08	By C. R. I. & P. R. R.	
(2) Fourth determination	961.89	By B. & M. and U. P. from Kearney Junction.	
(1) Fifth determination	984.11	By Saint Joe and U. P. from Kearney Junction.	
Mean with weights	977.90		
Adopted result.			
L. W. base of U. P. R. R. at Omaha			977.90
(The old 966-foot point given as Omaha on the published profiles of the U. P. R. R., was a stone standing upon the bank of the river. It is now washed away.)			
Stone on river-bank called 966 feet above sea	20.00	Above L. W. base	
Do			997.90
Present depot-grounds on main line U. P. R. R.	82.50	Above L. W. base	1,060.40

From this determination of Omaha, it seems that 31.9 feet must be added to all the elevations of the U. P. R. R. to give the true height above the sea; but the range among the results is so large that the leveling across Iowa must be very poor as compared with that of the lines east of the Mississippi River.

Omaha cannot be considered as well determined as Kansas City; but this mean of five level-lines is much more probable than the old determination, which rested on barometric observations.

ELEVATION OF KANSAS CITY.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
First determination.			
Kansas City, H. W. 1844, mark on abutment of railroad-bridge, by Mo. P. R. R., reported to me by general superintendent, Mr. Talmadge, October, 1873.	342.00	Above Saint Louis directrix.	
Saint Louis directrix			428.29
Kansas City, H. W. mark 1844			770.29
Second determination.			
Junction of St. L. K. C. & N. R. R. and H. & St. J., by St. L. K. C. & N. R. R.	325.88	Above Saint Louis directrix.	
Kansas City, H. W. mark 1844, by line of levels run for us by city-engineer.	18.54	Above junction	
Kansas City, H. W. mark 1844	344.42	Above Saint Louis directrix.	
Do			772.71

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
Third determination.			
Quincy, H. W. 1851, by C. B. & Q. R. R	94.04	Below Chicago directrix	
Quincy, H. W. 1851			493.11
Hannibal, H. W. by slope of river one-half foot per mile.	8.00	Below Quincy H. W	
Hannibal, H. W. 1851			485.11
Kansas City, by H. & St. J. R. R	375.00	Above Hannibal H. W. 1851.	
Kansas City			760.11
Kansas City, H. W. 1844	11.25	Above old St. J. R. R. depot	
Do			771.36
Fourth determination.			
Davenport, C. R. I. & P. R. R. datum			559.88
Leavenworth railroad-bridge, by C. R. I. & P. R. R., southwest division.	271.00	Above Davenport datum	
Leavenworth railroad-bridge track			830.88
Bridge over Five-Mile Creek, Leavenworth, by special levels run by city-engineer.	56.21	Below track of railroad-bridge.	
Bridge over Five-Mile Creek, track of L. & L. R. R.			774.67
Junction of the L. & L. branch with K. P. R. R., main line.	49.00	Above Five-Mile Creek	
Junction L. & L. and K. P. R. Rs			823.67
Kansas City track at State line	68.00	Below L. & L. junction	
Do			755.67
Kansas City, H. W. 1844	7.25	Above K. P. track at State line.	
Do			762.92
Final results.			
Kansas City, H. W. 1844, marked on abutment of railroad-bridge:			
(5) First determination	770.29	By Mo. P. R. R	
(5) Second determination	772.71	By St. L. K. C. & N. R. R	
(1) Third determination	771.36	By H. & St. J. R. R	
(1) Fourth determination	762.92	By C. R. I. & P., southwestern division.	
Mean with weights	770.77		
Adopted result.			
Kansas City, H. W. 1844			770 77

I have given the greater weights to the first and second determinations, which come directly from Saint Louis directrix, each one being a continuous line, run under the direction of one company. The old elevation for Kansas City H. W. 1844 was 655.51. This determination was reported by Mr. O. Chanute, chief engineer K. C. bridge, to Mr. E. C. Smead, chief engineer of the K. P. R. R., July 14, 1870, and has been used not only by the K. P. R. R. but by all the other lines diverging from Kansas City. The altitudes above sea given by all these lines need therefore to be increased about 115 feet. The cause of Mr. Chanute's main error was due to a false report of the profile of the Mo. P. R. R. height of H. W. 1844, K. C. above the Saint Louis directrix. He gives this height as 252.51 feet, when it should have been 352.51, which was the old result from computing their levels. I have four reports from this railroad, including Mr. Chanute's. The report given me personally by Mr. Talmadge, chief engineer and general superintendent, in October, 1873, gives 342 feet; another report, by the same gentleman, 351 feet; a report by Mr. E. Miller, 342.35 feet; and Mr. Chanute's report, 252.51 feet. I think the evidence conclusive that the report of 252.51 feet, heretofore relied on for this difference of elevation, was intended for 352.51, but altered in copying. The remainder of the error was due to assuming the old elevation of the Saint Louis directrix.

ELEVATION OF DENVER, COLO.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
First determination.			
State-line, eastern terminus of K. P. R. R. track	7.25	Below H. W. 1844, Kansas City.	
Kansas City, H. W. 1844			770.77
State-line, K. P. R. R. track			763.52
Denver junction of K. P. & D. P. R. R., by K. P. R. R.	4,448.70	Above State-line	
Denver junction			5,212.22
Denver, D. P. & K. P. R. R. depot track, by D. P. profile.	13.25	Below junction	
Denver, D. P. & K. P. passenger-depot track			5,198.97
Second determination.			
Cheyenne, U. P. depot track, by U. P. R. R.	5,095.00	Above Omaha U. P. R. R., L. W. datum.	
Omaha, U. P. L. W. datum			977.90
Cheyenne, U. P. R. R. depot track			6,072.90
Denver, D. P. & K. P. R. R. depot, by D. P. R. R.	878.70	Below Cheyenne	
Denver, K. P. & D. P. R. R. passenger-depot track			5,194.20
Third determination.			
Construction-station 3985, near Pine Bluff, on U. P. R. R., by U. P. R. R.	4,113.00	Above Omaha L. W. datum	
Station 3985			5,090.90
Denver, D. P. depot, by a D. P. R. R. preliminary	101.45	Above station 3985 U. P. R. R.	
Denver, D. P. depot			5,192.35
Final results.			
(1) First determination	5,198.97	By K. P. R. R	
(1) Second determination	5,194.20	By U. P. R. R. & D. P.	
(0) Third determination	5,192.35	By D. P. preliminary	
Mean with weights	5,196.58		
Adopted result.			
Denver, D. P. & K. P. R. R. passenger-depot track			5,196.58
Difference from the mean, by K. P. R. R	+ 2.39		
Difference by U. P. R. R	− 2.38		

The third determination is given no weight as against the construction-levels of the same railroad. Such a close agreement between the U. P. and K. P. lines was not to be expected when we realize that for the last thousand miles they are really independent, one being from Chicago, by way of Saint Louis and Kansas City, and the other by way of Omaha and Cheyenne. Though Denver is two thousand miles from the sea, this determination of its elevation is probably very close to the result that would be obtained by the most accurate line of levels run across the country for scientific purposes; but a considerable error must pertain to all results from the effect of the mass of the Rocky Mountains in deflecting the level from a truly horizontal position. We cannot tell how much this error is until a most accurate geodetic belt is completed from the Atlantic to the Rocky Mountains, and then, knowing the station-errors or the deflection of the plumb-line along the belt, we may correct the leveling proportionally. As this cannot be done for many years, the elevation of Denver, as here determined, will be made the base for our hypsometric surveys in the Rocky Mountains.

ELEVATION OF CHEYENNE.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
Cheyenne, U. P. passenger-depot track, by D. P. R. R.	878.70	Above Denver	
Denver			5,196.58
Cheyenne, U. P. passenger-depot track			6,075.28

ELEVATION OF GOLDEN DIRECTRIX.

Golden directrix, by C. C. R. R.	519.9	Above south Y junction near Denver.	
South Y at junction, by D. P. R. R	12.5	Above Denver depot	
Golden directrix	532.4	do	
Do			5,728.98

ELEVATION OF OGDEN, UTAH.

Cheyenne			6,075.28
Ogden depot, by U. P. R. R	1,749.00	Below Cheyenne	
Ogden			4,326.28
Second determination.			
Ogden depot, by C. P. R. R.	4,301	Above Pacific Ocean	
Ogden			4,301.00
Final result.			
(1) First determination	4,326.28	By U. P. R. R	
(10) Second determination	4,301.00	By C. P. R. R.	
Mean with weights	4,303.3		
Adopted result.			
Ogden depot track			4,303.3

The result by the Central Pacific of California is given much the greater weight, because it is a continuous line of levels run by one railroad-company, the same chief engineer, Mr. S. S. Montague, superintending the running of all the lines and the making-up of preliminary and final profiles. The length, also, of this line is only about one-third of that from the Atlantic Ocean.

If we consider these lines as one long chain of levels from the Atlantic to the Pacific, we have connected railroad-levels extending not less than thirty-five hundred miles, and reaching the Pacific Ocean with an error of 25 feet. If we form a continuous line of levels by joining those of the Pa., P. F. W. & C., C. R. I. & P., U. P., and C. P. R. R.s, they reach the Pacific with an error of +13 feet.

If a chain is formed by putting together the lines from New Orleans to Cairo; thence by I. M. R. R. to Saint Louis; thence by Mo. P., K. P., D. P., U. P., and C. P. R. R.s, the line is thirty-two hundred miles long, and reaches the Pacific Ocean with an error of +26 feet. In this chain, the levels of eleven different railroads are connected

ELEVATION OF COLORADO SPRINGS.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
(Denver depot of D. & R. G. R. W. track is reported to be one foot above D. P. R. R. track. This may be in error 0.2 foot. The following figures are taken from the official profile in use at the D. & R. G. R. R. company's office.)			
Denver, K. P. depot	5,142. 6		
Denver depot D. & R. G. R. R	5,143. 6		
Colorado Springs depot	5.931. 6		
Colorado Springs	789. 0	Above Denver K. P. depot.	
Denver, D. P. & K. P. depot			5,196. 58
Colorado Springs depot			5,985. 58
Colorado Springs Hotel floor, by report of Mr. E. S. Nettleton, C. E.	826. 67	Above Denver K. P. depot.	
Colorado Springs Hotel floor			6,023. 25
Rock basin of Manitou Spring, by levels from railroad-bench, by E. S. Nettleton, C. E.	1,153. 32	Above Denver K. P. depot.	
Rock basin of Manitou Spring			6,296. 92

ELEVATION OF PIKE'S PEAK.

I am greatly indebted to Mr. E. S. Nettleton, civil engineer, for a report dated June 29, 1874, of a line of levels which he has just run from a D. & R. G. R. W. bench at Colorado Springs to the exact summit of Pike's Peak. The line was run on the request of Gen. Albert J. Meyer, Chief Signal-Officer, U. S. A., and at the expense of the War Department, for determining the elevation of the United States Signal-Office meteorological station, which is situated on the summit of the peak.

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
Exact highest rock on Pike's Peak	8,950. 1	Above Denver K. P. depot.	
Do			14,146. 68

ELEVATION OF MOUNT LINCOLN AND FAIRPLAY.

The D. & S. P. R. R. having run a line of levels for the final location of their railroad up to Fairplay, we secured the services of their engineer to continue the line to the summit of Mount Lincoln, at the expense of our survey. The object of this was to determine the exact elevation of our barometric station situated near the top of the peak. The following are the results of this line of railroad levels:

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
Denver (D. P. & K. P.) depot			5,196.58
Door-sill of Sentinel office Fairplay	4,767.91	Above Denver depot	
Do			9,964.49
Cistern of Mount Lincoln barometer	8,991.05	Above Denver depot	
Do			14,187.63
Summit of Mount Lincoln	9,100.08	Above Denver depot	
Do			14,296.66

ELEVATION OF POINTS ON THE OHIO RIVER.

Pittsburgh, union depot track			746.00
Pittsburgh, L. W. city-datum	46.80	Below Union depot track	
Do			699.20
Pittsburgh, H. W. 1852			729.88
Pittsburgh, H. W. 1832			732.95
(These data are from report of city engineer, March 15, 1871.)			
Steubenville P. C. & St. L. R. R. depot track, by P. C. & St. L. R. R.	14.74	Below Pittsburgh depot	
Steubenville depot, P. C. & St. L. R. R.			731.26
Steubenville, L. W. in Ohio, by old P. & S. R. R.	68.43	Below L. W. in Ohio at Pittsburgh.	
Steubenville, L. W. in Ohio			630.77
Steubenville, about H. W. 1852, by C. & P. R. R.	103.55	Above Cleveland directrix	
Do			679.23
Bridgeport, about H. W. 1852, by C. & P. R. R.	96.55	Above Cleveland directrix	
Bridgeport, about H. W. 1852			672.23
(Bridgeport is opposite Wheeling.)			
Bellaire, 5 miles below Bridgeport, about H. W. 1852, by C. & P. R. R.	84.55	Above Cleveland directrix	
Do			660.00
Wheeling, H. W. February 1832, by B. & O. R. R.			[637.00]
By the same report the channel is given at			[588.00]
(These B. & O. R. R. results are considered too low, as they give an improbable fall to the Ohio from Steubenville. The L. W. fall from Pittsburgh to Steubenville is known by the P. & S. R. R. survey to be about one foot per mile. The report of the C. & P. R. R. for Bellaire seems to give the most probable result. From Steubenville to Bellaire the distance by river is about twenty-eight miles, therefore L. W. at Bellaire, giving the maximum probable fall one foot per mile.)			
Bellaire, L. W. about	60.3	Above sea	
Bellaire, H. W. about	65.1	do	
Bellaire, about H. W. 1852, by report of C. & P. R. R.	84.55	Above Cleveland directrix	
Bellaire, about H. W. 1852			660.00
(This result is about what it should be, for it is not probable that the fall here is one foot per mile. If the B. & O. R. R. result was true, it would give the river a fall of 42 feet in 23 miles. I therefore consider it most probable that Wheeling H. W. 1852 is about 663 feet, and the B. & O. R. R. report of 637 for H. W. 1832 is some thirty feet too low.)			
Parkersburgh, by several reports of B. & O. R. R., point not given.	523.7	Above M. T., Baltimore	
By the report of the engineers running the line from Parkersburgh to Cincinnati, the B. & O. Parkersburgh L. W.	573.00	do	
(I accept the latter, because it accords best with the next check at Point Pleasant, about seventy miles down the river.)			
Parkersburgh, L. W. in Ohio			573.00
Point Pleasant, very L. W. at mouth of Great Kanawha.	522.00	Above M. T., Richmond, Va.	
By two lines of levels agreeing within a foot			522.00
Portsmouth, Ohio, L. W. in Ohio River, by C. & X. R. R. report.	94.00	Below L. Erie	
Portsmouth, L. W.			479.00
Cincinnati, L. W. city base			439.74
Indianapolis, union depot track	721.75	Above M. T.	
Greencastle junction, by T. H. & I. R. R.	56.00	Above Union depot, Indianapolis.	
New Albany, passenger depot	326.00	Below Greencastle	

	Feet.	Various datum-planes.	Elevation in feet above mean surface of Atlantic Ocean.
New Albany, L. W. in Ohio River, by L. N. A. & C. R. R.	398. 00	Below Greencastle	
New Albany, passenger depot			451. 75
New Albany, L. W. of 1857 in Ohio River			379. 75
(This was not one of the years of lowest water, but it was probably about four feet above it.)			
Louisville, L. W	24. 00	Above New Albany, L. W.	
Louisville, L. W. 1857			403. 75
Evansville, L. W	81. 00	Below Vincennes	
Evansville rail, by E. & C. V. R. R	36. 00	do	
Vincennes	434. 39	Above M. T.	
Evansville, L. W. Ohio River			353. 39
Evansville, depot rail			398. 39
Evansville, H. W. 1847	334. 54	Below Union depot track	
By survey for E. & I. R. R., H. W. 1847			387. 22
Evansville Railroad track, by St. L. & S. E. R. R	35. 2	Below Saint Louis directrix	
Evansville Railroad track			393. 08
Evansville, L. W			348. 08

ELEVATION OF CAIRO.

First determination.			
Cairo, I. C. R. R. track on levee, by C. & V. R. R	96. 5	Below Vincennes	
Do			337. 89
Cairo, H. W. Ohio River, by C. & V. R. R	97. 00	Below Vincennes	
Do			337. 39
Cairo city-base, by engineer in charge of levees	43. 00	Below Illinois Central track	
Cairo city-base, ordinary L. W			294. 89
Second determination.			
Cairo, H. W. Ohio River, by mean of four routes, (see discussion of change in Saint Louis directrix, p. —)	96. 05	Below Saint Louis directrix	
Cairo, H. W. Ohio River			332. 24
Cairo city-base	41. 00	Below mean of highest floods	
Do			291. 24
Third Determination.			
Cairo, H. W. 1858 in Ohio River		Above M. T. New Orleans.	331. 51
Cairo city-base			291. 13
Fourth determination.			
Cairo, H. W. Ohio River	258. 50	Below Chicago directrix	
Do			328. 65
Cairo, city-base			287. 65
Final results.			
Cairo city base:			
First determination	294. 89	By Cincinnati	
Second determination	291. 24	By Saint Louis	
Third determination	291. 13	By New Orleans	
Fourth determination	287. 65	By Chicago	
Mean	291. 23		
Adopted result			291. 23
(By report of engineer in charge of levee construction,)			
Cairo, extreme L. W. October 15, 1871	11. 91	Below city-base	
Cairo, ordinary L. W	0. 00		
Cairo, H. W. 1858	40. 38	Above city-base	
Cairo, H. W. 1862	41, 69	do	
Cairo, H. W. 1867	41. 81	do	
Cairo, Illinois Central track on levee	43 to 43. 5	do	
Cairo Hotel, northeast corner	43. 26	do	
Cairo, Mississippi levee	44. 00	do	

Elevations of points determined in this investigation.

NOTE.—The evidence upon which each rests may be seen by reference to the map and foregoing text.

Names of determined points.	State.	Elevation in feet above mean surface of Atlantic Ocean.
Albany, mean tide in Hudson River	New York	4.84
Altoona, track P. R. R. station	Pennsylvania	1,177.91
Alliance, track P. F. W. & C. R. R. station	Ohio	1,082.88
Atchison, H. W. Missouri River, (supposed to be 1844)	Kansas	809.88
Atchison, L. W. Missouri River	...do	784.88
Athens, railroad-station	Ohio	647.01
Belmont, track of St. L. & I. M. R. R	Missouri	328.00
Buffalo, bottom of Erie Canal	New York	564.26
Buffalo, theoretical surface of Erie Canal	...do	573.26
Buffalo mean surface of Lake Erie	...do	573.08
Burlington, H. W. 1851 in Mississippi River	Iowa	529.32
Burlington, L. W. Mississippi River	...do	511.89
Burlington, Main street depot	...do	531.61
Carmi, junction of C. & V. and St. L. & S. W. R. R	Illinois	416.09
Cambridge, W. W. Val. R. R. depot	Ohio	947.74
Cairo, city-base = ordinary L. W. Ohio River	Illinois	291.23
Cairo, extreme L. W. October 18, 1871, Ohio River	...do	279.32
Cairo, H. W. 1858, Ohio River	...do	331.61
Cairo, H. W. 1862, Ohio River	...do	332.92
Cairo, I. C. R. R. track on levee	...do	334.48
Canton depot	Mississippi	240.00
Cedar Rapids, C. & N. W depot	Iowa	741.15
Cedar Rapids, city-datum, L. W. foot of Iowa avenue	...do	717.85
Cheyenne, track at U. P. R. R. passenger-depot	Wyoming	6,075.28
Chicago, city directrix	Illinois	587.15
Chicago, mean surface of Lake Michigan for the past 20 years	...do	589.15
Cincinnati, city directrix = L. W. in Ohio River	Ohio	439.74
Cincinnati, H. W. 1832, Ohio River	...do	502.24
Cleveland, city directrix	Ohio	575.68
Cleveland, mean surface of Lake Erie	...do	573.08
Clinton, bridge over Mississippi River	Iowa	611.15
Clinton, H. W. 1864, Mississippi River	...do	593.15
Columbus, depot track of P. C. & St. L. and C. C. C. & I	Ohio	742.60
Columbus, H. W. 1858, Mississippi River	Kentucky	320.01
Colorado Springs, depot track D. & R. G. R. R	Colorado	5,985.58
Colorado Springs, Colorado Springs Hotel floor, (see Manitou)	...do	6,023.25
Council Bluffs, union depot track	Iowa	999.70
Crestline, P. F. W. & C. depot track	Ohio	1,152.74
Davenport, old depot track, corner Fifth and Perry streets	Iowa	591.88
Davenport, railroad level datum of C. R. I. & P	...do	559.88
Davenport, top of west abutment of railroad-bridge	...do	589.06
Davenport, H. W. Mississippi River	...do	569.88
Davenport, L. W. Mississippi River	...do	553.22
Davenport, city-base of levels	...do	547.88
Decatur, I. C. R. R. depot	Illinois	675.65
Denver, K. P. & D. P. R. R. depot track	Colorado	5,196.58
Denver, D. & R. G. R. R. depot track	...do	5,197.58
Detroit, mean surface of river	Michigan	577.05
Dubuque, L. W. Mississippi River, I. C. R. R. datum	Iowa	599.15
Effingham, I. C. R. R. depot track and St. L. V. & T. H. R. R. depot	Illinois	599.10
Erie, L. S. & M. S. R. R. depot track	Pennsylvania	686.68
Evansville, depot track	Indiana	395.60
Evansville, L. W. in Ohio River	...do	350.60
Evansville, H. W. 1847, Ohio River	...do	384.43
Fairplay, door-sill of Sentinel office before fire of 1873	Colorado	9,964.49
Fremont, U. P. R. R. depot track	Nebraska	1,213.90
Fulton, H. W. 1864, Mississippi River	Illinois	593,15
Gloucester Point, permanent United States Coast Survey bench on granite block	New Jersey	8.10
Gloucester, mean tide in Delaware River	...do	3.35
Golden, city and railroad directrix	Colorado	5,728.98
Grand Haven, mean surface of Lake Michigan	Michigan	589.15
Grenada depot	Mississippi	184.00
Greencastle, junction depot	Indiana	777.75
Hannibal, H. W. 1851, Mississippi River	Missouri	485.10
Harrisburgh, Pa. R. R. depot track	Pennsylvania	319.91
Hickman, H. W. 1858, Mississippi River	Kentucky	313.01
Indianapolis, Union depot track	Indiana	721.75
Indianapolis, city base L. W. in White River	...do	688.67
Kansas City, H. W. 1844 of Missouri River, as marked on abutment of R. R. Bridge	Missouri	770.77
Kansas City, track of K. P. R. W. at State line	...do	763.52
Kearney junction depot	Nebraska	2,156.90
Keokuk, C. B. & Q. R. R. depot	Iowa	508.22
Keokuk, city base	...do	487.72

Elevations of points determined in this investigation—Continued.

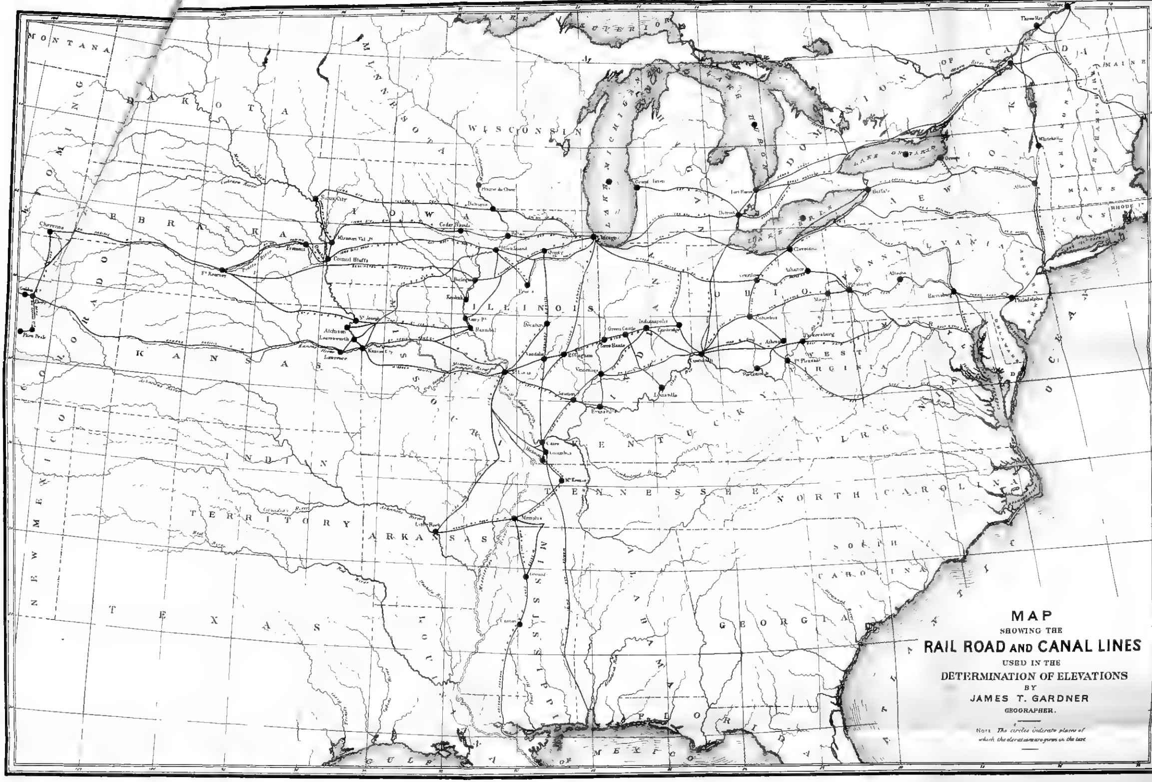
Names of determined points.	State.	Elevation in feet above mean surface of Atlantic Ocean.
Keokuk, H. W. 1851, Mississippi River	Iowa	502. 55
Keokuk, L. W. (extreme) Mississippi River	...do	481. 83
Lawrence, K. P. R. W. & L. & L. branch junction	Kansas	831. 52
Lawrence, K. P. R. W. depot track	...do	845. 52
Leavenworth, city-datum, extreme L. W. Missouri River, Jan., 1867	... do	763. 89
Leavenworth, H. W. Missouri River, (probably 1844)	...do	788. 89
Little Rock, C. & F. R. R. depot	Arkansas	309. 29
Louisville, L. W. in Ohio River, above falls*	Kentucky	403. 75
Lake Champlain, mean surface at Whitehall		100. 84
Lake Ontario, mean surface at Oswego		250. 00
Lake Erie, mean surface at Buffalo and Cleveland from 1844 to 1857		573. 08
Lake Michigan, mean surface since 1853 at Chicago		589. 15
Lake Huron		589. 15
Manitou Springs, rock around the Manitou Spring	Colorado	6, 296. 92
McKenzie junction depot	Tennessee	488. 21
Memphis, H. W. in Mississippi River previous to 1858, and is 100 feet above city-datum	...do	218. 65
Mendota, C. B. & Q. R. R. depot	Illinois	756. 22
Missouri Valley junction	Iowa	1, 019. 70
Mount Lincoln, extreme summit	...do	14, 296. 66
Mount Lincoln, cistern of barometer in 1873	...do	14, 187. 63
Montreal, summer water-level in river	Canada	30. 00
New Albany, depot of L. N. A. & C. R. R	Indiana	451. 75
New Albany, L. W. 1857, Ohio River	...do	379. 75
Ogden, U. P. & C. P. R. R. depot track	Utah	4, 303. 30
Omaha, base of levels of U. P. R. R., L. W. in Missouri River	Nebraska	977. 90
Omaha, H. W. in Missouri River	...do	996. 90
Omaha, bed of river	...do	964. 10
Omaha, bench heretofore called 966 feet above the sea	...do	997. 90
Omaha, track at present depot in main line U. P. R. R	...do	1, 060. 40
Omaha, tops of east and west abutments of railroad-bridge	...do	1, 049. 40
Oswego, mean surface of Lake Ontario	New York	250. 00
Parkersburgh, L. W. in Ohio River	West Virginia	573. 00
Peoria, city-datum, L. W. in Illinois River	Illinois	439. 00
Peoria, C., R. I. & P. R. R. depot	...do	464. 70
Pittsburgh, Union depot track	Pennsylvania	746. 00
Pittsburgh, city-datum, L. W. in river	...do	699. 20
Pittsburgh, H. W. 1852	...do	729. 88
Pittsburgh, H. W. 1832	...do	732. 95
Pike's Peak, exact summit	Colorado	14, 146. 68
Pike's Peak, top of U. S. G. & G. survey monument on east side of summit	...do	14, 124. 84
Philadelphia, city-datum	Pennsylvania	8. 733
Philadelphia, Pa. R. R. datum or base of levels	...do	6. 913
Philadelphia, mean tide in Delaware River	...do	3. 349
Philadelphia, high tide in Delaware River	...do	6. 484
Philadelphia, low tide in Delaware River	...do	0. 214
Point Pleasant, very L. W. in Ohio River	West Virginia	522. 00
Portsmouth, L. W. in Ohio River	Ohio	479. 00
Port Huron, mean surface of Lake Huron	Michigan	589. 15
Port Sarnia, mean surface of Lake Huron	Canada West	589. 15
Port Sarnia, G. W. R. W. track	...do	593. 15
Prairie Du Chien, probable L. W. in Mississippi River	Wisconsin	613. 00
Quincy, C., B. & Q. R. R. depot	Illinois	495. 22
Quincy, L. W. 1854 Mississippi River	...do	472. 39
Quincy, H. W. 1851 Mississippi River	...do	493. 11
Quebec, mean high tide in Saint Lawrence River	Canada	15. 37
Rock Island, C., R. I. & P. depot track	Illinois	568. 68
Rock Island, H. W. 1852 Mississippi River	...do	566. 68
Rock Island, city-base	...do	546. 68
Sioux City, R. R. track on levee	Iowa	1, 123. 35
Sioux City, bed of Missouri River	...do	1, 094. 00
Sioux City, L. W. Missouri River	...do	1, 104. 00
Saint Joseph, H. W. Missouri River	Missouri	820. 11
Saint Louis, city directrix	...do	428. 29
Saint Louis, H. W. 1844, Mississippi River	...do	435. 87
Saint Louis, H. W. 1858, Mississippi River	... do	431. 57
Saint Louis, H. W. 1851, Mississippi River	... do	431. 17
Saint Louis, L. W. extreme	...do	394. 48
Saint Louis, ord. wa. Mississippi River	...do	408. 00
Saint Louis, center of bridge on R. R. track	...do	485. 80
Saint Louis, center of bridge on wagon-road	...do	510. 04
Steubenville, L. W. in Ohio River	Ohio	630. 77
Terre Haute, T. H. & Ind. depot	Indiana	504. 75
Terre Haute, H. W. in Wabash River	...do	485. 45

*This determination is not checked, and should not be considered of equal quality with the others.

Elevations of points determined in this investigation—Continued.

Names of determined points.	Name of State.	Altitude in feet above the mean surface of the ocean.
Terre Haute, ord. wa. Wabash River	Indiana	467.45
Terre Haute, bed Wabash River	....do	453.95
Three Rivers, mean tide	Canada	15.00
Vincennes, Ind. & V. R. R. depot track	Indiana	434.39
Vincennes, H. W. in Wabash River	....do	425.39
Vincennes, L. W. in Wabash River	....do	413.39
Vandalia, junction of track of St., L. V. & T. H. & Ill. C. R. R	Illinois	511.89

3.


MAP
SHOWING THE
RAIL ROAD AND CANAL LINES
USED IN THE
DETERMINATION OF ELEVATIONS
BY
JAMES T. GARDNER
GEOGRAPHER.
Note. The circles indicate places of which the elevations are given in the text

TOPOGRAPHICAL REPORT OF MIDDLE PARK DIVISION, 1873.

BY S. B. LADD, M. E.

Introductory letter to Dr. F. V. Hayden.

WASHINGTON, D. C.

SIR: In accordance with your instructions, I herewith present a report on the topographical work of the Middle Park division of the United States Geological and Geographical Survey of the Territories for the year of 1873.

As Mr. A. R. Marvine, in his report as a director as well as geologist of this division, has necessarily given all the statistical facts and general description of the surface of the country which go to make up a topographical report, I have thought best, rather than duplicate that portion of it, to refer you to the first part of his report, and to give here a general account of the extent of timber, grazing, and agricultural lands, and the means of travel and communication; also, some notes on the rain and snow fall of the country and the present population, for which I am greatly indebted to Mr. William N. Byers, of Denver, who previous to the establishment of the signal-service station there kept a meteorological record for the Smithsonian Institute. I would also like to express my thanks to Dr. C. C. Parry for information afforded me.

Very respectfully, yours,

S. B. LADD.

F. V. HAYDEN,
United States Geologist in Charge.

REPORT.

The territory surveyed by the Middle Park division during the season of 1873, is embraced between the parallels of north latitude 39° 30′ and 40° 20′, and between longitude 104° 45′ and the Park range, which forms the western boundary of the Middle Park; this has a northeast and southwest trend, and the meridian 106° 30′ would be an average western limit.

The total area covered, about 5,400 square miles, was not as large as was intended at the outset; this was due to the nature of the country on the eastern slope of the mountains, which rendered a large number of stations necessary, and as it is quite thickly settled it was thought desirable to procure as much detail as possible.

The topographical features of a country being but the expression of its geological structure, a thorough discussion of the latter must necessarily involve a description of the former, in order to make the geological report intelligible to the reader who is not familiar with the country. Therefore, rather than repeat a general description of the topographical features of the country surveyed by us this year, I will refer you to the first pages of the geological report of Mr. A. R. Marvine, where he has given all that can be said on the subject.

The district surveyed may be divided into three natural areas, separated by the line formed by the eastern edge of the mountains where the sedimentary beds are upturned against the metamorphic rocks, forming the ridges known as the Hog-backs; and by the line of the main watershed of the continent. The Hog-backs make a sharp line of demarkation between the plains and the mountains; the plains being essentially destitute of timber, except a growth of cottonwoods and willows along the streams.

The central mountainous portion, drained by Big and Little Thompson Creeks, Saint Vrain's Creek, Bowlder Creek, Clear Creek, and Bear Creek, with their numerous branches and forks, all of which are tributaries of the South Platte River, contains about 1,700 square miles.

The ridges and mountains are well timbered, mostly with the yellow and white pines, *Pinus ponderosa* and *Abies Engelmanni*, and the parks and valleys bear a fine growth of scattered timber.

In the vicinity of the mining towns a great deal of the timber has been cut, and in places over large districts it has been destroyed by fire; 1,200 square miles of this section is timber-bearing, the remainder being either above timber-line or else taken up in the open valleys and parks.

The western division, including the Middle Park, contains about 2,025 square miles, all of which is drained by the Grand River and its tributaries. This area may be divided into timber, grazing and farming, or bottom lands.

The spurs thrown out from the main range which surrounds the park on the north, east, and south, and the ridges and mountain masses forming the divides of the principal streams, are well timbered, especially in the eastern half of this section.

The relation between the geological formations and the growth of timber is very interesting. There is apparently a greater change from this cause than that due to difference in altitude.

The hills formed by the metamorphic rocks, wherever they occur, except above timber-line, grow good timber, mostly white pine, although on western slopes it is smaller, and therefore of poorer quality than on eastern. The amount of this granite-timber area is about 675 square miles.

The lignitic areas, which comprise a large portion of the park, as the Williams Mountains, and the greater portion of the country drained by the Willow, Corral, and Troublesome Creeks, are essentially timber-regions; but the quality of the timber is very inferior to that growing on the metamorphic rocks, and the southern slopes are generally bare.

Over large areas the timber has fallen, making it often difficult to travel away from the trails. This class of timber-land might be estimated at 425 square miles.

The regions covered by the lake-beds are, as a rule, totally destitute of timber.

The areas covered by Cretaceous No. 1 bear timber, while the remainder of this formation, usually occupying the lower valleys and partially covered by the lake-beds, does not represent a timber-country. This is illustrated in the valley of the Blue, where the timber-growth follows the outcrop of Cretaceous No. 1 across the valley. This class covers about 150 square miles of country.

The hills capped with lava grow timber. All told there are about 1,250 square miles of timber-land in this western subdivision.

Along the valleys of the Williams, Blue, and Muddy Rivers, and also to a smaller extent in the valley of the Frazier and some of the smaller streams, there are broad tracts of terraced prairie country, 400 square miles altogether, covered mostly with the lake-beds, and growing short bunch-grass and often sage-brush, available for grazing only, at least for some time to come.

The river-bottoms of all the streams furnish fine farming-land, especially east of the Hot Springs, along the Upper Grand and its branches.

Below the Hot Springs the Grand River is bordered with broad bottom-lands along its course to the cañon in the Park range. Large tracts of land could easily be made cultivatable by irrigation.

The total amount at present capable of cultivation I should estimate at 175 square miles, a liberal estimate, ranging in elevation from 7,183 feet above sea-level, which is the height of the mouth of Blue River, up to 8,463 feet, the altitude of the Frazier Valley. Grain can be raised at an elevation of 9,000 feet, but above 7,000 feet or 7.500, it is liable to be injured by frosts. Potatoes and the common vegetables can be cultivated up to 9,000 feet elevation.

The eastern slope of the mountains and the portion of the plains bordering the mountains are so well settled, and the means of communication between the many towns and settlements so numerous that it would not be advisable to give a detailed description of them, and I will confine myself to the main lines of travel and the ways of communication open into the Middle Park.

Denver now has railroad communication with all the large towns scattered along the base of the mountains. The Denver Pacific, running north, connecting with the Union Pacific Railroad at Cheyenne; the Kansas Pacific, running east to Kansas City, and the Denver and Rio Grande Railroad south to Pueblo, and eventually, when completed, to Santa Fé, N. M. The Colorado Central Railroad connects Denver with Golden City, Boulder City, Valmont, and Longmont. A narrow-gauge branch of the Colorado Central Railroad passes up the famous Clear Creek cañon, follows the windings of the stream, branching at the junction of North Clear Creek, one branch following up that fork to Black Hawk and Central City, and the other up the main stream to Floyd Hill, five miles below Idaho.

Most of the main streams draining the eastern slope have roads following up their valleys whenever it is practicable, and winding along the ridges when the cañons become impassable.

Estes Park, near Long's Peak, is accessible by means of a road from Longmont. Jamestown and Gold Hill are connected with the plains by roads up Jim Creek, Left-Hand and Four-Mile Creeks.

Caribou has a tri-weekly stage to Black Hawk and Central City, passing through Middle Boulder and Rollinsville. All the towns are connected with each other by good roads.

Georgetown, Idaho, and the settlements on Clear Creek, have daily connection with Floyd Hill, the present terminus of the railroad, thereby giving daily connection with Denver.

The Denver and South Park road enters the mountains at Turkey Creek cañon and follows the general course of that stream to its source, then across to the North Fork of the South Platte, then across the divide into South Park, through Hamilton to Fair Play.

At Hamilton, a road connects with Breckinridge, from which town there is a tri-weekly stage connecting at Hamilton with the daily stage from Fair Play to Denver.

From Georgetown a road crosses the divide at the Argentine Pass, southeast of Gray's Peak, at an elevation of about 13,100 feet, passes down the Snake River, two miles below Montezuma, with which there is a connecting road, and joins the road down the Blue River at the junction of the streams.

A trail connects Georgetown with the Denver and South Park Road, joining the latter at the mouth of the North Branch of the North Fork of the South Platte.

Four miles above Grant post-office on the South Park Road a trail turns off to Montezuma.

At Jefferson, on the South Park Road, a road, formerly the stage-road, branches off, crosses over Jefferson Pass to Georgia Gulch, and joins the road down Snake River.

A trail not often used except for the ascent of Gray's Peak, crosses between Gray's and Torrey's Peaks connecting Montezuma with Georgetown.

At present there are a number of trails crossing the main crest, and this season a good wagon-road has been built.

Commencing at the north, there is no way known of crossing the summit ridge until we go as far south as Arapahoe Peak. Up to this point the mountains are very rough, averaging 13,000 feet in height, Long's Peak rising to 14,271 feet, with no passes between the peaks.

The eastern side is bordered with a line of steep precipices and amphitheaters, filled with immense snow-fields and inclosing countless lakes. The precipice on the eastern face of Long's Peak, a sheer wall extending from the summit to timber-line, is over 3,000 feet in height by barometric measurement.

South of Arapahoe Peak a trail crosses from Caribou over into the park, passing by the Fourth of July lode. It is used only by the miners of that district, and is not an easy way of reaching the park.

Next in order, going south, is the new road, passing up South Boulder Creek from Rollinsville and crossing the summit-ridge where the Ute trail crosses near the center of the low portion of the range between Arapahoe and James Peaks at an elevation of 11,613 feet. It then winds down the western slope into the valley of the Frazier, which it follows nearly to the cañon, when it swings to the west to the Hot Springs.

A road was started from Central City with the intention of continuing it over into the park; it is now built as far as James Peak and makes the ascent of that peak very easy, as it extends nearly to the summit. An excellent trail leaves this road near its terminus and crosses the range to the north of James Peak, joining the Boulder road down in the valley of the Frazier.

Berthoud's trail, starting from Empire City, follows up the North Fork of South Clear Creek, crosses the divide below timber-line through Berthoud's pass at an elevation of 11,316 feet, and passes down Moses Creek.

Vasquez's trail is the continuation of Berthoud's on the eastern side and crosses through Vasquez's Pass, the next in order southwest of Berthoud's, at an elevation of about 11,500 feet.

Vasquez's, Berthoud's, and the James-Peak trails join on the western side, and farther down in the park the combined trail joins the wagon road to the Hot Springs.

Jones's trail follows up the North Fork of South Clear Creek from Empire, and crosses through Jones's Pass about five miles southwest of Vasquez's Pass, at an elevation of 12,513 feet, (Parry,) follows down the Williams River to within a few miles of its junction with the Grand, when it turns to the west and crosses the hills to Jones's ranch on the Grand near the mouth of the Troublesome River.

This covers all the roads and trails now open into the park from the east, the only other way of reaching it being from Montezuma or Breckenridge by means of the valleys of the Snake and Blue Rivers.

A good road is built down the valley of the Blue from Breckenridge, joined by the one from Montezuma down the Snake. It follows the Blue to a point about three miles from its mouth, when it crosses the hills forming the divide between the Blue and Williams Rivers to Jones's ranch on the Grand, and follows up the north side of the Grand to the Hot Springs. A trail which joins this road passes up Ten-Mile Creek and crosses over to the Eagle River, west of the Park range. Another trail leaves this road on the east and crosses through Ute Pass to the north of Ute Peak, goes almost straight to the Hot Springs, considerably shortening the distance. Within the park communication between the different portions is easy.

A road passable for wagons leaves the Boulder road at a point thirteen miles from the Hot Springs, and crosses to the Frazier below the cañon, then to the Grand and up the Grand to Grand Lake.

Berthoud's road to the White River agency and Utah crosses the hills from the Hot Springs to a ford on the Troublesome, about four miles from its mouth, then across to the Muddy and through Gore's pass in the Park range to the headwaters of the Bear River.

A trail leaves this road and runs north across the main divide from the headwaters of the Muddy into North Park.

The continental divide at this point between the Middle and North Parks is only a low rolling country, about 9,400 feet in elevation, and easily crossed at any point.

A trail up the Troublesome River crosses to the west of Park View Mountain into the North Park, and one up Willow Creek crosses to the east of Park View at an elevation of 9,683 feet.

The heavy falls of snow which blockade the mountain-passes make access or egress to and from the park in winter very difficult, and almost impossible, except by the road up the valley of the Blue to Breckenridge, with which communication is generally kept open during the whole year.

In Denver the average rain-fall is 12 inches per annum, and probably in the Middle Park 18 inches. Along the main crest of the mountains, and for a distance of five miles on either side, the yearly rain-fall will probably reach 25 inches.

The time for the first heavy fall of snow is very variable and no precise rule can be given. Often a heavy fall of snow comes late in October or early in November, sufficient to close the mountain-passes for the winter; but if there is not a heavy snow-storm then, there will be none until the last of February or early in the spring.

For about one-half of the winters a great deal of snow falls between the 20th of October and the 15th of November, and for the remaining years the greatest amount will fall between the 20th of February and the 25th of March. One of the severest storms known was on the 24th of March, when 3 feet of snow fell at Denver, and in the mountains the fall was 5 feet. The greatest depth of snow that has fallen at one time was on the 22d of October, 1866, when the fall on the Snake and Blue Rivers was about 6 feet.

The snow remains in the mountains until the first or middle of June. The passes are not open generally until the last of May, and then they have to be shoveled out; if left to themselves they would not be passable until the last of June.

The winter of 1872 and 1873 was quite mild and open, and horses crossed the mountain-passes as late as the last part of February, but the heavy spring-snows blocked the trails, and in the middle of June there was still 5 feet of snow in the Berthoud Pass. In 1867 there was a large amount of snow there as late as the 29th of June.

The new road from Rollinsville across the main divide is closed this winter by the snow, and it will be impossible to keep it open during the winter-season, as it crosses above timber-line.

The most practicable route for a road to be kept open the whole season, in case the settlements in Middle Park increase sufficiently to require it, is through the Berthoud Pass, where it can cross below timber-line.*

A list of the towns, with the date of their settlement, the population as given in the census-report of 1870, together with their present population, as gathered from various sources, is appended.

	Year of settlement.	Population.	
		Census 1870.	Estimated. 1873.
Black Hawk	1859	1,068	1,500
Boulder City	1859	343	1,500
Breckenridge	1860	....	250
Caribou	1870	....	400
Central City	1859	2,360	3,000
Denver	1859	4,759	15,000
Empire	1860	....	50
Erie	1871	....	400
Georgetown	1861	802	3,500
Golden City	1859	587	2,000
Gold Hill	1860	....	600
Idaho	1859	229	400
Jamestown	1866	....	25
Longmont	1871	....	800
Nederland, formerly Middle Boulder	1871	....	600
Mill City	1861	....	75
Montezuma	1864	....	100
Mount Vernon	1859	31	30
Nevada City	1859	973	800
Peru	1865	....	25
Silver Plume	1871	....	200
Valmont	1864	....	150
Ward District	1862	....	200

The towns and mining-camps on the Blue and Snake Rivers are almost deserted in the winter, with a very variable population in the summer. Empire, now almost forsaken, was once very active and prosperous. Gold Hill was of considerable importance when first settled, and then declined until it was nearly deserted, but within the last year or two, since the discovery of the rich telluride ores at the Red Cloud and Cold Spring mines, it has returned to its former prosperity. A number of towns and mining-camps, like Gold Dirt and Bakerville, are now entirely abandoned.

* Since this was written a road has been built over this pass, connecting Empire City directly with the Hot Springs in Middle Park, and a bridge across the Grand River at the Springs renders crossing there possible at all seasons of the year.

The heights of the mountains, &c., given are mostly barometric, a few only being determined trigonometrically from adjacent points, and those are marked with a *t*. The heights of Gray's and Torrey's Peaks are determined by angles of elevation and depression from Mount Lincoln, fore and back sights having been taken. The height of Mount Lincoln is determined by means of a line run with spirit-level, and one of the base-barometers was stationed near its summit, so that the Lincoln barometer has been used as a base for determining the heights of peaks above timber-line. But the barometer was not located on Lincoln until after Gray, Torrey, and also Mount Evans were visited, so the trigonometric heights of these mountains are given as being nearer the true height than a barometric determination referred to Denver as a base, 9,000 feet below.

Capt. E. L. Berthoud calculated the height of Long's Peak, from a base line, 8,400 feet in length, measured near the Big Thompson, as 13,767, assuming the bench at Golden City as 5,300; this, when reduced to sea-level, gives the height of Long's Peak as 14,196 feet. The height calculated from our barometric observations is 14,271 feet.

All the heights depend upon the altitude of Denver, which has been taken as 5,196.58 feet for the depot of the Kansas Pacific Railroad, and as 5,244.58 feet for the Denver signal-service barometer.

The heights at Golden City and along the line of the Colorado Central Railroad to Longmont are taken from the levels of the construction-line of that road. The heights on Clear Creek up to Black Hawk are also from the Colorado Central Railroad levels.

The heights of Georgetown, Downieville, and Fall River are determined from the survey for the Denver, Georgetown, and Utah Railroad, and are the best results at present obtainable. The connection with the Colorado Central Railroad levels is made at the bridge in Idaho. Capt. E. L. Berthoud's preliminary survey made in 1866 agrees very well at corresponding points. His levels make the height of Fall River as 7,719 feet; Downieville, 8,018 feet; and Georgetown, lower bridge, 8,514 feet. This survey was carried over Berthoud's Pass, the summit being 11,313 feet.

MOUNTAINS.

	Elevation.
Arapahoe, front range	13, 520
Audubon, front range	*t*13, 173
Bald Mountain, front range, near Ward District	11, 493
Mount Morrison, foot-hills	7, 903
Bergen's Mountain, overlooking Bergen's Park	9, 773
Bross, Middle Park, overlooking the Hot Springs	9, 468
Byers, Middle Park, divide between Williams and Frazier Rivers	12, 778
Chief, foot-hills	11, 833
Coffin Top, overlooking Antelope Park	8, 003
Conical Butte, Middle Park, upper Valley of the Muddy	9, 848
Corral Peak, at the park head of Corral Creek	11, 333
Evans, front range	*t*14, 330
Gray's Peak, front range	*t*14, 341
Griffith Mountain, overlooking Georgetown	11, 273
High Point, front range, south of the Boulder road	11, 988
Hog-Back, between Big and Little Thompson Creeks	7, 923
James Peak, front range	13, 283
Lillie's Mountain, near Este's Park	11, 433
Long's Peak, front range	14, 271
McClellan, front range	*t*13, 423
Mount at head of Turkey and Cub Creeks	10, 623
Park View, between Middle and North Parks	12, 433
Powell, Park Range	13, 398
Prospect Hill, in Este's Park	8, 893
Ralston Butte	10, 593

	Elevation.
Rosalie, front range	t14, 340
Smith's Peak, front range	t13, 093
South Boulder Peak, foot-hills	8, 533
Squaw, foot-hills	11, 733
Station LX, south end of the Medicine Bow Range	12, 513
Station LXVII, Middle Park, Lower Valley of the Muddy	t8, 263
Sugar-Loaf, foot-hills	8, 933
Torrey's Peak, front range	t14, 336
Ute Peak, Middle Park	t11, 968
Williams, Middle Park	t11, 413
Whiteface Mountain, north of the Hot Springs	t11, 493

PASSES.

Summit of the Boulder road	11, 613
Berthoud's Pass, (Parry)	11, 462
Berthoud's Pass, E. L. Berthoud's preliminary railroad survey of 1866	11, 316
Jones's Pass, (Parry)	12, 513
Pass at head of Willow Creek to North Park	9, 683
Divide at head of Muddy River, (about)	9, 400

TOWNS AND MISCELLANEOUS HEIGHTS EAST OF THE MAIN DIVIDE.

Denver, Kansas Pacific Railroad depot	5, 196. 58
Denver, United States signal-service barometer	5, 244. 58

FROM RAILROAD SURVEYS.

Golden Depot	5, 687
Golden Junction	5, 615. 4
Ralston Station	5, 606
Ralston Creek, water	5, 579
Church Station	5, 439
Rock Creek	5, 309
Coal Creek	5, 329
Coal Creek siding	5, 349. 7
Davidson	5, 409
Lake side	5, 252
South Boulder Creek	5, 236
North Boulder Creek	5, 234
Crossing of Boulder Valley Railroad, depot	5, 278
Ni Wot, depot	5, 118
Longmont depot	4, 956. 5
Longmont town	4, 976
Guy Gulch, up Clear Creek	6, 204
Beaver Creek, up Clear Creek	6, 411
Fork of North and South Clear Creek	6, 893
Fish Creek	6, 889
Black Hawk	7, 975
Soda Creek	7, 531
Idaho, north end of bridge at east end of town	7, 535
Fall River, water	7, 719
Downieville	8, 018
Georgetown, Alpine street, about 400 feet east of the north branch of Clear Creek	8, 530. 4
Foot of Berthoud's Pass, Berthoud's preliminary railroad line of 1866	9, 615

BAROMETRIC.

Terrible Mine	9, 243
Bakersville	9, 753
Kelso Cabin	10, 893
Stevens's Mine, on McClellan Mountain	11, 943
Junction House, Denver and South Park road	8, 153
Bergen's Park	7, 643
Rollinsville	8, 323
Nederland, formerly Middle Boulder	8, 263
Caribou, Planter's Hotel	9, 905
Gold Hill	8, 463
Jamestown	7, 123

	Elevation.
Antelope Park	6,433
Allen's Park	8,513
Este's Park, Evans's ranch	7,500
Little Thompson Creek, inside the Hog-Backs	5,623
South Saint Vrain's Creek, at crossing of road from Ward District to Allen Park	8,653
Middle Saint Vrain's, at crossing of same	7,703
Park on the South Boulder Creek, above Rollinsville	8,823

WEST OF THE MAIN DIVIDE.

Grand Lake	8,153
Junction of East Fork of Grand and Grand Rivers	8,123
Mouth of Frazier Cañon	8,088
Valley of the Frazier River, above cañon	8,463
Hot Springs	7,713
Junction of Blue and Grand Rivers	7,183
Muddy River, near Conical Butte	7,603
Blue River, opposite Ute Peak	8,013

TIMBER-LINE.

	Exposure.	Approximate latitude.		Elevation.
		Deg.	*Min.*	*Feet.*
Mount Evans	East	39	35	11,300
Gray's Peak	North	39	40	11,100
Mount Powell	North	39	45	*11,600
Mount Byers	South	39	50	11,400
James's Peak	East	39	50	11,100
Arapahoe Peak	South	40	00	11,100
Bald Mountain	East	40	00	11,100
Long's Peak	East	40	15	11,100
Mount Lillie		40	15	11,100
Station LX	South	40	20	*11,600
Park View	East	40	20	*11,100

*Estimated.

GEOGRAPHICAL REPORT OF HENRY GANNETT, M. E.

SIR: I have the honor to submit to you herewith my geographical report on the field-work of 1873.

The party in my charge was composed as follows: Dr. A. C. Peale, geologist; W. R. Taggart, assistant geologist; Henry W. Stuckle, assistant topographer, and J. H. Batty, naturalist, with two packers and a cook.

The party left the depot camp near Denver on May 29, and spent the following six weeks in the country east and north of South Park. At Fairplay, in the middle of July, we met your party, and together crossed the Arkansas Valley, the Sawatch Range, and the Elk Mountains, working a belt of the country through the middle of the district as far west as the one hundred and seventh meridian. After separating from your party on August 10, we finished the southern part of the district, then crossed the Elk Mountain divide and finished the northern part, reaching the Arkansas Valley again about the middle of September. The remainder of the season was used in finishing up work which had previously been left partially done, in the country south and east of South Park.

The plan of the topographical work was as follows: It was all, with slight exceptions, carried on from commanding points, usually the highest peaks in the neighborhood. A connected system of secondary triangulation, within the primary system, was carried on with the gradienter. In this system all three angles of the triangles were observed whenever possible. The number of stations was 96, and the average distance between them was eight and a half miles. At each station a drainage and a profile sketch were made of the country within the range of vision, and all prominent points were located. Elevations were measured by barometers and dip-angles with the gradienter. The more important streams were meandered.

The party reached Denver on October 23, and immediately disbanded.

The notes in the accompanying report concerning the common mammalia and birds of Colorado were furnished me by Mr. J. H. Batty, naturalist of this division.

The botanical notes, giving a list of the most valuable trees and herbs of the Territory, were given me by Mr. J. M. Coulter, botanist of the survey.

Very respectfully, yours,

HENRY GANNETT.

Dr. F. V. HAYDEN,
United States Geologist, in charge United States Geological and Geographical Survey of the Territories.

REPORT.

The district assigned to the middle division is bounded in latitude by the parallels of 38° 45′ and 39° 30′, and in longitude by the eighth guide-meridian of the land-survey on the east, and by the one hundred and seventh meridian on the west. The area is about 7,200 square miles. This district is very much diversified, consisting of high plains, plateaus, and mountain-ranges.

The drainage systems may be classified as follows:—

1st. That of the South Platte, which drains South Park and most of the country east of it. The area embraced by this system is 3,300 square miles, of which 1,700 square miles are plain or valley country, and the remaining 1,600 square miles are mountainous.

2d. That of the Arkansas River, consisting mainly of a broad, trough-like valley, lying between the South Park and the main range of the Rocky Mountains, (which is there known as the Sawatch Range,) and a considerable portion of the plains east of the mountains, and the mountainous region about Pike's Peak, which are drained by a branch of the Arkansas, known as the Fontaine qui Bouille. The area drained by the Arkansas system is about 1,700 square miles, of which 500 square miles are plain and valley country and 1,200 mountainous country.

3d. That of the Gunnison and the Grand Rivers, which, heading in the western slopes of the great Sawatch Range, flow in a general westerly direction, draining all the country west of the Sawatch Range.

The divide between these streams is a high range, known as the Elk Mountains. The drainage area of the former is about 700 square miles, of which 100 square miles are valley country and 600 mountainous. The area drained by the latter is 1,500 square miles, 200 of it being valley and 1,300 mountainous.

Of the total area of the district, 2,500 square miles, or little more than one-third, are plain and valley country, the remainder, 4,700 square miles, being mountainous.

The plains which form the eastern part of the district are drained in part by the South Platte and its numerous branches, and in part by the branches of the Fontaine qui Bouille, the divide between the two systems, consisting merely of a slight rise in the level of the plains. The elevation of the plains at the north line of the district is about 5,300 feet, thence the slope is gradual up to the divide, which has an elevation of about 8,000 feet, and thence the plains slope gently and regularly down to the south line, where the elevation is about 5,600 feet. The valleys of the streams are very slight, and in the dry season much of the water sinks in the gravelly soil. There is no timber, except on the summit of the divide.

The list of elevations along the Denver and Rio Grande Railroad, which is appended, shows the profile of the plains very well.

Rising abruptly from the plains on the west is a plateau-like range, known as the Colorado or Front Range, which increases gradually in elevation toward the south, until, near the south line, it culminates in the group of mountains of which Pike's Peak is the center. Near the north line the South Platte cuts through this range, and just north of Pike's Peak the Fontaine qui Bouille heads in its western part, and cuts a cañon through nearly its whole width. Its elevation near the north line is 8,000 feet, near the cañon of the Fontaine qui Bouille it is about 9,000 feet.

The mountains of the Pike's Peak group are from 10,000 to 14,000 feet in elevation. The plateau is crested in many places by ragged granite ridges, of which Platte Mountain or Devil's Head is the highest, 9,203 feet above the sea. This range is sparsely timbered with pine and spruce. West of this range the country consists alternately of beautiful, well-watered parks and rugged granite slopes, as far west as the great cañon of the South Platte. This cañon is cut in granite, bordered on the east by a granite plateau, on the west by a high granite range, the continuation of the Kenosha Range, which I call the Tarryall Range, from the large creek which flows along its southern face. The cañon is thirty-five miles long, following the general course of the river; the depth differs greatly in different parts, ranging from 400 to 1,000 feet. It is barely passable for pack-animals at the lowest stage of the water.

The Tarryall Range lies between the cañon of the South Platte, Tarryall Creek, and South Park. It is more properly a group of mountains than a defined range. Its elevation reaches, in a few summits, 12,000 feet, with an average elevation of 11,000 feet.

Between Tarryall Creek and the South Platte, the country is open, park-like, and well watered, as also is most of the country lying south of the South Platte. There is plenty of the best of timber and grass.

South Park is a table-land, very uniform in surface, with the exception of a few minor ridges, which traverse it in a direction generally a little east of south, and in the southern part numerous volcanic buttes. Its shape is nearly elliptical, the longest axis having a direction about north and south, and a length of 50 miles, while its shorter axis is 25 miles long. The area is about 1,000 square miles. The prevailing slope is from northwest to southeast. The elevation is, in the northern and northwestern part, 9,500 to 10,000 feet; in the western and south-western part, 8,500 to 9,000, and in the southeastern part, 8,000 feet. The mean elevation is fully 9,000 feet.

The limits of the park are sharply defined by the mountains, which rise on all sides abruptly from the plains to the highest summits. The Tarryall Range bounds it on the east as far as Tarryall Creek; thence to the south end, around the south end, and up the west side as far north as Buffalo Peaks, the boundary consists of wooded hills, having elevations of 10,000 to 11,000 feet, and rising about 2,000 feet above the plain. At Buffalo Peaks the range rises abruptly to mountains from 13,000 to 14,000 feet high, called the Park Range, which joins the main range at Mount Lincoln, at the northwest corner of the park. The north end of the park is bounded by the main range, which has there an elevation of 12,000 to 14,000 feet.

In general the park is not well watered. Near its borders, especially its northern and western sides, there is at all seasons an abundance of good water, but throughout the whole interior part of the park water is scarce. The large streams water but a very narrow belt in their immediate neighborhoods, and the smaller streams sink in the gravelly soil.

The surface of the park is covered with bunch-grass of an excellent quality, making it an excellent range for cattle and sheep in summer, but the great elevation makes it extremely hazardous to winter stock out of doors.

There is no timber except on the sides, but in the mountains there is an abundance of the best timber.

West of the Park Range is the valley of the head-waters of the Arkansas River. This is five to ten miles broad, well watered, sparsely timbered, and covered with bunch-grass and sage. From the extreme head of the river in Tennessee Pass to Lake Creek the valley is very broad, open, and fertile. From Lake Creek south about fifteen miles the river is in cañon. Below this is again a broad valley without timber, and tolerably good for grazing purposes. The whole valley is much more sheltered than South Park, and on that account is much better for wintering stock.

Eagle River heads opposite the head of the Arkansas, in Tennessee Pass, and flows nearly northwest to the Grand River. Its valley consists in the upper portion of broad, fertile meadows, with good grass, and abundance of timber in the hills.

West of the Arkansas and Eagle Rivers is the great Sawatch Range, which terminates on the north in the Mountain of the Holy Cross. The main divide joins it at Tennessee Pass, and thence south follows its crest. The peaks of this range are between 14,000 and 14,500 feet in height. Few points in the range are below 13,000 feet high, and the average elevation of the range is fully 13,500. The orographical character of these mountains, as well as those of the Park Range and of the main divide on the north end of South Park, is broad and massive. Heavy, bulky mountain-forms abound, while sharp pinnacles and serrated ridges are entirely wanting. This range has an average width of fifteen to twenty miles.

The country west of the Sawatch Range is drained by the Gunnison River and Roaring Fork, a branch of the Grand River. Their valleys are separated by a heavy range, the Elk Mountains, second only to the Sawatch in magnitude and elevation. The direction of the divide between the two drainage-systems is generally east and west, but the range is, in reality, made up of a series of ranges parallel to the Sawatch; *i. e.*, having a direction about south 30° east, and north 30° west, joined together by saddle-like ridges, this formation giving rise to a number of large branches of each river, all parallel, approximately, to one another. This range is composed in great part of stratified rocks, principally sandstones, disturbed in several places by upheavals of granite. These mountains present aspects entirely different from those of the Sawatch Range, both in color, which ranges from a dull red to a dark brown, and in form, which, instead of the heavy, massive, dome-like structure of the Sawatch Range, presents us here with sharp pinnacles, spires, jagged ridges, &c.

The valleys of most of the branches of the Gunnison are narrow, though in some places, as on the main Gunnison and on East River, they expand to broad bottoms several miles in width covered with sage and bunch-grass.

The vegetation in the mountain valleys is of almost tropical luxuriance, the sandstone and limestone making a deep, rich soil. Pine and spruce trees cover the ridges heavily, while the bottoms are choked by quaking-aspen trees.

On the north side of the divide the character of the country is very similar to that on the south side; *i. e.*, a system of parallel ridges, parallel to the Sawatch Range. This direction of the ridges is, however, changed as we go farther north to a nearly east and west direction in the latitude 39° 15′, by the large branch of Roaring Fork, known as Frying-Pan Creek, which drains the west face of the northern half of the Sawatch Range. The elevation decreases rapidly toward the north, being at the mouth of Frying-Pan Creek, in latitude 39° 15′, only 7,000 feet; and with this decrease in elevation there comes a great change in the character of the vegetation.

The range and extent of agricultural pursuits are determined in this country rather by the elevation than by any other agency.

The following notes concerning the limits in altitude of the growth of different crops were given me by Mr. W. N. Byers, of Denver, from his own experience and observation:

Wheat, barley, oats, potatoes, turnips, peas, and the hardier garden vegetables are safe crops at any elevation under 7,500 feet. Potatoes generally do well as high as 9,000 feet, and turnips always up to that altitude. Wheat grows splendidly at as high an elevation as 9,000 feet, but above 7,500 feet it is a hazardous crop, liable to be injured by early autumn frosts or snow. Oats grow splendidly up to 9,000 feet, but generally have to be harvested green.

The list of elevations submitted at the end of this report will show the application of these facts to the area under consideration.

Cattle and sheep do well as high up as grass grows, but it is not safe to try to winter them without provision of hay above 7,500 or 8,000 feet. Nearly every year since the settlement of the Territory stock has wintered out of doors in South, Middle, and Estes Parks, but the lowest and most sheltered parts were sought for this purpose.

The total population I estimate at 6,500. This is necessarily a rough estimate, as I have no means of learning the number who are scattered about on ranches, &c., away from the settlements.

The principal settlements are as follows:

Colorado Springs, on the Fontaine qui Bouille and the Denver and Rio Grande Railroad. This place is the county-seat of El Paso County. It was founded, on the colony system, in 1871. Its present population is about 2,000, and rapidly increasing.

Colorado City, on the Fontaine qui Bouille, two and a half miles above Colorado Springs; population, 600. This place was started in 1859, at the time of the first gold-discoveries in South Park. It has been much larger than at present.

Manitou, on the Fontaine qui Bouille, about five miles above Colorado Springs, at the mineral springs, and at the immediate foot of Pike's Peak. The town was started in 1872 by the Colony Company. It has a population of 200.

Fairplay, South Park, the county-seat of Park County. It was started during the mining excitement of 1859–'60. It now has a population of about 1,000.

Dudley; started in 1872; population, 300.

Alma; started in 1872; population, 500.

Quartzville; started in 1871; population, 200.

(The three latter settlements owe their birth to the rich mineral deposits recently discovered on Mounts Bross and Lincoln. They, as well as Fairplay, are situated on the South Platte, very near its head, at or near the foot of Mount Bross.)

Montgomery, at the extreme head of the South Platte, which had, ten years ago, a population of 2,000, now consists of one family.

Hamilton and Tarryall, on Tarryall Creek, near its head, have populations respectively of 100 and 200. They were started during the mining excitement in 1860, and were at one time large places, as Tarryall had for several years a population of 2,000 to 3,000.

Oro City, at the head of California Gulch, in the Arkansas Valley, was started in 1860. In 1861 it had a population of 3,000. Now its population is 300.

Granite, on the Arkansas River, at the mouth of Cash Creek, was started in 1868, with a population of 1,000, which has now decreased to 100.

Dayton, on Lake Creek, Arkansas Valley, in 1865–'6 had 400 or 500 inhabitants; now the population consists of but one or two families.

The only settlements in the park or mountains are dependent on mining for their existence.

West of the Sawatch Range there are no settlements whatever, with the exception of two small mining-camps, one in the Elk Mountains, at the head of East River, and one in Union Park, on the Gunnison River.

PRINCIPAL PASSES IN THE HIGH MOUNTAINS.

The following are the practicable passes in the main range:

Georgia Pass, at the head of Michigan Creek, north of South Park. Its elevation is 11,811 feet, while the level of South Park, in the neighborhood, is about 10,000 feet. The grades are easy on both sides, and a small outlay of money would suffice to build a good wagon-road over it. An indifferent one now exists.

Tarryall Pass, a few miles west of the latter. Elevation, approximately, 12,000 feet. The stage-line from Breckenridge to South Park crosses this pass. The approaches are equally easy with the latter, and road well built.

Hoosier Pass, near the head of the South Platte. Elevation, 11,540 feet, while Montgomery, on the South Platte, just at the foot of the pass, has an elevation of 11,540 feet. The ascent on the south side is extremely steep, and the road is obliged to wind a great deal to overcome the ascent. On the north side it is not as steep.

Tennessee Pass, at the heads of the Arkansas and Eagle Rivers. Elevation, 10,418 feet. The easiest pass over the main range in the Territory, if not in the United States, with the exception of Reynolds Pass, Montana.

Frying-Pan Pass, at the heads of Colorado Gulch and Frying-Pan Creek. Elevation, 12,017 feet. This pass is very steep and difficult on both sides, more particularly so on the east side.

Lake Creek Pass, at the head of the South Fork of Lake Creek. Elevation, 12,329 feet. This is quite steep on both sides, but rather more so on the west. The summit of the pass is covered with shingle, which increases its difficulty.

In the Park Range the most northerly pass is the Mosquito Pass, at the head of Mosquito Gulch. Its elevation is 13,438. The ascent is steep, and difficult for pack-animals on both sides; and except in midsummer, there is a great deal of snow on the trail.

Weston's Pass, Park Range, at the head of the Little Platte. Elevation, 11,676. A good wagon-road crosses this pass. The ascent on the South Park side is by easy grades, but on the Arkansas side it is much steeper.

Trout Creek Pass, Park Range. Elevation, 9,346 feet. This pass is through the low rugged hills south of Buffalo Peaks, and near the saltworks. The stage-road to the Arkansas Valley crosses this pass. It is an extremely easy one.

The Elk Mountains can be crossed by a pack-train in several places, with more or less difficulty. Near the head of the main Gunnison the summit of the range is broad and flat, and though the ascent on each side is extremely steep and rocky, still it is practicable. Elevation, 11,795 feet.

At the head of East River there is quite an easy pass to the head of Rock Creek. One of the main trails between the White River and the Los Pinos agencies crosses the range at this pass. The elevation is about 11,163 feet.

MEANS OF COMMUNICATION.

The Denver and Rio Grande Railroad (narrow gauge) runs nearly north and south from Denver to Pueblo, on the Arkansas River, at the east foot of the Colorado Range. This is the only railroad at present in operation in this district, but surveys for railroads have been made from Denver and Colorado Springs to Fairplay and the Arkansas Valley.

The located line from Denver follows up the Platte to the mouth of the North Fork; thence up the North Fork, crossing to South Park at the Kenosha Summit; thence along the northwest border of the Park to Fairplay. From Fairplay it passes down the west border of the Park to Trout Creek Pass, by which it crosses to the Arkansas Valley. The located line from Colorado Springs follows up the cañon of the Fontaine qui Bouille, crosses the divide at its head, passes over the high, rolling country northwest of Pike's Peak to the Platte, and follows that river up to Fairplay.

A daily stage-line connects Fairplay and the towns in South Park with Denver. A tri-weekly stage-line connects the settlements in South Park with Colorado Springs. A bi-weekly stage-line connects the settlements on the Arkansas with Fairplay, and a bi-weekly stage-line connects Breckenridge with Hamilton, in South Park.

PRINCIPAL WAGON-ROADS AND TRAILS.

A road connects Denver with Colorado Springs and all the minor settlements on the plains. The line of the road is generally quite near that of the Denver and Rio Grande Railroad.

The stage-road from Denver to South Park crosses the plains from Denver to the foot of the cañon of Bear Creek, crosses the divide to Turkey Creek, follows up Turkey Creek, crosses to Elk Creek, thence crosses the high divide to the North Fork; follows North Fork up nearly to its head, and crosses into South Park at Kenosha Summit; thence it skirts the northwestern border of the Park to Hamilton and Fairplay. A branch leaves it at Michigan Creek, and, crossing the main range at Georgia Pass, goes down to Breckenridge. Another branch leaves it at Hamilton, and connects with Breckenridge by way of the Tarryall Pass and Swan River. From Fairplay, a road runs up the South Platte, connecting the mining towns above Fairplay, crosses by Hoosier Pass, and goes down the Blue River to Breckenridge.

Colorado Springs and the towns in its neighborhood are connected with Fair Play by a road which follows very closely the course of the located railroad-line as far as the crossing of the South Platte. There it leaves the South Platte, and crosses to South Park in a direction somewhat north of east, reaching the South Platte again in South Park, and follows it up to Fairplay. A branch leaves it in the southern part of the park, and runs to the Salt-works and the Arkansas Valley. Another branch leaves it at the first crossing of the South Platte, and follows Tarryall Creek up to Hamilton.

From Fairplay a road skirts the western side of the park, a branch of it crossing the Park Range, at Weston's Pass, to the Arkansas Valley, while the main road continues on down to the Salt-works, and thence to the Arkansas Valley, by way of Trout Creek Pass and Trout Creek. From the Salt-works a road runs to Cañon City.

There is an excellent road throughout the whole length of the Arkansas Valley. These wagon-roads are all excellent, and this in a country in many parts extremely rough and mountainous.

The most direct route from Fairplay to the Arkansas Valley is by a pack-trail up Mosquito Gulch and over Mosquito Pass.

At the head of the Arkansas River the wagon-road dwindles to a trail, which crosses the main range at Tennessee Pass and follows the Eagle River down to the crossing of the Grand River, and thence to the White River agency.

From the Twin Lakes, Arkansas Valley, a heavy trail passes up Lake

Creek and its south fork, crosses the Sawatch Range at Lake Creek Pass, follows Pass Creek down to the Gunnison, which it crosses near its head; thence it follows up Spirifer Creek, crosses to Taylor River, then up Deadman's Gulch, crosses the divide to Cement Creek, and follows Cement Creek down to its mouth. At East River it forks, one branch going southerly down East River and the Gunnison to the Los Pinos agency; the other up East River to its head, where it crosses to Rock Creek, and, generally speaking, it follows Rock Creek down to the Grand River. This is one of the principal Indian trails in the Territory.

BOTANICAL NOTES.

Quercus alba, L., var. *Gunnisoni*, Torr., scrub-oak.—The only oak in Colorado, and of little value. Grows 6 to 10 feet high.

Populus balsaminifera, L., var. *Candicans*, Gr., cottonwood.—Occurs at middle elevation. Is the only poplar that can be used for timber.

Pinus ponderosa, Dougl., yellow pine.—Grows 70 to 100 feet high. Common through all the lower slopes. Is a most valuable timber-tree.

Pinus flexilis, James.—Found on the divide between South Park and the Arkansas Valley, (Park Range.)

Pinus edulis, Eng., piñon or native pine.—Found near Colorado Springs and Twin Lakes.

Abies Engelmanni, Parry, white pine.—A magnificent tree, growing 60 to 100 feet high, with a straight, even trunk, and of rapid growth. Wood is remarkably white and soft. This species is closely allied to the black spruce *(Abies nigra)* of the East. Found on the mountain-slopes of the Elk and Sawatch Ranges.

Buchloe dactyloides, Eng., buffalo-grass.—One of the most nutritious grasses. Is the common pasturage on the plains and in South Park.

Poa alpina, L., and *Phleum alpinum*, L.—The best of mountain-grasses, growing far up on the mountains.

Triticum repens, L., blue-joint.—Found along the Platte and around Weston's Pass.

Poa serotina, Elrob., false red-top.—A good grass. Found in moist meadows, even nearly to the timber-line.

Hordeum, wild barley.—Found about Colorado Springs and in South Park.

Elymus, wild rye.—Found around Colorado Springs and Twin Lakes.

Dauthornia, wild-oat-grass.—Found at Ute Pass and along the South Platte.

Avena, wild-oats.—Found in Middle and South Parks.

Caltha leptosepala, D. C.—Very abundant in all sub-alpine swamps.

Linum perenne, L., flax.—Abundant throughout the district at all elevations.

Trifolium, clover.—Occurs in comparative abundance; mainly at high altitudes.

Rubus triflorus, Richards, raspberry.—Occurs in cañons at middle elevations.

Ribes aureum, Parsh, currant.—Occurs in South Park.

Valeriana edulis, Nutt.—Abundant in Clear Creek Cañon and about Twin Lakes.

Eurotia lanata, Mog., winter-fat, or white sage.—Found around Colorado Springs and Cañon City.

Humulus lupulus, L., common hop.—Found along the South Platte and in the cañons about Snow-Mass Mountain.

HYPSOMETRICAL.

The most important elevations in the following lists were determined with the mercurial barometer, until August 22, when the last barometer-tube was broken. Elevations of minor importance, and, after August 22, all elevations, except those measured trigonometrically, were measured by aneroids. While there was a cistern barometer in the party, the aneroids were compared daily; and after this barometer was broken, corrections were obtained for the aneroids whenever possible, and in every case these showed a remarkably good performance on the part of these instruments.

A part of the elevations submitted below were measured by vertical angles taken with the gradienter. The vertical circle of this instrument is four inches in diameter, and reads, by a vernier, to single minutes. The correction for refraction was determined by a series of fore and back sights between mountain-peaks to be approximately one-sixth of the curvature, and this correction has been applied to obtain these results.

Barometric observations taken in Denver by the officers of the United States Signal-Service Bureau, during the summer and autumn, were placed at our disposal for use as base observations. At Fairplay, South Park, elevation 10,048 feet, barometric observations were taken for us three times a day from July 19 to October 1, and at the Moose Mine, near the summit of Mount Lincoln, elevation 14,188 feet, observations have been taken since July 20.

To the Denver observations as a base have been referred all work at elevations below 8,000 feet; to Fairplay, all work between 8,000 feet and the timber-line, that is, about 11,600 feet; and to Mount Lincoln, all above the timber-line.

In the following lists *a* refers to an aneroid measurement, *t* to a trigonometrical determination. In other cases the measurement was made by a mercurial barometer. The elevation of Denver above sea-level has been assumed at 5,197, the level of the track of the Denver Pacific Railroad. This makes the elevation of the barometer in the United States Signal-Service office, 5,245 feet.

LIST OF ELEVATIONS

Along the line of the Denver and Rio Grande Railroad from Denver to Colorado Springs at the east foot of the mountains.

	Miles.	Elevation, feet.
Denver	0	5, 197
Littleton	10	5, 362
Acequia	17	5, 530
Plum	25	5, 835
Citadel	31	6, 123
Douglas	35	6, 325
Larkspur	43	6, 666
Greenland	47	6, 928
Divide	52	7, 209
Henry's	56	6, 984
Berst's	58	6, 812
Husted	62	6, 600
Monument	67	6, 355
Colorado Springs	76	5, 984

TOWNS, ETC.

Colorado City		6, 049
Colorado Springs, railroad levels		5, 984
Manitou	*a*	6, 357

	Elevation, Feet.
Fairplay, South Park, railroad levels	10,048
Hamilton, South Park	9,743
Tarryall, South Park	10,254
Jefferson, South Park	9,868
Dudley, South Park	*a* 10,621
Alma, South Park	*a* 11,044
Montgomery, South Park	*a* 11,181
Farnham's Ranch, South Park	9,548
Salt-works, South Park	*a* 8,749
Oro, Arkansas Valley	*a* 10,704
Old Oro, Arkansas Valley	*a* 10,247
Dayton, Arkansas Valley	9,441
Granite, Arkansas Valley	*a* 8,883
Mining Camp, in the Elk Mountains	11,404

MOUNTAIN-PEAKS.

Platte Mountain, Colorado Range	*a* 9,203
Pike's Peak, Colorado Range, (spirit-level)	14,147
Cameron's Cone, Colorado Range	*t* 11,460
Cheyenne Mountain, Colorado Range	*t* 9,948
Bergen Peak, (at foot of Bergen Park)	*a* 9,415
Highest summit in the Tarryall Range	12,327
Mount Guyot, Cross Range, between Middle and South Parks	13,425
Mount Silverheels, Cross Range, between Middle and South Parks	13,767
Mount Lincoln, Cross Range, between Middle and South Parks, (spirit-level)	14,297
Buckskin Mountain, Cross Range, between Middle and South Parks	*a* 14,156
Quandary Peak, Park Range	*t* 14,269
Station 52, Park Range	13,928
Horseshoe Mountain, Park Range	13,842
Sheep Mountain, Park Range	13,292
Buffalo Peak, (highest,) Park Range	13,541
Holy Cross, Sawatch Range	*t* 14,176
Massive Mountain, Sawatch Range	*t* 14,368
Mount Elbert, Sawatch Range	*a* 14,326
La Plata Mountain, Sawatch Range	14,302
Mount Harvard, Sawatch Range	14,384
Mount Yale, Sawatch Range	*t* 14,151
Mount Princeton, Sawatch Range	14,199
Grizzly Peak, Sawatch Range	13,962
Station 75, Sawatch Range	*a* 13,315
Park Cone, at head of cañon of Gunnison River	12,052
Station 63, Elk Mountains	*a* 12,142
Italia Mountain, Elk Mountains	13,431
White Rock Mountain, Elk Mountains	13,847
Teocalli Mountain, Elk Mountains	*t* 13,274
Crested Butte, Elk Mountains	12,014
Gothic Mountain, Elk Mountains	*t* 12,491
Snow Mass, Elk Mountains	13,961
Maroon Mountain, Elk Mountains	*t* 14,000
Castle Peak, Elk Mountains	14,106
Station E, Elk Mountains	*t* 13,842
Capitol, Elk Mountains	*t* 13,992
Sopris Peak, Elk Mountains	*t* 12,972

PASSES AND DIVIDES.

At the head of the Fontaine qui Bouille to Hayden Park	*a* 8,625
At the head of the Fontaine qui Bouille to Bergen Park	*a* 8,344
Hayden Summit, (Hayden Park)	*a* 8,882
On the Colorado Springs and Fairplay road, over the range bordering South Park on the east	*a* 9,319
Kenosha Summit, on the Denver and South Park stage road	*a* 9,937
Georgia Pass	11,811
Tarryall, or Breckenridge Pass, (approximate)	12,176
Hoosier or Ute Pass	*a* 11,540
Summit of the Mosquito trail over the Park Range	*t* 13,438
Weston's Pass, over the Park Range	*a* 11,676
Trout Creek Pass, over the Park range	*a* 9,346

	Elevation, Feet.
Tennessee Pass, over main divide, at head of the Arkansas River	10, 418
Main divide, at the head of Frying Pan Creek	12, 017
Lake Creek Pass, Sawatch Range	12, 329
Pass at the head of the North Fork of Lake Creek, Sawatch Range	*t* 12, 462
Pass at the head of Cottonwood Creek	*a* 12, 695
Divide at the heads of the Gunnison and Roaring Fork, Elk Range	*a* 11, 795
Divide between Taylor's River and Cement Creek on trail of the party	*a* 11, 186
Divide between Taylor's River and Cement Creek on the Indian trail	10, 675
Pass at the heads of East River and Rock Creek	11, 163
Pass at the heads of Rock Creek and Slate River	11, 679

ELEVATIONS ON STREAMS, ETC.

South Platte River.

At Montgomery, (head)	11, 176
At Dudley, mouth of Buckskin Gulch	10, 621
At Fairplay	9, 976
At mouth of Little Platte	8, 683
At head of upper cañon, (exit from South Park)	8, 166
At foot of upper cañon	7, 623
At mouth of Tarryall Creek, (head of lower cañon)	7, 326
At mouth of Trout Creek	5, 876
At foot of lower cañon	5, 476
At Denver	5, 176

Tarryall Creek.

At Hamilton	9, 743
At exit from South Park	8, 754
At mouth	7, 326

Arkansas River.

At head, in Tennessee Pass	10, 176
At mouth of East Arkansas	9, 827
At mouth of Colorado Gulch	9, 586
At mouth of Lake Creek	9, 098
At mouth of Cash Creek	8, 883
At mouth of Pine Creek	8, 620
At mouth of Cottonwood Creek	8, 317
At mouth of Chalk Creek	7, 877

Gunnison River.

At head	11, 176
At mouth of Pass Creek	9, 869
At head of cañon	9, 576
At mouth of East River	8, 176

Roaring Fork.

At head	11, 676
At mouth of Hunter's Creek	10, 326
At mouth of Difficult Creek	8, 241
At mouth of Castle Creek	7, 942
At mouth of Frying Pan Creek	6, 626

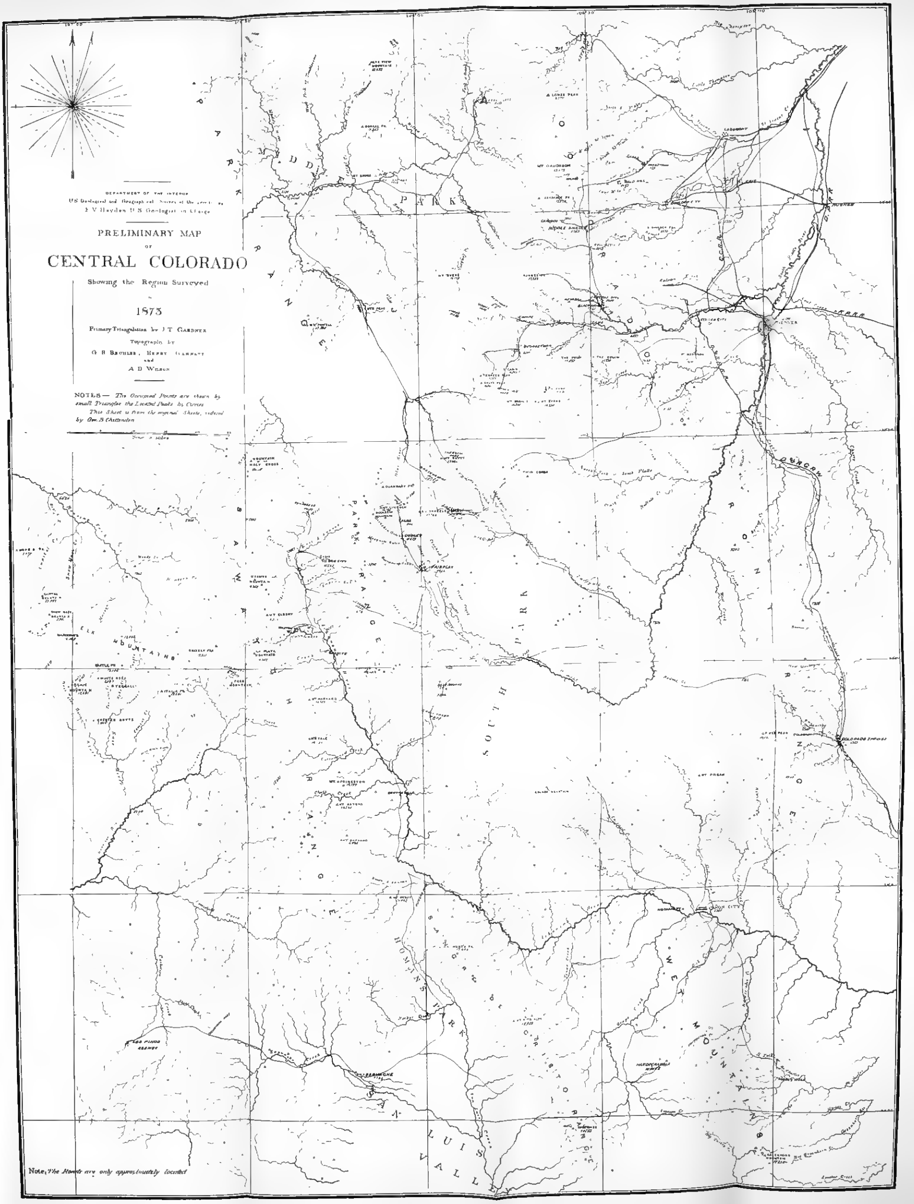
Frying Pan Creek.

At head	11, 012
At foot of upper cañon	8, 566
At mouth of North Fork	8, 176
At head of box cañon	7, 742
At mouth	6, 626

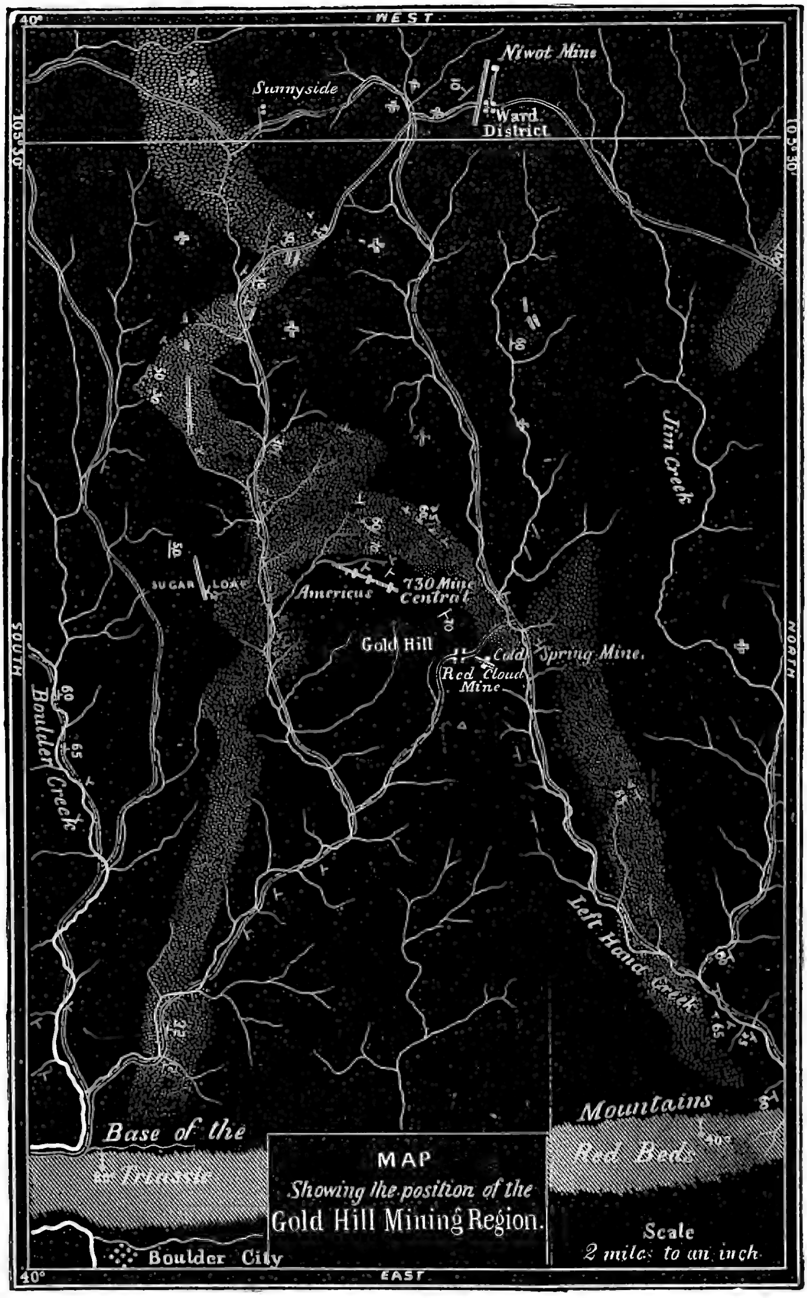
ELEVATION OF THE TIMBER-LINE.

On Pike's Peak, east face	11, 721
On Mount Guyot, north face	11, 811
On Mount Silverheels, northeast face	11, 549
On Mount Lincoln, east face	12, 051

	Elevation, Feet.
At head of Buckskin Gulch, south face	11,587
On station 52, Park Range, east face	11,663
On station 56, Park Range, east face	11,752
On Park Range, on Mosquito trail, west face	11,656
On Park Range, on Mosquito trail, east face	11,536
On station 40, near Mount Evans, south face	11,559
On Buffalo Peak, northwest face	12,041
On Sawatch Range, at head of Frying Pan Creek, west face	11,583
On Massive Mountain, north face	11,607
On Mount Elbert, east face	11,871
On La Plata, east face	12,080
On Grizzly Peak, south face	11,758
On Mount Harvard, east face	12,117
On station 89, near Mount Princeton	11,514
On station 63, Elk Mountains, east face	11,513
On White Rock Mountain, south face	11,919
On station 68, in Elk Mountains	11,686
On station 82, on ridge north of Frying Pan Creek	11,830
On station 75, near head of Texas Creek	11,574
Mean elevation of the timber-line	11,694


DEPARTMENT OF THE INTERIOR
F V Hayden U S Geologist in Charge
PRELIMINARY MAP
OF
CENTRAL COLORADO
Showing the Region Surveyed
1873
Topography by
and
A D Wilson
NOTES— The Occupied Points are shown by small Triangles the Located Peaks by Circles
MIDDLE PARK
PARK RANGE
SOUTH PARK
PARK RANGE
SAWATCH RANGE
ELK MOUNTAINS
FRONT RANGE
WET MOUNTAINS
SAN LUIS VALLEY
DENVER
BOULDER CITY
LONGMONT
COLORADO SPRINGS
FAIRPLAY
MT ELBERT
MT HARVARD
PIKES PEAK
Note, The Heads are only approximately located

APPENDIX.



MAP
Showing the position of the
Gold Hill Mining Region.

GOLD HILL MINING-REGION: ITS POSITION AND GENERAL GEOLOGY.

By Arch. R. Marvine.*

The accompanying map has been prepared to show the general outlines of the country in the neighborhood of the Gold Hill and Ward mining-districts, in the mountains of Colorado, while the following remarks explain briefly the position of the region in relation to the surrounding country, as well as its general geology, as determined during the explorations of the summer of 1873.

Nearly parallel with, and a few miles west of, the western border of the country represented on the map, rises the main continental "divide" in a north-and-south crest, which here reaches an altitude of nearly 13,000 feet above the sea-level. From the base of the main crest, a zone of mountainous country extends eastward, which is cut through by the streams in a general east-and-west direction.

The intervening ridges are not sharp, but of a massive character, often with undulating surfaces, their higher points usually reaching in general a pretty uniform level, the ruggedness of the country being produced by the deep cañons of the stream. It is a portion of this region that is represented on the map.

At the east (near the border of the map) the region abruptly ends along a nearly north-and-south line, the massive spurs falling to the zone of "hog-backs," or ridges of upturned sedimentary rocks, which lie all along the base of the range.

The "red beds," probably of Triassic age, form the innermost ridge, lying directly on the Archæan rocks of the mountains. These, in going eastward, are followed by the upturned edges of Jurassic shales, the Cretaceous groups, and the great Lignitic formation, of as yet disputed Cretaceous or Eocene age, which stretches eastward, and forms the beds directly underlying the great plains.

Boulder City is on the border between the mountains and plains, and is reached by railroad, Denver City being but twenty-five miles to the south and east. From Boulder City, wagon-roads up the various cañons give access to the mines in the mountains. South of the region represented on the map, from fifteen to twenty miles, is Clear Creek, much like the Boulder in general character, on the tributaries of which the better known mining-regions of Georgetown, Idaho, Empire, Black Hawk, and Central City are situated.

The rocks of the mountains, as a whole, may be considered as being composed of a great series of metamorphic rocks of Presilurian age. Quartzites, siliceous, micaceous, some hornblendic and garnetiferous

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*The following notes were originally prepared to accompany an article of Prof. Benjamin Silliman, jr., in the July number of the American Journal of Science, on the telluride ores of Colorado.

They should have been printed with Mr. Marvine's report, but were accidentally omitted; but as they refer to the area occupied by the survey, and should form a portion of the report proper, it seems advisable to print them in this connection.

schists, gneisses, and granites, all occur; the gneiss, with possibly granite, in the greater proportion. While large areas of structureless granite abound, apparently of so-called plutonic or eruptive origin, search seldom fails in finding spots or areas more or less large of gneissic or even distinct schistose structure. The fact that these usually merge imperceptibly into the surrounding granite, as well as conform in their strikes and dips to the general system of folds, as more plainly indicated perhaps in adjacent schistose regions, show that such granites have been metamophosed *in situ*, and are indigenous rocks. At the same time, sharp lines of demarkation, and the occurrence of dikes and allied features, show that the conditions of extreme metamorphism have probably been accompanied by a great softening of the rock, allowing ready molecular re-arrangement into structureless forms, and producing plutonic and other appearances indicative of an exotic character.

The same granite mass, approached from opposite sides, might convey entirely different impressions as to its origin; a metamorphic indigenous nature being indicated upon the one hand; an eruptive, exotic origin upon the other.

I doubt if any of the large granite masses of the mountains are of true intrusive character, and even if those smaller ones which are clearly intrusive have come from great distances below, or are other than of the same series of rocks melted by the heat accompanying the metamorphism of the mass.

Along the south side of the map, and exposed by the cañon of the Boulder Creek, are massive gray granites, with but few points where any structure was observed.

All along this half of the map, the general strike is approximately east and west, with a northern dip. This is the case also along its west border. Near the north and east sides, however, the dip is south, indicating a synclinal structure running through the middle of the eastern portion of the map.

A horizon in which a definite schistose structure tends to occur is indicated by the dotted area running through the center of the map. Some of the rocks here are distinct schists, but little changed, and include very irregular red and black banded mica-schists, garnetiferous, and some handsome, fine, and evenly-banded, gray gneissic schists. In places, this zone may be lost in granite, but opportunity did not offer to carefully follow it throughout.

Most of the granite on the north edge of the map contains little if any mica, tending to a reddish granular aplyte. The schist zone shows the fold of the formation very well, some of them being very abrupt, and regions of great contortion. All the observed strikes and dips are indicated on the map, but the general structure of so small an area cannot be well shown separated from the surrounding country.

These schists and granites are pierced at many points by a number of dikes of felsite porphyry, which are also indicated on the map. Usually these form hills or ridges, and while some are quite long, the porphyry has apparently often found vent through less extended openings, now showing as sugar-loaf-formed hills, without the direction of the dike being clearly indicated. Such forms are shown by a cross. The porphyries vary considerably in character, but no careful comparative examination of them has yet been made. Some contain remarkably handsome crystals of feldspar, often of the form of the Carlsbad twins.

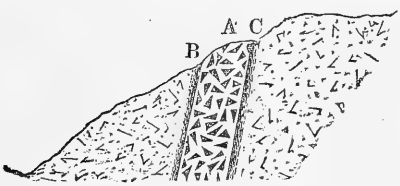
The tellurium ores of Gold Hill occur in connection with one of these dikes, (see section beyond.) This dike varies from 45 to 35 feet in width, trends about north 30° east, and dips approximately 80° to the northwest. On the east side is the Red Cloud; on the west, the Cold Spring mines. The former, upon a casual examination, showed a well-defined hanging-wall, or that on the side of the porphyry, a vein usually three or four feet in width, but in places pinching out to a few inches, with at one point a clay-like "gouge," and an indefinite foot-wall on the side of the coarse gneissic granite, which is here the country-rock. Some of the vein-matter appeared as if a decomposed granite, while the pyrite is the most frequently occurring mineral in the dull quartzose gangue of the vein.

THE TELLURIDE ORES OF THE RED CLOUD AND COLD SPRING MINES, GOLD HILL.

By B. Silliman.*

In May, 1873, I briefly announced the discovery of tellurium gold-ores at the Red Cloud mine in Colorado, and stated that Prof. N. P. Hill, of Black Hawk, had proposed to send me specimens of these ores.† The specimens sent by Professor Hill were long in reaching me, and it is only recently that I have examined them. The observations made in the summer of 1873 by the officers of Dr. Hayden's expedition have supplied the data needful to understand the mode of occurrence of these ores, for the details of which reference is made to Mr. Marvine's notes and map, which form part of this paper.

It appears from them, in general, that near the mining-hamlet of Gold Hill, about twenty-five miles northwest of Denver City, and at an elevation of almost 8,000 feet above tide, is a wide dike of porphyry cutting the metamorphic rocks, probably of Archæan age, about six miles west of where the Triassic rocks die out at the base of the mountains.



A, porphyry-dike; B, C, veins with gold and tellurium-ores.

A section of this dike, A, furnished by Mr. Marvine, is annexed, showing the tellurium-bearing veins B and C on its sides. The porphyry of which it is composed has distinct crystals of feldspar implanted in a purplish-gray paste. These crystals have a greenish-white color, and are evidently partly decomposed. As seen in a microscopic section, it shows the usual obscurely crystalline ground-mass of felsite, with crystals of quartz, and sections of feldspar crystals showing the parallel bands of a triclinic species. A glance at the map shows the position and course of this dike, and also the existence of other dikes of porphyry in the same region. The porphyry from the "7.30" and "Central" mines closely resembles that from the "Red Cloud," while that from a dike (No. 136) between the "7.30" and the "Americus" is distinctly trachytic, and that from the "Niwot" mine, at the west margin of the map, (No. 181,) is a quartz-porphyry, with distinct crystals of biaxial mica. Those from the dikes at Jim Town, (specimens No. 147,) on the north border of the district, are distinct sanadin-trachyte.

The tellurium-ores have been explored so far only in connection with the dike near Gold Hill, shown in the section, although they exist with the dike at "7.30" and the "Central." These ores are found along the

* The substance of the following remarks was originally communicated at the April session (1874) of the National Academy of Sciences at Washington, and afterward appeared in the form of an article entitled "Mineralogical Notes; Tellurium Ores in Colorado; by B. Silliman," in the American Journal of Science and Arts for July, 1874, and from which they are now here reproduced by the permission of the author. It was in connection with this article that the preceding notes on the general geology of the region about Gold Hill were prepared and approved.

† American Journal of Science and Arts, III, vol. V, 286.

line of contact of the walls of the dike, in a quartz gangue, associated chiefly with pyrite in small, brilliant, highly-modified crystals, and rarely with chalcopyrite and sphalerite. Professor Hill speaks (*loc. cit.*) of lead; but I have found no salts of this metal in the specimens received. The quartz is chiefly hornstone and uncrystalline quartz, and, on the side of the country-rock, it is mixed with feldspar. Native gold is not visible in any of the specimens I have seen of this ore from below the surface; but where the surface is weathered, it exhibits free gold, arising from the decomposition of the tellurets.

On the sides of the dike, the line of division is clearly defined, but not so on the side adjacent to the metamorphic rocks, it blending on this side with the granitic materials. The thickness of the veins varies from four or six feet to a few inches, but the rich tellurium-ores form a comparatively narrow seam near the center of the vein. The Red Cloud mine, which is found on the under side of the dike, has been explored to a depth of about 70 feet. The Cold Spring mine is explored on the upper side of the dike. The tellurium-ores are not found in the body of the dike, but have (owing probably to the long-continued high temperature of the dike) found lodgment in the granite outside of the walls, and not in immediate contact with them.

The species at the Red Cloud mine are native tellurium sylvanite and hessite, (which has been called petzite.) The simplicity of the mineralogy of this locality is in strong contrast with what is found in the tellurium-veins of Transylvania, which are mentioned more particularly farther on.

Native tellurium.—The occurrence of this rare species in the United States, in California, was mentioned by Dr. Genth, with a query, in his Contributions to Mineralogy, No. vii, (American Journal of Science, II, xlv, 313.) Its existence in the Red Cloud mine is unequivocal. It was simultaneously, yet independently, detected by Dr. Endlich and myself in a small specimen from the collection made at the mine last summer, and now forming part of the Smithsonian collection in Washington. It did not exist in the collection of those ores sent to me by Professor Hill. The hexagonal cleavages are perfect, and one small and very perfect crystal was found, which has been measured by Mr. E. S. Dana. Its reactions before the blow-pipe are perfectly in accordance with those of the species. It contains no selenium and only a trace of gold.

Auriferous hessite.—This mineral has been spoken of as petzite; but it contains much too little gold for this latter species.* Its specific gravity is 8.6; luster splendent when freshly broken; fracture conchoidal, brittle, but somewhat malleable; under the pestle laminates into thin scales, and is with difficulty reduced to fine powder, leaving on the agate surfaces metallic streaks of plumbago-like color. Color telluric, tarnishes blackish on exposure, sometimes irridescent. Cleavage none.

Before the blow-pipe in the closed tube, the pure mineral (with no trace of pyrite) decrepitates, fuses to a globule adhering to the glass, and exhales a white sublimate, fusing into clear, colorless globules. Alone on coal, in both flames, it gives a globule, coats the coal with the characteristic areola of tellurium and tellurous acid; it does not exhale any odor of selenium, nor show any trace of lead. The globule is nonmagnetic if pyrite is absent, and does not vegetate with silver as hessite does with soda; it gives a large bead of silver, which dissolves in nitric acid, leaving gold in powder.

*Mr. A. Eilers, M. E., in a notice of the Red Cloud mine, in the Transactions of the American Institute of Mining Engineers, vol. i, p. 315, considers it petzite.

Cupellation gave, gold, 4.40 per cent.; and silver, 50.90 per cent.

By a partial analysis I found, in the wet way, gold, 7.131; silver, 51.061 per cent. Understanding from Dr. Genth that he is engaged in the chemical investigation of this species, as well as of the other tellurium minerals of the Red Cloud mine, with abundant material, I have willingly abandoned this work to him, satisfied that it cannot be in better hands.

Sylvanite.—This species from the Red Cloud mine yields in the open tube a faint odor of selenium, and the gray ring of tellurium is preceded by a slight reddish ring of selenium. In the closed tube, the ring of tellurium is more distinct, and the deep yellow-brown vapor of the metal is clearly seen, but the selenium is not evident.

Alone on the coal it fuses with exhalation of the odor of selenium and its well-characterized blue flame. The first touch of the outer flame causes a liquid fusion, coating the coal, like argentic nitrate, with a silver film, and a yellow areola appears before the white film of tellurium-oxide. Continuous flaming in the reducing-flame produces a well-marked yellow-brown areola within the tellurium-ring, becoming, as it cools, much more brown. It probably contains lead and antimony. Its reactions are not those given by Berzelius for sylvanite. It contains by assay gold and silver in the proportion 1.7 to 1. In the formula, (Au 28.5, Ag 15.7,) the ratio of the gold and silver is 1.8 : 1. My stock of this species was not sufficient to permit a determination of the specific gravity.

Professor Hill, who has smelted large quantities of the ores of the Red Cloud mine, informs me that "these minerals exist in this ore as minute particles, or so finely divided as to produce the effect of a stain in the rock. One of the specimens sent—the darkest colored—assayed here was found to contain 1,890 ounces of gold and 5,300 ounces of silver to the ton of 2,000 pounds"—about $50,000 in value.

Comparing what is known of the mineral associates of the tellurium-ores of Colorado with those of Transylvania, as described by von Cotta, the great simplicity of the mineralogy of the Colorado veins becomes very conspicuous. The age of the porphyry-dikes which cut the Archæan rocks of Colorado has not been determined; but it is probable that they are more recent than the Triassic rocks which flank the base of the mountains. The tellurium-veins of Offenbánya are accompanied by igneous rocks of more recent date than the Eocene sandstones, and those of Nagyag exist only in connection with igneous rocks, also of probable Eocene age, (called by von Hingenau "greenstone-porphyry,") and composed of feldspar and amphibole, which have broken through sandstone and argillaceous shales.

In Offenbánya, the tellurium-ores occur under very peculiar geological conditions; that is, in veins in igneous rocks and in segregated masses in granular limestone. The veins occupy thin clefts, fifteen of which on one property are tolerably parallel to each other, (east and west, dip 30°–40° north,) with an average width of about an inch, and they carry chiefly sylvanite, and nagyagite, sparingly distributed, and more rarely native gold. The chief matrix is quartz and diallogite, associated with pyrite, galenite, sphalerite, stibnite, native silver, and pyrargyrite.

The gangue of the Nagyag lodes is diallogite, or brown spar, or calcite, or hornstone and quartz; it varying in the different lodes and in different parts of the same lode. The gold-bearing tellurium-ores are scattered through this gangue with mangan-blende and pyrite. The chief ores worked are nagyagite, sylvanite, gold, auriferous iron pyrites, argentiferous tetrahedrite, native silver, and galenite. Associated with these are hessite, bournonite, jamesonite, barite, sphalerite, stibnite, native arsenic, realgar, orpiment, silver-glance, chalcopyrite, marcasite, native copper, malachite, pyrrhotite, sulphur, &c., with various epigene species. In all, over forty mineral species are enumerated as found in the veins of Nagyag. Compared with this abundance, we find at the Red Cloud mine only native tellurium, sylvanite, hessite, pyrite, chalcopyrite, and more rarely galenite and sphalerite, with native gold and an epigene species at surface. The gangue-stone is hornstone or chalcedonic quartz, with feldspar.

Possibly explorations at greater depths may develop other species, but this result has not followed the deep-workings of the silver-mines in Nevada, where, at the depth of 1,500 feet, the number of species found is not greater than it was at the surface. A like paucity of species characterizes the metamorphic and volcanic rocks of the Sierra Nevada in California.

GENERAL INDEX.

NOTE.—For alphabetical lists of minerals and rocks, (not repeated in the following,) see pp. 267, 270, and 356; for list of elevations, pp. 657–659.

C.

D.

E.

INDEX OF SYSTEMATIC NAMES.

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