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## NOTE ON THE GLACIAL DEPOSITS OF SOUTHWESTERN ALBERTA.

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In the *Geology and Resources of the Forty-ninth Parallel* (1875), the writer first gave some account of the superficial deposits and glacial phenomena of that part of the Great Plains now included in the district of Alberta. This was followed, in the *Report of the Geological Survey of Canada* for 1882–84, by a somewhat more complete presentation of the facts relating to the same region. Since that time considerable areas of the adjacent plains have been examined by Messrs. McConnell and Tyrrell, much further information has been obtained respecting the Cordilleran region and many very important advances have been made in the study of the glacial period in North America generally. It thus appeared to be desirable that some further examination should be made, by way of revision and addition, in this region in which the Great Plains border upon the Rocky Mountains, and with this object, the writer, accompanied by Mr. R. G. McConnell, spent some time there in June 1894.

The main points which seemed to require attention were those connected with the relation of the eastern and western drift along the slopes of the mountains, the western limit of the former and the nature of this limit. It appeared probable that facts of value might, in particular, be obtained in the Porcupine Hills, which rise to heights exceeding 5000 feet, at a distance of from twenty to thirty miles east of the Rocky Mountains, where, if anywhere, the highest margin of the glacial deposits should be marked either by moraines or by beach-lines.

In the course of a much closer examination of these hills than had previously been possible, it was in effect found, that they show a series of terraces, running up from about 3200 feet to a maximum height of 5300 feet above sea level, and that drift from the Laurentian Plateau, on the east and the Rocky Mountains on the west occurs, as well-rolled shingle, up to the highest level of these terraces and no further. The elevation is nearly three times that of the Laurentian Plateau, and the circumstances show that the Laurentian and Rocky Mountain stones reached these high levels at the same time.

A comparison of the highest levels of the drift in several places in southwestern Alberta, indicates the existence of a tract of greatest depression and of subsequent maximum elevation in a part of that district, and probably that of a series of nearly parallel isobases of decreasing amount to the northeastward of this tract, trending east-southeast by west-northwest, but turning to a northwesterly direction (corresponding with that of the mountains) further to the northward.

Whether the upper limits of glacial deposits be accepted as the shore-lines of an extended body of water, as marking the surface level of a *mer de glace* or as the margin of a glacier-dammed lake, enormous changes of level in the region must equally be admitted.

A search for eastern erratics upon higher parts of the foot-hills, in certain localities somewhat extends the spread of this drift to the westward, beyond the line drawn for it by me upon previous maps. These erratics in fact become quite sporadic in their distribution on approaching the mountains.

Some years ago, while examining the sections of glacial deposits along the Bow Valley, eastward from the mountains, Mr. McConnell found reason to believe in the existence of a "western" bowlder-clay which changes gradually to the east into the typical Saskatchewan gravels of the plains. This observation has now been confirmed, and it follows from it and from the inferior position of the Saskatchewan gravels to all the previously recognized glacial deposits of the plains, that we have in this region no less than three bowlder-clays to reckon with. The earliest of these is derived entirely from the Rocky Mountains and does not, as a bowlder-clay, extend very far from them. The two later bowlder-clays contain stones of mixed eastern and western origin, each variety preponderating in the direction of its origin. A general section of the drift deposits of the region, as now understood, thus shows, in descending order:

1. Silts, sands and gravels.
2. "Upper" bowlder-clay.
3. Inter-glacial deposits.
4. "Lower" bowlder-clay.
5. Saskatchewan gravels derived from "western" bowlder-clay.

It is not quite certain to which of these deposits the high-level terraces and shingles correspond, but it appears probable that they may be assigned to the time of the "upper" bowlder-clay or to that of its close. Neither is it yet definitely known whether the "lower" or "upper" bowlder-clay of the plains extends furthest in toward the base of the mountains. In the absence of the inter-glacial beds, no satisfactory means of distinguishing these deposits in isolated exposures has been found.

It is hoped shortly to publish in sufficient detail the observations upon which these preliminary statements depend; but without entering at all into the question of the mode of origin of the several deposits, it may be of interest here to note their possible relation to those of the glacial epochs or stages recently classified by Professor T. C. Chamberlin. The "lower" bowlder-clay of the plains of western Alberta, may I believe be pretty certainly correlated with his first or Kansan formation, in which case the inter-glacial deposits of the Belly River would represent the Post-Kansan interval and the "upper" bowlder-clay of the same region the Iowan formation. Like the Iowan formation the "upper" bowlder-clay is characterized by abundant associated silty beds, and no extensive moraine-like deposits are known to be connected with either the "lower" or "upper" bowlder-clays. Further eastward, the northern continuation of the Missouri Côteau to the North Saskatchewan may indicate the limit of the Wisconsin formation. It is at least notable that beyond the Côteau a well-marked system of eroded valleys exists,[1] which finds its limit at the Côteau in a manner much resembling that ascribed to the valleys of the Post-Iowan interval.

According to the scheme of correlation suggested above, it will be observed that the "western" bowlder-clay must represent an epoch of glaciation antecedent to the Kansan. There can be but little doubt that this corresponds with the time of maximum development of the Cordilleran ice-sheet, but as there was at least one subsequent epoch of important development of this ice-sheet, I would suggest that this stage may be named "Albertan." The Albertan "formation" to comprise both the "western" bowlder-clay and the derived Saskatchewan gravels.

We may further, although with some reserve as yet and provisionally, accept the hypothesis that the Saskatchewan gravels are contemporaneous with the Lafayette gravels, and in this case the suggestion made by Professor C. H. Hitchcock in a late number of the *American Geologist*[2] that the Lafayette gravels represent in the East a glacial epoch earlier than any of those of Professor Chamberlin's classification (which it must be remembered is based upon the region of the Laurentide glacier only) would be substantiated. The bowlder-clays of this epoch may have been obliterated by later events in the East, but still remain unchanged along the base of the Rocky Mountains. Professor Hitchcock further suggests in the same note that the two periods of maximum moisture in the Great Basin may correspond with his supposed first epoch of glaciation and the Kansan epoch, a hypothesis which would correspond very well with that here proposed.

[1] Geology and Resources of the Forty-ninth Parallel, p. 230.

[2] Vol. XV., p. 330.

The migration of the great center of glaciation from the northern Cordillera to the Laurentian Plateau must have been intimately connected with the very notable changes in relative levels which have already been alluded to.

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# EXPERIMENTAL APPLICATION OF THE PHOTO-TOPOGRAPHICAL METHOD OF SURVEYING TO THE BAIRD GLACIER, ALASKA.

It is believed that the method of photographic surveying, as developed by Mr. E. Deville, surveyor general, Dominion of Canada, will prove of great assistance to those engaged in the study of the motion of glaciers. The method is briefly described by the writer in the annual report for 1894 of the Association of Ontario Land Surveyors.

While engaged at other work in connection with the Canada-Alaska boundary survey, — Mr. W. F. King, H. M. Commissioner, — during the past season (1894) I embraced the opportunity of taking a number of views of the Baird Glacier, Thomas Bay, from the same stations and at different times for the purpose of studying its motion near its termination. The stations occupied were three in number, all situated on the fluvio-glacial plain which extends for upwards of half a mile between the glacier and the sea. The bases used were 865 and 2065 feet in length, and were measured with a tape, and their azimuth determined with a transit from solar observation. Mountain peaks and other fixed points within the photographic field were also read upon, for the purpose of orienting the views. Two crossed rings were painted on the rock bordering the east side of the moraine and tied to the triangulation for future reference, should any one again take observations or measurements of the glacier. The work done is but a small part of what might or should be done for a complete study of the motion of the glacier in all its parts. This was beyond my sphere and the time available. However, the little that was accomplished will show satisfactorily the applicability of the camera for the study of glacial motion, and also give some facts regarding the motion of the Baird Glacier.

It may be interesting to state how I proceeded to arrive at the results hereafter given, and to point out the difficulties encountered.

From views taken from the 865-foot base,—about 1700 feet from the glacier, which has a frontage of a mile—I plotted that part of the glacier that was intervisible; this gave me some thirty points on the glacier-front whose distance and height became known, and thereby the general contour and slope; the latter was found to be 1:3. This, of course, is far in excess of the slope of the glacial stream proper, which is found from our surveys to extend (the western branch) over fifteen miles in in a straight line into the interior and to have a slope of 1:20. It may be mentioned that this branch and the Dawes Glacier emptying into Endicott Arm have the same névé. The mean slope of the Patterson Glacier, lying southeast of the Baird, is in ten miles, 1:13.

The difficulty in using a long base for photographing the face of the glacier is that it is then pretty difficult to recognize many points common to both stations. The photographs were taken on May 15, 19, July 13 and August 11, 1894. The nearest base station (No. 3) was about 900 feet from the ice. The photographs taken from this station show most markedly the change and motion that took place between July 13 and August 11,—twenty-nine days—on which dates views were taken too from station No. 1, 2065 feet from the former. Some fifteen points on the glacier were distinctly recognizable from both stations, and hence plotted in distance and altitude. We had now a fairly accurate delineation of a part of the glacial front so that the distance to any point therein became well enough known to utilize for the purpose to be shortly explained.

It is evident that from photographs from the same station but at different times changes are best seen. A photograph itself, however, only furnishes the angular measurement of any point thereon, both in azimuth and altitude, but not linear measure. Hence, when we are comparing photographs of the same views from the same station, we must know the distances—or approximately at least—to points under consideration for interpreting properly the changes as shown by the photographs. The glacier having been plotted as already stated, any required distance was obtainable.

A question that suggested itself from the photographs was that of determining the shrinkage or melting of the ice (ablation) between July 13 and August 11, irrespective of any motion. This was obtained in the following manner: On the photographs well-marked points were selected on the adjacent mountains, verticals through which cut the glacier. Each point selected was common to both views. Evidently points which lie in the same vertical plane in one photograph lie in the same plane in another photograph from the same station. There were thus eighteen intersections common to two photographs of the crest of the face of the glacier obtained. We hence had the angular measurement of these intersections, and as the distances thereto were sufficiently well known, the linear measure followed. It is not forgotten that, especially near the face of the glacier, the motion of the ice causes crevasses and upheavals so that in a particular vertical section there may be an abnornal decrease or increase in elevation and the phenomenon of shrinkage obliterated or at least hidden. In fact, the observations or photographs show such to be the case; for in one instance we have a rise of nearly six feet, instead of a decrease of two feet as the average shows. From these eighteen intersections we find that during the twenty-nine days,—July 13 to August 11,—the mass of the glacier—ice front—fell a little over two feet (2.1 feet).

Let us now examine the linear motion of the ice. This problem we can attack from two points—using only photographs from one (nearest—No. 3) station.—Firstly, by finding the vertical motion, and secondly by determining the change in azimuth. The former is directly obtained by measuring on the photographs the distance of a point on the two photographs, above the horizon line, then from its known distance the absolute height in each case is obtained, and the difference will be the motion in altitude for the interval of the photographs. From the general plotting of the glacier we have its average slope, which in this case is 1:3. From points treated in this way we obtain a mean fall for any particular point during the twenty-nine days of 11.2 feet, being equivalent to a motion of 33.6 feet.

For comparing the azimuths of the same point in two photographs we refer the point in each to the same vertical through some point on the mountains—(the verticals drawn for the purpose of ascertaining the shrinkage were utilized). The linear measure taken on the photographs combined with the fixed focal length of the camera gives the desired angular differences in azimuth, and this latter applied to the known distance of the point gives the motion of the point at right angles to its direction from the station. The quantity expressive of the above motion must be corrected for the actual direction of the point. This latter direction we again obtain from our general plot of the glacier whereon the direction of ridges is established.

For eighteen points change of azimuth was thus determined, and from the relative position of the station to the glacier front the change in the absolute azimuth of a point changed from minus to plus, those to the left or west decreasing, those to the right or east increasing in azimuth, while those directly in front, *i. e.*, where the direction from the station to the point was coincident with the line of motion, showed no change in azimuth. From these we obtain a mean absolute motion of 29 feet, which, combined with the above, gives a mean motion of a fraction over a foot per day from July 13 to August 11. From this data alone it would be imprudent to give an estimate of the total motion in the year. The greatest distance of any point considered was about 3000 feet from the station.

The results obtained may be summarized:

Between July 13 and August 11, 1894, the end of the Baird Glacier was lowered by melting a little over two feet, and the average motion of the ice in that part was one foot per day.

The Baird Glacier consists of two arms, each about 16 miles long. About one and three-quarters miles from the terminal moraine they merge into one stream. At the western side emerges a subglacial torrential river, carrying an enormous amount of ground and disintegrated rock—mud. It looks almost too thick to flow. In consequence of its eroding action and the pressure of the moving glacier, its vaulted ice roof near the ice front from time to time collapses, and large masses of ice are then carried out to sea by the rushing waters. Water is found issuing from other parts of the glacier, and not only from underneath but at various points on its face, but only in small streams, and is generally clear or has the characteristic milky color. Although the greater part of the face of the glacier looks "dirty," yet but very few stones are imbedded therein. There is a large quantity of débris on the surface of the glacier, brought down many miles from the eastern arm. The débris is composed of material varying from fine gravel to large bowlders.

An interesting feature of the photographs obtained is the morainic ridge that borders almost continuously the ice front. Its height is about five feet. Examining the photographs of July 13 and August 11, taken from the same station, it is seen that the mounds of which the ridge is composed have changed. This change, like the mounds themselves, is not due to addition of detritus from the face of the glacier, otherwise the accumulation of matter would lie in contact with the ice, which is not the case. The formation of the ridge, and consequently any change thereof, is due to the motion of the toe of the glacier. A side-view photograph taken just beside the glacier makes this apparent.

When we approach the glacier within one or two hundred yards, we meet with depressions in the fluvio-glacial deposit, which increase in depth and sharpness of outline as we advance. The depressions or holes have a maximum depth of about five feet and diameter of about fifteen feet. In a few of the deeper ones a pool of clear water was found. The cause of these depressions is not very apparent. They have not been excavated by streams, but to explain them by the melting of parts of the glacier which projects for some distance underneath the terminal deposit, though plausible, is yet not quite satisfactory.

It would take up too much space to describe in detail our methods of photographic surveying, but a few hints may be suggested to those unfamiliar with the subject and whose explorations and scientific inquiries afford an opportunity for gathering valuable data in the field by means of the camera, which may be subsequently worked out. The first requisite is the utilization of a constant (the principal) focal length for all photographs taken. This necessitates a rigid camera box with no focus adjusting arrangement (bellows). The lens should be a good one, giving a flat image and having an angle of about 60°. To give sharpness to distant points an orange glass screen is always screwed to the front of the lens. This, of course, increases the time of exposure. In the center of each side of the box and in front of the plate is fixed a brass point or comb each of which shows on every photograph and together they serve to orient the photographs. The camera must always be horizontal, to insure which a small level is placed on top; preferably one composed of two in the form of a T. It is convenient to have a foot for the camera so that it can be placed and leveled on the tripod of the transit or theodolite necessary for making the skeleton triangulation, to which the photographs are referred. For good work glass plates are essential. They should be orthochromatic. A convenient size for transport is 4¾ by 6½ inches. In panoramic views, adjoining photographs should have at least one well-recognizable point in common, *i. e.*, the photographs should overlap.

In applying the camera to the study of the motion of glaciers, it is difficult to give definite instructions what to do, as the conditions presented vary so widely. Each case will suggest the most advantageous course to pursue; what length of base to measure; how many pickets to plants across a glacier (it is well to distinguish the pickets by having alternate ones with a "cross-head" T), etc. The photographs want to be taken from the stations, and at intervals of time of a week or weeks, or months, dependent upon the conditions and thoroughness of investigation required. In general we may say that the same considerations obtain in the selection of photo-topographic stations as for trigonometric stations, *i. e.*, that the intersections for the location of points may be of fairly well conditioned triangles. Every photograph gives—knowing the focal length of the lens—the angular measurement of every point on the photograph, *i. e.*, the azimuth of any point from any other point, and also the angular elevation or depression above or below the horizon of the camera.

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# THE CAMBRO-SILURIAN QUESTION IN MISSOURI AND ARKANSAS.

It is a remarkable fact that of all the great Mississippi basin with its area equal to more than one-third of that of the whole United States, its very center, the portion which is richest and most important of all in mineral wealth, should be the only portion which has remained geologically a veritable *terra incognita*. The region is widely known as the Ozark uplift, a broad dome which occupies the southern half of Missouri and the northern part of Arkansas. The rocks composing it form an important sequence of dolomitic and arenaceous beds which are known to lie between the horizon of the Trenton limestone and the crystalline, or Archæan, complex; and which have recently been termed by Broadhead[1] the Ozark series.

In the earlier geological reports of Missouri great prominence was given to the succession of magnesian beds. By Swallow[2] there were considered to be four thick limestones, separated by sandstones. They were known as the First Magnesian limestone, at top, the First or Saccharoidal sandstone, Second limestone, and so on to the Fourth Magnesian limestone at the bottom. The aggregate thickness of this "Magnesian Limestone" series was considered to be over 1200 feet. It was referred to the Calciferous division of the New York section as then understood.

Since the appearance of Swallow's report other work has been done in the region, and of recent years interest in the subject has been revived. In southeastern Missouri more attention has been directed to the Magnesian rocks than perhaps anywhere else in the Ozark uplift, and although many new facts have been obtained much additional information is necessary before satis-

[1] American Geologist, Vol. VIII, p. 33. Minneapolis, 1891.

[2] Geol. Sur. Missouri, 1st and 2d Ann. Repts., p. 60. Jefferson City, 1855.

factory conclusions concerning the exact geological age of the different parts of the general section can be drawn.

The igneous masses beneath the sedimentaries are known to be Archæan in age. They were subjected to prolonged degradational action; and it was upon their profoundly eroded surface that the sand and limestones were laid down during early Palæozoic times, burying to very considerable depths probably all of the old peaks and elevations. While it is true that the relations of the different sections of the region has not yet been determined with accuracy it appears evident from the data at hand that the Silurian is well represented and that a part belongs to the Cambrian.

In southeastern Missouri the Palæozoic rocks from the top of the column down to the base of the Trenton are well known. Beneath the latter there is, as first made out by Shumard, a bluish, limerock having a thickness of upwards of 100 feet, which has been regarded as the non-fossiliferous portion of the formation just mentioned. Below all this there comes the sequence of dolomites and sandstones to which reference has been made. It has further been stated that there were formerly considered to be four great limestones alternating with arenaceous beds; but of late it has come to be believed that the relations of these beds are not exactly in accordance with the views expressed at first. East of the crystalline area and trending in a broad curve northwest and southeast, a direction which is nearly at right angles to the axis of the uplift, are the oldest Palæozoic rocks whose geological age is definitely known. Immediately west of this belt of strata, which is the fossiliferous Trenton limestone and the band of similar rock but almost without fossils, is a narrow zone of what has been termed the First Magnesian limestone, and then in a somewhat broader belt the First or Saccharoidal sandstone. A short time ago[1] it was suggested that the latter probably rested unconformably upon the strata beneath; and more recently Winslow[2] has reported from the vicinity of

[1] Keyes: Missouri Geol. Sur., Vol. IV, p. 35. Jefferson City, 1894.

[2] Missouri Geol. Sur., Vol. VI, p. 356. Jefferson City, 1895.

Pacific, forty miles west of St. Louis and elsewhere, unmistakable evidences of a marked unconformity at this horizon. Now the Magnesian limestones and sandstones of the crystalline area, are, according to the best accounts, at a geölogical level considerably below the Saccharoidal sandstone. Regarding the age of the rocks Broadhead,[1] who has been in the region more than any one else perhaps, is inclined to assign a large part of them to the Cambrian. Lately, Walcott[2] in his correlation essay on the Cambrian of North America, has summed up all that is known on the subject and has colored on his map of the continent as Cambrian all of the sedimentaries of the crystalline district of Missouri.

The correlation of the Magnesian limestone of southern Missouri has been almost entirely upon very meager stratigraphical grounds. From one end of the broad uplift to the other, wherever the rocks of this series are open to view, there has been found up to the present time a great paucity of fossil forms. Not only are the rocks almost devoid of the ordinary faunal means by which the different terranes may be determined with precision, but the organic remains thus far secured are so poorly preserved that they are largely worthless for systematic purposes. Further, it is quite remarkable that of all the forms obtained from these rocks there have been none which have been identified with certainty with species described from other districts. In every case where specific comparisons have been made more or less doubt has always been expressed concerning the actual identity of the species referred to. Of the many fossils mentioned in connection with the various allusions to, or descriptions of, the region, few of the references have been more than generic. In a recent critical review[3] of the fossils of Missouri, collections made by different individuals from the Magnesian limestones were examined. The material proved to be so fragmentary on the whole, and the exact or even approximate horizons where the particular forms were obtained so poorly determined that

[1] American Geologist, Vol. III, p. 7. Minneapolis, 1889.

[2] U. S. Geol. Sur., Bulletin 81. Washington, 1891.

[3] Missouri Geol. Sur., Vols. IV and V. Jefferson City, 1894.

practically nothing could be inferred regarding the relations to one another of the fossil-bearing horizons in the different localities. Many of the fossils imperfectly preserved, as most of them were, appeared to be undoubted Silurian forms, while others possessed a very decided Cambrian aspect, but in no case were the faunas extensive enough to warrant an exact arrangement of the succession. All the fossils that have been mentioned or recorded from the limestones of Missouri have recently been tabulated by Winslow & Robertson.[1] By these tables and the accompanying paragraphs of explanation the utterly intrustworthy character of the faunal evidence thus far obtained for separating the Ozark series of Missouri into its proper terranes is admirably shown. Of the total of 151 entries more than one-half of the forms are duplicated; only twenty-two are specifically different and of this number but half a dozen are referred to species occurring in other localities. Although considerable information concerning the geology of the district has been obtained there yet remains to be done much detailed work. What is true in regard to the fossils in the strata of this region is equally applicable to those found in other portions of the uplift, except that in most other localities they are of even rarer occurrence.

The Silurian rocks of well determined age which lie above the lower part of Ozark series of Magnesian limestones occur chiefly in the eastern part of the region. They are best exposed along the Mississippi river between St. Louis and the mouth of the Ohio, and include the Trenton limestone, the Hudson shales and certain Upper Silurian limestones. Farther south in northern Arkansas strata thought by Williams[2] to represent a part of this sequence are reported. But it is beneath the Trenton in the eastern portion of the uplift that the difficulty comes in attempting to fix the geological age of the strata.

As explicitly stated elsewhere[3] the Ozark series of Broadhead includes both Silurian and Cambrian, instead of the latter alone,

[1] Missouri Geol. Sur., Vol. VI, pp. 380–385. Jefferson City, 1895.

[2] Arkansas Geol. Sur., Ann. Rep. 1890, p. 108. Little Rock, 1893.

[3] KEYES: Missouri Geol. Sur., Vol. IV. Jefferson City, 1894.

as was finally thought by the author of the name. The limestones of the series cover a very large part of the Ozark region, and it is quite probable that a very considerable proportion of them will be found to be Silurian not only in Missouri but in Arkansas. In the Batesville region Trenton fossils have been recognized by Williams,[1] and beneath the strata containing them are Magnesian limestones and sandstones which are referred to the Calciferous. "Only the upper members, however, are such. The larger part remain to be studied. Below them and exposed to the north is a series which according to Branner pass into Missouri."[2] Farther to the west in the Ouachita district the novaculite rocks are said to be largely Silurian. As evidence a number of Graptolites have been described and a few molluscan remains recognized.

The nearest region presenting rocks of similar age and lithological characters, one which has been, moreover, thoroughly investigated and with which the Missouri strata are to be compared, is in northeastern Iowa and the adjacent portions of adjoining states. It is therefore the Cambro-Silurian section of the Upper Mississippi that must serve as a standard of comparison for the Missouri rocks under consideration, and with which detailed correlations must be made. This fact necessarily has great weight in all attempts to correlate the rocks of the two districts. In the absence of faunal evidence that was at all satisfactory; with so small a proportion, in the Mississippi valley, of the Silurian existing below the Trenton which is an horizon clearly defined in all parts of the basin; with a thickness in Missouri of Magnesian and Saccharoidal sandstone below the Trenton nearly twice as great as in Iowa between that formation and the top of the Cambrian; with the evidence of a marked line of unconformity at the base of the First sandstone; and with a considerable sequence of limestones and sandstones beneath the physical break mentioned, the evidence appeared at the time of the recent review of the geological formations of Missouri amply sufficient for regard-

[1] Arkansas Geol. Sur., Ann. Rep., 1890, Vol. I, p. 112. Little Rock, 1891.

[2] Ibid., p. 116.

ing, provisionally at least, the Magnesian limestone series below the Saccharoidal sandstone as Cambrian. The facts requisite to a final conclusion as to whether or not this line is the correct divisional one must be derived from a consideration of abundant fossils after a careful stratigraphic connection of the various sections has been made. In making a comparison of the Magnesian series with the Cambro-Silurian of Iowa and Minnesota it may be noted that according to the recent work of Hall and Sardeson[1] the line between the Cambrian and Ordovician (Lower Silurian) is carried up to the base of the St. Peter sandstone, where a very distinct faunal break occurs. The Middle Cambrian is also recognized. This narrows down the space between the Cambrian and the Trenton limestone in that region to still smaller dimensions, so that if the inference is correct only a thin sandstone now intervenes. If, further, the correlation by Worthen[2] of the St. Peter formation of northern Illinois and the sandstone at Cap-au-Grès, near the mouth of the Illinois river, and that sandstone with the Saccharoidal of Missouri is right, there is added further weight to the existence of the unconformity at the base of the latter.

Regarding the age and history of the Ozark uplift much might be said. Since it is quite probable that the Archæan peaks of southeastern Missouri formed the first land in the region to appear above the waters of the continental ocean it has been the general opinion among those who have worked in the district that the crystallines remained above sea level as an archipelago from pre-Cambrian times until the close of the Palæozoic when all the area around became a land surface. This has led to the inference that the existing geographic features are very old. But the validity of these conclusions is not only very questionable but it is manifest that the present features of the Ozarks are essentially modern.

It is probable that from Archæan times the region has been one of constant oscillation, for the most part slight, perhaps, but at

[1] Bul. Geol. Soc. America, Vol. VI, p. 170. Rochester, 1865.

[2] Geol. Sur. Illinois, Vol. I, p. 150. Springfield, 1866.

certain periods quite marked. Some of these changes in elevation are clearly defined, but the records of most of them are now obliterated. One of the most notable results of the warping of the lithosphere in this district was at the beginning of Palæozoic time, when the crystalline complex was subjected to profound subaërial erosion. Minor changes of level are also recorded. Another period of notable uprising was during Devonian times. A third was towards the close of the Lower Carboniferous, after the deposition of the St. Louis strata. Still another was one which closed Palæozoic deposition in the continental interior. Unconformities of greater or less prominence record these episodes in the geological history of the region. In post-Palæozoic times the oscillations of level were manifestly not less marked than in the earlier periods. The most noteworthy perhaps was the gain of the land after the protracted submergence recorded by the Cretaceous. It was probably at this time that the forces of compression were felt most and that the warping and folding was more intense than at any other period in the history of crustal movement in the Ozark region. Moreover, it is to this period that the intrusions of igneous rocks along the southern or coastal margin of the uplift in central Arkansas are assigned. Evidences of a subsequent lower level of the land surface are manifested in the peculiarities of the topographic forms in the plateau district and in the relatively uniform evenness of the upland plain. Conclusions deduced from glacial investigations point to a depression in very late geological times of the surface of the continental interior below its present position. This carries with it the inference that since the close of the Tertiary elevation has taken place. This is clearly indicated in the youthful topography now existing along the borders of the uplift. The watercourses have cut profound valleys in the general upland plain, and now flow in canyon-like trenches which are ever deepening as the streams recede from their sources. Erosion is now going on vigorously. The rivers are carrying away the débris from their steep-sided banks as fast as formed, and are rapidly cutting lower and lower their confined and contracted channels, while their deepening gorges are being constantly carried back towards the crest of the great divide. The cycle of the last movement is not yet ended; and the change in level of the region is probably going on now as rapidly as it ever has in past geological time, and as rapidly as oscillations of the land surface usually take place.

From the foregoing it may be inferred that since the original deposition of the Ozark series, the rocks have been profoundly eroded, and that the later formations which are known to have covered in great part the Magnesian beds of the uplift have been almost entirely removed during the periods of emergence.

As yet, then, the exact geological age of the different parts of the Ozark series is not determined, but the horizons where the proper lines should be drawn are foreshadowed, and with the passage of another season it is believed that the question, both faunally and stratigraphically, will be satisfactorily settled.

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# NOTES ON THE EXAMINATION OF A COLLECTION OF INTER-GLACIAL WOOD FROM MUIR GLACIER, ALASKA.

At the solicitation of Mr. Harry Fielding Reid I have undertaken the examination of a small collection of inter-glacial woods obtained by him in the summer of 1892, from the Muir glacier, Glacier Bay, Alaska. These woods were mostly found in place under glacial drift, and there can therefore be no question as to their position.

The buried woods were also accompanied by a number of specimens of living wood from trees found growing at the present time near Sitka. With these living trees were specimens of the leaves that came from them, but unfortunately all the leaves were placed together in a box without numbering, so I had no means of connecting the leaves and wood. The wood has been identified, however, by comparing the internal structure with that of a series of named woods belonging to the Sargent collection obtained for the Tenth Census.[1]

I have also taken the liberty of adding to Mr. Reid's collection a single fine specimen of wood obtained by Miss E. R. Scidmore of Washington, D. C. This specimen, as I am informed by Miss Scidmore, was found protruding from a gravel bank which lay beneath an ice-sheet some seventy feet in thickness, on the eastern moraine of the Muir glacier. As it happens to be the only piece of dicotyledonous wood thus far detected beneath this glacier, it is of particular interest.

## LIST OF INTER-GLACIAL WOODS WITH BRIEF MACROSCOPIC DESCRIPTIONS.

1. *From the buried forest, Muir glacier.*

This consists of a single piece six inches long and, approxi-

[1] Tenth Census of the United States, Vol. IX. "The Forest Trees of North America."

mately, an inch in diameter, and several smaller fragments, which all appear to have come from the same trunk. The large piece is slightly worn on one side, but the rest of the specimen appears freshly broken, as do the smaller pieces. This wood is very light and is the most metamorphosed of any of the specimens. It can be easily rubbed to powder between the thumb and fingers, appearing in this respect like wood affected with what is known as "dry-rot." There is no evidence, however, of the presence of attacking fungi, and its softness is doubtless due to its prolonged masceration. It is very dark brown, almost black, in color.

As already stated this specimen has been badly changed, so much in fact that it has been impossible to identify it with satisfaction. It is the only one left undetermined.

2. *From the buried forest, Muir glacier.*

A piece evidently cut from near the root, which is $20^{cm}$ long and about $40^{cm}$ in diameter. It is without bark, yet is only slightly abraded. One end is much split and "broomed" as though by action of water. The wood is very hard, and is but little changed.

3. *Found on surface of gravel deposits south of Camp Muir; very abundant.*

A segment cut from a trunk or branch $8^{cm}$ in diameter. It is without bark and bears evidence of having been exposed. The wood is compact and shows little if any change from the normal condition.

4. *From buried forest, Muir glacier.*

A number of small water-worn branches, the largest being less than $2^{cm}$ in diameter. The woody structure is very little changed, being still compact and bright where freshly broken.

5. *From buried forest, Muir glacier.*

This consists of two pieces of bark $20^{cm}$ long and $10^{cm}$ wide, without trace of wood. This bark, which is less than $1^{cm}$ in thickness, is but very little abraded and is indistinguishable from recent bark.

$5^a$. *From buried forest, Muir glacier.*

Consists of a piece of bark $18^{cm}$ long, $11^{cm}$ wide and about $4^{cm}$ thick. It is not the least changed by water action and presents the same bright reddish appearance as a piece from a living tree. It is also accompanied by a number of fragments of wood that are very light, yet appear very little changed. The larger piece is riddled by a number of worm holes, showing that the wood had been exposed for a time to the attack of insect larvæ, before being entombed.

6. *A piece of stump on east side of Muir Inlet, near Camp Muir; uncovered only at very low tide.*

A thin chip, evidently cut from a large stump, having a thin bark still closely attached to it. It has been very little changed by the action of the elements.

*A single specimen from under the eastern moraine, obtained by Miss E. R. Scidmore.*

This represents a branch or stem $30^{cm}$ long and about $5^{cm}$ in diameter. A thin bright-colored bark still adhered to most of the piece, while the wood is very little changed, being bright colored and fresh.

The living woods mentioned above were accompanied by only three kinds of leaves, which have been identified as follows: *Picea Sitchensis*, Carr., *Tsuga Mertensiana*, Carr., and *Chamæcyparis Nutkænsis*, Spach.

PICEA SITCHENSIS, CARR.

The tide-land spruce is a tree of very large size, found from Alaska south to Mendocino county, California, not extending more than fifty miles from the coast. The wood is light, soft, straight-grained, compact and satiny. The bands of summer cells are narrow and inconspicuous, and the resin passages are few and obscure. The medullary rays are numerous and prominent. The color of the wood is light-brown tinged with red, but the sap-wood is nearly white.

To this species I have referred Nos. 2, 3, 4, and $5^a$. Of these $5^a$ is perhaps the most interesting. It has the annual rings clearly marked, the medullary rays in a single series from three or four to thirty cells high with an average of about twelve or fifteen. The rays in radial section show the walls to be thickened in an irregular manner as represented in Fig. 1. They are provided with a single row of small oblong pits, about two in the width of each wood cell. The wood cells are broad in the sum-

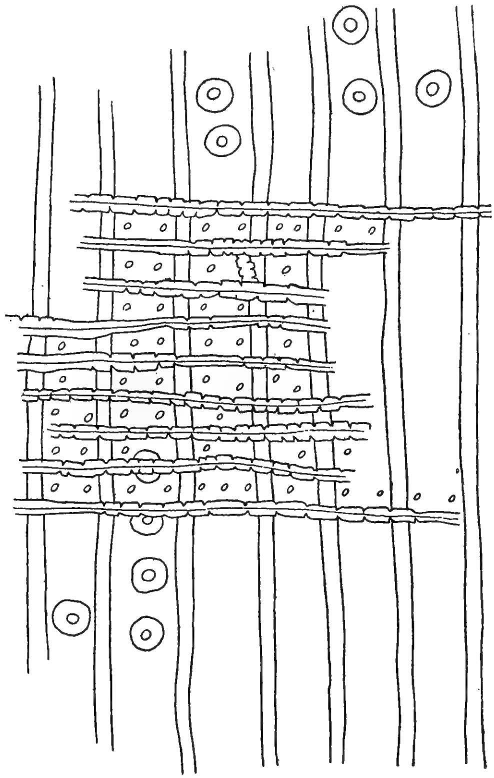


FIG. 1.

mer wood and provided with a single row of contiguous circular pores with a round or oblong inner pore.

This specimen is without doubt the same as that determined by Professor F. H. Herrick[1] who has so accurately described it that it is unnecessary to go further into its description.

[1] Nat'l Geogr. Mag. Vol. IV. 1892, pp. 75–78. Figs. 4, 5.

As stated under the macroscopic description of No. $5^a$, it was accompanied by a very thick piece of bark which agrees in every particular with that of the living tree. It is bright-colored and unchanged.

No. 3 is undoubtedly the same as $5^a$. It has the medullary rays a little smaller and an occasional resin-duct.

Nos. 2 and 4 do not offer differences of particular account.

### TSUGA MERTENSIANA, CARR.

This hemlock is a large tree extending from Alaska south along the islands and coast of British Columbia and thence along the Cascade Range to southern Oregon. The wood is light, hard, close-grained but not strong, with bands of small thin summer cells and numerous prominent medullary rays. In color the wood is light brown, tinged with yellow, with the sap-wood nearly white.

Nos. 5 and 6 are referred to this species. Of No. 6 the small piece submitted has the thin close bark of a branch of hemlock. The medullary rays are two or three to six or eight (or exceptionally twelve) cells high. The annual rings are clearly demarked; the wood cells have a single row of rather small pores with perfectly circular inner pores. In radial section the rays appear simple, that is the walls are straight and not unevenly thickened as in Picea. The walls of the rays have small round pits.

The thin bark (No. 5) described above belongs with little doubt to this species, and I have so regarded it, but in absence of samples of the wood for comparison it cannot be positively stated.

### CHAMÆCYPARIS NUTKÆNSIS, SPACH.

The yellow cypress, yellow cedar or Sitka cypress is also a large tree ranging from Sitka south through the Coast Ranges to Oregon. The wood is light, brittle, very close-grained and possesses an agreeable resinous odor. In color the wood is bright, light clear yellow, with thin nearly white sap-wood.

None of the inter-glacial wood obtained by Mr. Reid has appeared to belong to this species, although it is possible that No. 1 may represent it.

ALNUS RUBRA, BONG.

This species, the common alder of the region, is a comparatively large tree with light, soft, close-grained satiny wood, which is light brown tinged with red in color, the sap-wood being nearly white.

The specimen described above that was obtained by Miss Scidmore, is referred without hesitation to this species. It is so little changed that it might be mistaken for a recently grown example.

F. H. Knowlton.

U. S. Geological Survey.

# LAKE PASSAIC—AN EXTINCT GLACIAL LAKE.[1]

CONTENTS.



LAKE PASSAIC is the name given by Professor Cook in 1880 to an extinct glacial lake supposed to have existed in northern New Jersey during the last glacial epoch. Although the existence of

[1] GEO. H. COOK. Annual Report of the State Geologist of New Jersey, 1880; pp. 61–64. ROLLIN D. SALISBURY. Ibid., 1892; pp. 126–144. ROLLIN D. SALISBURY and HENRY B. KÜMMEL. Ibid., 1893; pp. 225–328. HENBY B. KÜMMEL. Thesis for the Degree of Doctor of Philosophy, University of Chicago, July 1895 (In Press).

the lake has been called into question, recent work has shown that Professor Cook was right in his main conclusion, although he was not in possession of the large body of facts which together demonstrate that conclusion. The lake occupied the basin-like area between the curving trap ridges, known as the Watchung or Orange mountains on the southeast, and the gneissic highlands on the northwest. Its northeastern end was in the vicinity of Little Falls, and its southwestern near Liberty Corner.

The basin is now drained in a roundabout way by the Passaic river, which finally escapes across the Watchung mountains at Little Falls and Paterson. Of the Watchung mountains it was the Second which formed the rim of the basin in which the lake lay.

The height of the Passaic river where it crosses this mountain at Little Falls is 158 feet. During the life of Lake Passaic, this outlet, as well as the valley now occupied by the Pompton river was choked by glacier ice. Leaving the Pompton valley and the Little Falls Pass out of account, there is no other break in the rim of the lake basin lower than 331 feet. At this altitude there is a pass across the enclosing trap ridge at Moggy Hollow, about two miles west of Liberty Corner, at the southwestern end of the basin. This outlet regulated the level of the lake for a considerable period of its history.

Within the area of the lake there are several trap ridges, of which Long Hill, extending from Chatham to Basking Ridge, is the most important. Its general course corresponds with the longest diameter of the lake. The lake basin is divided in the direction of its shortest diameter into two nearly equal parts by the terminal moraine between Chatham and Morristown.

The record of itself, which Lake Passaic left, consists principally of (*a*) shore features, (*b*) berg deposits, (*c*) lacustrine deposits, (*d*) a slight difference in the nature of the till within the lake basin and of that without. Most reliance is placed upon the shore features, but the other lines of evidence have much corroborative weight.

THE SHORE FEATURES OF LAKE PASSAIC.

The shore features of Lake Passaic are not conspicuously developed, and their obscurity is plainly not the result of subsequent erosion. It follows that they were never well developed. Since the size of the lake was sufficient for waves of several miles fetch, the meager development of shore features cannot be ascribed to the smallness of the lake. Since the conditions for the development of shore features seem to have been favorable at many points, their local absence and their general indistinctness is not to be explained on the basis of unfavorable conditions. We are left to conclude, therefore, that the meager development of shore features about the border of the lake is due to its shortness of life. In spite of the general fact expressed in the statements above, shore features are locally pronounced enough to be unmistakable.

The distribution of the shore features seems to be somewhat fortuitous. They are absent from some localities where their presence was to have been expected, and they are sometimes well developed where there seems to be good reason for their exceptional distinctness.

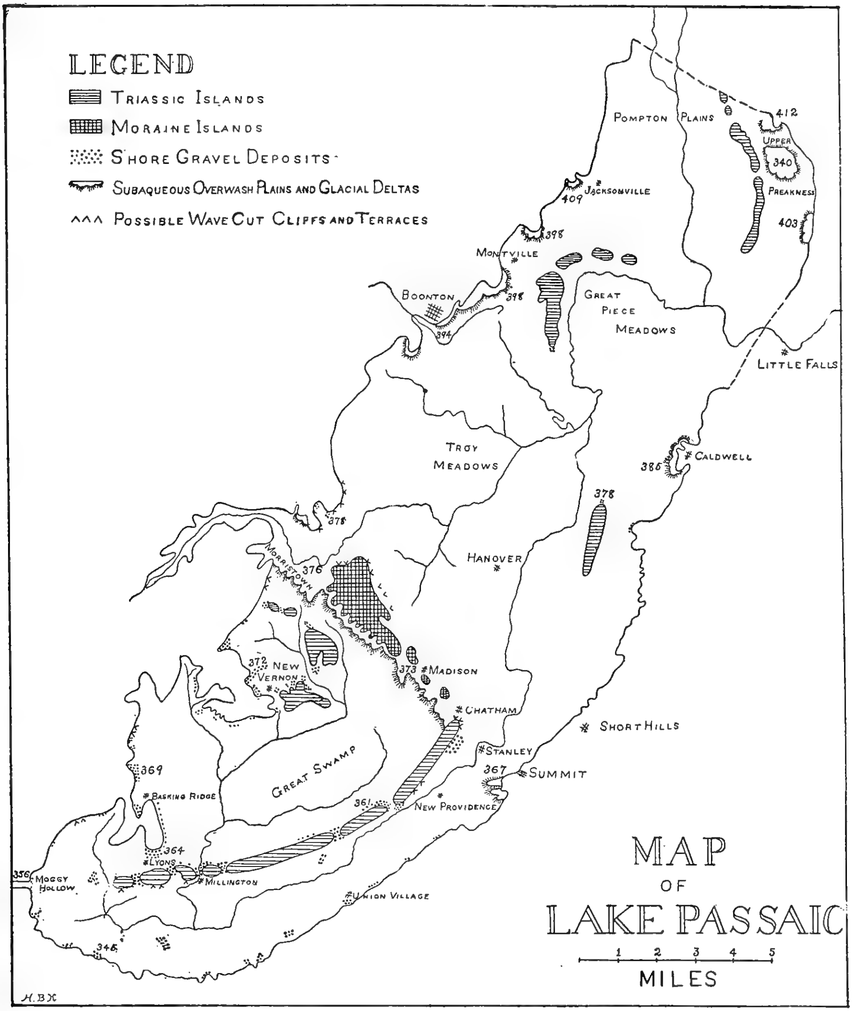
*Shore features of the extra-morainic basin. A. Degradational forms.*—Wave-cut terraces and lake cliffs are but poorly developed. In numerous localities, ill-defined terraces have been observed at about the level of the lake, some of which, as shown by their close connection with constructional forms, are probably of lacustrine origin. The best marked of these are upon Long Hill. At its north end, half a mile south by west of the Chatham depot (see map), there is a distinctly marked cliff and terrace. The cliff rises by a steep slope from the terrace, at the upper edge of which there are a number of drift bowlders apparently washed out of the till in which the cliff is cut. At several points on the terrace the trap rock is exposed, indicating that the terrace was formed by erosion, not by deposition. The upper edge of the terrace has an altitude of 369 feet, and is sharply defined. This wave-cut terrace can be traced southward along the eastern side of Long Hill. Its surface there becomes sandy, and it soon passes into the wave-built terrace to be seen in the lower part of the Chatham cemetery. The clearly defined cliff above the bowlder-strewn cut terrace, and the graduation of the latter into the distinct wave-built terrace, make this one of the best marked features of the extra-morainic basin.

Along the southeastern or front face of Long Hill, narrow terraces with steep rock slopes above may be observed in several places. Probably not all of them, and perhaps none of them, are to be ascribed wholly to the lake. Some of them may be benches and cliffs of differential degradation, due to the contrast in hardness between the trap and the underlying Triassic sandstone, which here and there have their junction at or near the lake level. This, however, will not account for all of them. Northwest of New Providence there is a distinctly marked bench in the sandstone, at an elevation of 367 to 369 feet. It can be traced almost continuously into a well-marked spit a mile west of New Providence. Because of this connection, especially, its reference to the lake seems proper.

Near the outlet at Moggy Hollow, a mile and a half west by north of Liberty Corner, there are slight traces of wave cutting. The phenomena are such as would be produced on a gently sloping, rocky shore against which the waves had beaten but a short time, and where the finest material had been carried away, leaving the ill-rounded pebbles where they originated. Both above and below the zone thus affected, the rock is covered by a much deeper layer of residuary soil. The height of the mean lake level at this point, as shown by other evidence, was between 351 and 356 feet.

After everything possible has been said in favor of the lacustrine origin of the terraces and cliffs found around the lake basin, it must be admitted that, were the proof of the existence of the lake dependent upon them alone, its existence could not be stoutly maintained. There is not a terrace in the extra-morainic part of the basin, the wave-cut character of which, taken by itself, can be said to be beyond question.

*B. Constructional forms.* 1. *On the trap, shale and gneiss*


LEGEND
Triassic Islands
Moraine Islands
Shore Gravel Deposits
Subaqueous Overwash Plains and Glacial Deltas
Possible Wave Cut Cliffs and Terraces
Pompton Plains
412
Upper
340
Preakness
403
Jacksonville
409
398
Montville
Boonton
398
394
Great Piece Meadows
Little Falls
Troy Meadows
Caldwell
386
378
378
Morristown
376
Hanover
372
New Vernon
373
Madison
Chatham
Short Hills
Stanley
367
Summit
369
Great Swamp
Basking Ridge
361
New Providence
364
Lyons
356
Mossy Hollow
Millington
Union Village
346
MAP OF LAKE PASSAIC
1 2 3 4 5
MILES
H.B.K.

*slopes.*—The constructional forms are more distinct. In a number of localities there are small but distinct spits, bars, and constructional terraces, whose heights are closely accordant one with another. In many more localities, on the slope of the lake basin, or on the slopes of the islands which stood in it, there are beds of stratified, poorly rounded, but nevertheless distinctly water-worn gravel of strictly local origin.

Although not possessing distinct topographic form, these beds of local gravel agree in height, material, and structure with the well defined constructional terraces at other points. Where the gravel is not present in beds, scattered water-worn pebbles of local origin have been found at numerous places at levels corresponding with those of the well defined shore features. So general is their presence, as to warrant the belief that the shore gravel is much more nearly continuous about the former margin of the lake than superficial inspection would indicate. Nowhere have constructional shore features, beds of local gravel, or scattered water-worn pebbles of local origin been found about the lake basin, or on the islands in the lake, above the level at which the waters of the lake could have been confined.

On Second mountain well-defined beds of local gravel have been found at thirteen points. The location and the height of the more important of these is shown on the accompanying map. With one exception they range in altitude from 344 to 369 feet A. T., while single beds have a vertical range of as much as fourteen feet. A single bed of gravel is known at a lower level—about 300 feet. On the gneiss highlands between Bernardsville and Morristown, two small deposits of wave-worn gneiss pebbles are known at elevations of 371 feet to 380 feet.

During the life of the lake, the cols of the ridge known as Long Hill were straits. At the same time, the crests above the cols constituted islands. Of these there was a series of nine. They were long and narrow, and rose above the water to heights not exceeding 125 feet. Débris carried by the waves and currents along the shores of these islands, accumulated at their ends, (in or near the present cols) as spits, bars, or beds of gravel and sand. Considerable beds of trap gravel occur in four of the cols. Water-worn trap pebbles in lesser quantity are found in all the others at accordant heights. Between the cols along the shores of the former islands, there are frequent traces of gravel identical with that of the cols at corresponding heights. Such gravel is probably more widespread and greater in quantity than is now shown, since exposures are few. Such as exist are often most insignificant. Thus on the northern slope of Long Hill, one and three-fourths miles west of New Providence, a shallow, freshly-dug trench several hundred feet in length was seen (1893). Its course was across the shore line. On the surface there was no topographical evidence of wave action, nor were the water-worn pebbles abundant enough to attract attention. Above an elevation of 361 feet, the material exposed in the trench was material which had arisen from the decay of the trap rock. Below 361 feet the trap residuary was succeeded lakeward by coarse, wave-worn trap pebbles. The gravel was roughly stratified, and contained occasional foreign pebbles. Further down the slope the gravel was succeeded by sand, and that again by gravel. A thin layer of clayey loam, the result of post-lacustrine wash from the slopes above covered the whole. This exposure proved conclusively that some agent had been at work on the lower slope, re-working and re-arranging the local material up to a certain definite level, above which it did not reach. The element of height appeared to be the only controlling factor. Waves could produce the observed phenomena; running water could not. This significant exposure showed that the absence in some localities of topographic shore features, and of rounded surface gravel, does not militate against the lake hypothesis.

In addition to the beds of gravel on Second mountain and Long Hill, similar deposits occur at the proper heights upon the hills near New Vernon and south of Morristown.

A few of the constructional shore features deserve separate mention. (*a*) In the lower part of the cemetery of Chatham, there is a high, well marked, wave-built terrace of sand and gravel, to which reference has already been made. It is composed of glacial gravel, derived from the till which covers this end of Long Hill. The elevation of its upper edge is 369 feet A. T. (*b*) A wave-built terrace of trap gravel, 100 to 150 yards wide, is found just north of Lyons Station, at the southern end of what was a peninsula. Northward from this terrace along the shore line rounded pebbles of local origin occur in considerable numbers. As the red shale rises to the lake level at Basking Ridge the shale pebbles become more abundant in the shore gravels, while the trap pebbles become proportionally less. (*c*) Southwest of Moore's hotel, Basking Ridge, where the old shore line has an elevation of about 367 feet, there is a broad wave-built terrace at the head of what was a small bay. The gravel of which it is composed is chiefly from the local shale. (*d*) Near the sag in Long Hill, a mile and a quarter west of New Providence, there is a short but pronounced spit. Northeastward it is continuous with what may be a wave-cut terrace, as elsewhere noted. The gravel is chiefly of red shale, derived from the subjacent terrane. In cross-section the lines of bedding are seen to dip outward, forming what may be called anticlinal stratification. (*e*) Another short spit occurs about three-quarters of a mile west by north of Berkeley Station. Its elevation is somewhat (45–50 feet) less than the maximum level of the lake.

The composition of these gravel beds, considered in relation to the underlying and adjacent indurated formations, is most significant. On Second mountain—a great trap ridge—the gravel deposits attributed to shore action are composed almost wholly of fragments or pebbles of trap, with only occasional foreign pebbles. The same is true, in the main, of Long Hill, though on the south side of this ridge the red shale occasionally rises to the level of the lake. Where gravel beds are found on shale slopes instead of trap, shale has made the principal contribution. The spit west of New Providence is an instance in point. Where the shore of the lake was against a drift-covered slope the gravel beds are composed of drift gravel. The terrace in the cemetery of Chatham is an illustration. In the vicinity of Basking Ridge, deposits of trap gravel grade into those of shale where the shore line passed from the trap to the shale. Along the gneiss highlands the two gravel beds known along the margin of the lake, are largely of gneissic gravel and sand, and local sources for the other constituents are at hand. Near New Vernon the gravel deposits on the trap hills are mainly of trap, those on the shale are composed chiefly of shale, while those on the Triassic conglomerate are of quartzite pebbles, derived from the conglomerate itself. The foreign pebbles in the shore gravels may belong (*a*) to the older drift, remnants of which occur at various points about the lake; or (*b*) they may have been transported along the shore of the lake from the newer drift; or (*c*) they may have been carried to the shore of the lake by blocks of floating ice, starting from the moraine.

Waves and shore currents are the only known agencies which can develop water-worn, stratified gravel, sustaining this definite relationship to the adjacent and subjacent formations. The topographic situation of some of these shore deposits of gravel, taken in connection with their composition, is such as to admit of no second interpretation. Generally speaking, they occur along a horizontal belt at a definite elevation, either (*a*) on the slopes of higher lands, or (*b*) in the passes and cols between them. Above this definite level, gravel such as described does not occur. Below this level, such beds of gravel occur as might have been formed during the later stages of the lake's history, when its level was sinking and its area diminishing.

A careful study of the shore deposits, particularly their relations to headlands of rock and wave-cut benches, gives us some knowledge of the general direction of the waves and shore currents. On Long Hill the shore drift traveled, in general, southwestward, as shown by the terrace near Chatham, the spit west of New Providence, and the spit west of Berkeley station. Near Basking Ridge the material was carried southward, as shown by the shale gravel southwest of Moore's hotel, and the trap gravel at the south end of the ridge near Lyons. Three different deposits on the hills a mile and a half south of Morristown were clearly formed by westward moving currents.

Three particularly favorable classes of localities for the deposition of the shore gravels can be made out. These are (*a*) in the shallow, narrow straits between islands, the numerous deposits along Long Hill being the most marked examples; (*b*) at the ends of the islands or peninsulas where the shore currents (1) kept their course as the island was passed, spits being the result, the spit near New Providence being a good example; or (2) where the shore currents lost their velocity by spreading, in which event terraces were formed, the terrace just north of Lyons being an example; (*c*) at the heads of small converging bays, the terraces west of Basking Ridge and east of Bernardsville being good examples.

2. *On the outer face of the moraine.*—In addition to the constructural shore features already described, there are still others in the extra-morainic part of the basin which testify in no doubtful way to the former existence of Lake Passaic. The outer face of the terminal moraine, in so far as it lies in the lake basin, is bordered by a subaqueous overwash plain[1] of goodly proportions. The special characteristics of deltas and subaqueous overwash plains are flat tops, sloping gently from the head to the front, a steep front slope (indicated by hachures on the map), a lobate margin with deep re-entrant angles and projecting cusps, and a tripartite structure, as seen in vertical section. This structure consists of (*a*) nearly horizontal beds at the top, underlain (*b*) by beds dipping steeply towards the front, and these in turn rest upon (*c*) horizontal or nearly horizontal layers of fine material. All these features are illustrated by the plains bordering the moraine on its outer face. Thus near West Summit there are three prominent marginal lobes on the subaqueous overwash plain. West of Madison, the flat top of the plain is a third of a mile wide, with a fall of about ten feet in this distance, whereas its steep front falls off 60 feet in 100 to 200 yards. Southwest

[1] An overwash plain made in standing water. See Annual Report of the State Geologist of New Jersey, 1892, p. 41.

of Convent station the top of the plain is half a mile wide. From its upper edge at the moraine it slopes gently to the southwest, declining 20 to 25 feet in the half mile. Here it falls off abruptly, with a slope which declines about 50 feet in 125 to 150 yards. While no single exposure was found which showed the complete tripartite structure, exposures were seen which showed the several beds individually, and there can be little doubt that good exposures would reveal the three in vertical section.

The line marking the junction of the gently sloping upper surface of the plain, with its abrupt front, marks the approximate water level at the time the plain was finished. But when it is desired to fix the water level exactly, or even within two or three feet, many inconsistencies seem to be involved if it be assumed that the line marking the change of slope corresponds accurately with the water level. There are several reasons for believing that it does not. (*a*) It has been found that even where the change of slope is most marked and can be accurately fixed, its height varies three, five, or even seven feet within comparatively short distances. (*b*) A consideration of the manner in which glacial delta plains are formed shows that the pronounced change of slope must mark the point where the bottom current of the running water which was rolling the débris, so far lost its velocity that its load was dropped. It would seem, therefore, that the upper edge of the steep slope cannot be built nearer the surface of the lake than the depth of the current which, at that particular point, is supplying detritus. Since the depth and velocity of the various streams supplying detritus were different, and since a subaqueous overwash plain was built by a number of streams or by the distributaries from a single stream, all of which have various depths and velocities, the upper limit of the frontal slope should be of varying heights on adjoining lobes, and might even vary to some extent on the same lobe. We conclude, therefore, that the lake level was somewhat (perhaps sometimes several feet) higher than the upper edge of the highest "fronts," and that the water covered the outer and lower part of the gently sloping top. The depth of the submergence at different points would depend upon local conditions.

From data supplied by the other shore features, it seems probable that west of Madison, the lake shore corresponded approximately with the present elevation of 373 feet, covering nearly all of the plain whose outer edge has an altitude of 362–5 feet; that west of Convent the shore corresponded approximately with the present level of 374 feet, the outermost lower edge of the plain having an altitude of 356 to 364 feet, and the upper edge of 382 feet; and that at West Summit the former water level has a present elevation of 367 feet, whereas at this point the outer edge of the plain has an elevation of only 345 to 356 feet, rising to about 380 feet at its moraine edge. It is perhaps not necessary to suppose that the edge of the plain was developed contemporaneously at these several points, or that the level of the lake was absolutely constant.

The subaqueous overwash plain bordering the moraine is a very considerable one. Since deposits of this sort may be of very rapid construction, a long period is not demanded for its growth.

### SHORE FEATURES OF THE INTRA-MORAINIC BASIN.

The shore features of the intra-morainic portion of the basin differ in several important respects from those of the extra-morainic basin. These differences are due to the different conditions which prevailed in the two parts of the basin. The intra-morainic part of the basin was occupied by ice for a portion of lacustrine time. Its lake history, therefore, must have been briefer than that of the extra-morainic portion. In so far as it was briefer, its shore features should be less strongly developed than those of the extra-morainic portion of the lake. On the other hand, since the glacier left thick deposits of sand, gravel, and till upon which the waves could readily work, and since an enormous amount of loose material was furnished to the lake directly by the melting ice, constructional terraces, spits, bars, etc., could have been rapidly built under these favoring conditions. The abundant supply of shore and glacial-stream drift might even more than compensate for the shorter life of this part of the lake. It is to be remarked that deposits of water-worn gravel in this part of the lake must possess the structure and topographic forms characteristic of shore deposits. Otherwise they are no proof of the existence of the lake, since streams from the melting ice might form beds of gravel at any elevation, within or without the lake basin.

*Degradational features.*—Within the intra-morainic basin, there are no terraces which can be asserted to be wave-cut. On the inner face of the moraine, between Chatham and Littleton, there are discontinuous, often bowlder-strewn terraces in the drift, sometimes limited above by steep cliff-like slopes. They may be of lacustrine origin. On the east shore of the lake between Summit and Caldwell, particularly east and southeast of Livingston, benches have been observed, which resemble wave-cut terraces in some respects. Similar benches occur at one or two other points. In themselves these terraces would be an insufficient basis for affirming the existence of a lake in the intra-morainic part of the Passaic basin. They may, however, have some corroborative significance.

*Constructional features.*—The chief constructional shore features of this part of the basin are deltas, built in immediate juxtaposition to the ice, by heavily laden glacial streams. Under such conditions the supply of material was great and the growth of the deltas rapid, resulting in the production of very considerable plains in a comparatively brief time. The deltas are numerous and decisive in character. They occur in greater numbers, and in better development on the west and northwest sides of the lake, than along its eastern shore. The most important of them are represented on the map, their steep fronts being shown by hachures.

A mile north of Parsippany, there is a gently sloping, slightly undulatory plain of sand and gravel, having an area of a quarter of a square mile. It has the lobate margin, steep front, and re-entrant angles characteristic of deltas. Its lobes rise thirty feet above the lower land to the south and west. Northward, the plain passes into an irregular kame area, which it is believed marks the site of the ice edge during the formation of the delta. The water level corresponded to the present elevation of 394 or 395 feet.

Between Boonton and Montville, southeast of the canal, there is another glacial delta having an average width of half a mile or less, and a length of two miles. Towards the upper limit of the plain, bowlders are numerous, and the surface somewhat irregular. Patches of till are also present, apparently indicating that the ice lay on the higher ground to the northwest during the formation of the plain. The general level of this plain is less than 400 feet. Along much of the front of this delta, there is a lower terrace marking a stage of the lake 70 to 75 feet below the maximum stage.

Just north of Montville there is a perfect example of a glacial delta, having an area of about a quarter of a square mile. The top slopes gently from north to south, and then falls off abruptly for 70 to 90 feet. Its margin or front is distinctly lobate. The water level here seems to have been along a line which now has an elevation of 397 to 398 feet.

A mile and three-quarters north of Whitehall, and west of the Jacksonville schoolhouse, there is another small delta, whose frontal lobes are well marked. This deposit indicates a shore-line having an elevation of 408 to 410 feet.

The largest and most typical delta of Lake Passaic occurs at Upper Preakness. Its surface is nearly flat. Its margin is strongly lobate, falling off abruptly 50 feet. Its area is about one square mile. Its elevation, 335 to 340 feet, indicates a lake stage about 70 feet below the maximum in this region. It is to be correlated with the lower terrace on the Boonton delta. Just north of this plain is a moraine-like kame belt, half a mile in width. The hillocks are of coarse material, and are often thickly strewn with bowlders. At the same time that the Upper Preakness delta was building, the kame belt was probably formed just beneath the ice and at its irregular margin.

North of the kame belt is another but more irregular plain of sand and gravel, the surface of which seems to have been more or less modified, by the action of standing water. To have extended over it, Lake Passaic must have covered a surface which now has an elevation of 412 feet.

A mile and a half west of Haledon, near Paterson, there are delta-like terraces at two levels. They mark water levels which now stand at 412 feet, and 340 feet respectively. In the vicinity of Caldwell, also, there is a somewhat extensive sand and gravel plain, which has a similar significance.

Of the glacial deltas and terraces, those (*a*) at Montville, (*b*) west of Jacksonville, and (*c*) at Upper Preakness, are the most typical. The northern margins of the two last named have the irregular, hummocky surfaces characteristic of gravel beds, which were originally built against the ice, but which have since slipped and fallen down as the ice melted. In places the slopes still retain the irregularities of the ice mold in which they were cast. Several of the other plains pass into kame areas, which are believed to have been formed beneath the ice and at its irregular edge and to mark the position of the ice front, at the time of the formation of the deltas. In a number of cases, kames of an older generation have been partially buried by the advancing front of the growing deltas.

In addition to the deltas, there are a few small spits connected with what appear to be wave-cut terraces, and a few kames whose summits seem to have been truncated by the waves; but aside from the glacial deltas, the constructional shore forms are not conspicuous or decisive. The largest deltas within the moraine may have required far less time for their building, than the gravel beds along the trap ridges in the extra-morainic part of the lake.

THE LACUSTRINE DEPOSITS OF LAKE PASSAIC.

*Iceberg deposits.*— Iceberg deposits in the extra-morainic part of the lake basin consist mainly of bowlders similar to those of the moraine. They are found frequently up to altitudes of 340 feet, and more rarely up to the maximum level of the lake. Although distributed widely over the area of the basin, they are particularly conspicuous on the low land in the immediate vicinity of Moggy Hollow outlet.

Bowlders of granite, gneiss, quartzite, and conglomerate are found at some points above the probable shore-line on the trap ridges. As compared to the bowlders of corresponding material below the shore-line, their greater age is shown by their greater decomposition. They are regarded as remnants of a pre-morainic sheet of drift.

North of the moraine, iceberg deposits cannot be differentiated with any degree of certainty from the deposits formed directly by glacier ice.

*Clays and silts.*—Clays and silts, which are believed to be lacustrine, are very generally present over the low areas of the extra-morainic basin. They underlie all the area of the Great Swamp and its immediate surroundings. Within this area they do not occur above an altitude of 240 feet. Somewhat similar clay has been found in a few places at higher levels, but always much below the highest shore-line. The clay of the eastern half of this area is covered with fine, sandy loam, which, as the moraine is approached, grades into sand and gravel. Though more or less buried by stratified drift, clay also occurs south of Morristown, southwest of Convent, and southwest of Madison. These relationships show that the lacustrine clay passes under, and therefore antedates the moraine and its contemporaneous overwash plain. The upper part of the clay may represent the bottom-set beds of the extra-moraine stratified drift.

In the Great Swamp area the clay attains great thickness. Wells 25 or 35 feet deep do not pass through it. A mile and a half south of Green Village it was penetrated to a depth of more than 100 feet, although there is no positive evidence that all this deposit is lacustrine. The lacustrine clay is "fat" or "greasy," and a little below the surface is finely laminated, the laminæ of clay being separated by fine partings of a more sandy nature. It is highly calcareous, and frequently contains concretions of carbonate of lime. These concretions are very abundant at certain horizons, in various localities.

Clays which are of the lacustrine type have been found at several localities in the intra-morainic portion of the basin. They are similar in general appearance to those outside of the moraine. They are generally at low levels, and in places are associated with clays which may be post-glacial in origin. In some places this clay is covered by till. Where this is true, the relations suggest either (*a*) that the clay belongs to an early period of the lake's history, if it be lacustrine at all, or (*b*) the till over it is berg till, or (*c*) till deposited by the ice during a temporary re-advance in the general period of its treat.

*The till of the intra-morainic part of the basin.*—Much of the till of the intra-morainic part of the lake basin is not of the normal type. This abnormal phase is stony, but not gritty. On the contrary, it is very clayey. It has a more or less greasy feeling, a waxy or glazed surface when cut, and a pronounced tendency to crack on drying. Many of the pebbles are coated with a thin film of clay, which is not easily removed. The color is dark red, tinged with brown. This type of till occurs most commonly at low levels. It has nowhere been found up to the level of the shore-line. Normal till is not uncommon within the lake basin, and it sometimes occurs in close proximity to the type noted above.

It is not possible to say to what extent this abnormal type of till was formed beneath the ice, and afterwards submerged, and to what extent it was formed beneath water by icebergs floating on the lake. A somewhat similar, waxy, clayey character affects much of the soil on the red shale in the extra-morainic part of the basin, a characteristic foreign to unmodified red shale residuary.

## THE OUTLETS OF LAKE PASSAIC.

*The Moggy Hollow outlet.*—A mile and a half west by north of Liberty Corner, at Moggy Hollow, there is the notch in the rim of the basin, through which Lake Passaic drained during its maximum stage. The bottom of the notch has an altitude of 331 feet, and with the exception of the gaps at Little Falls and Paterson and the low ground along the Pompton river, all of which were closed by the ice when the lake existed, this is the lowest point in the rim of the basin. The notch is a flat-bottomed, steep-sided trench, 60 yards wide at the bottom and 157 yards wide at the height of the maximum lake level. It is cut in hard trap rock, which outcrops at many points on the sides and bottom of the trench. Its form is altogether conclusive that it was the channel through which flowed a stream of water, whose average width was about 150 yards, and whose depth was sufficient to give it great velocity. In pre-lacustrine times there may have been a col on the site of the notch, but the notch in its present form is due largely to erosion by the outflowing current of the lake. Through this outlet the drainage of the lake entered the North Branch of the Raritan.

*The Millington gorge.*—The Passaic river escapes from the area of the Great swamp by a deep narrow gorge through Long Hill, at Millington. The gorge is 60 to 70 feet deep, very steep sided, and, so far as shape is an index, seems to be of very recent origin. So young does it appear, that the hypothesis was for a time entertained, that it was largely or wholly post-glacial. This hypothesis was finally abandoned because of the small amount of trap gravel in the valley below the gorge (too little by far to fill it), and because of the evidence afforded by the Stanley gorge, as to the amount of post-glacial cutting by the Passaic. This evidence is cited below.

*The Stanley outlet.*—Near Stanley, the Passaic river has cut a passage through a drift barrier in post-lacustrine times. The amount of post-glacial cutting is here 25 to 30 feet of which 18 feet is in drift, the remainder in red shale. The passage which the river has cut here is much wider, much less steep-sided, and less deep than the gorge at Millington. The differences in width and slope may well be due to the differences in the hardness of the material. The difference in depth between the post-glacial cut at Stanley, and the gorge at Millington is most significant. All conditions seem to favor erosion at Stanley, as compared with Millington:—(*a*) the size of the stream is greater at Stanley; (*b*) its gradient is slightly greater; and (*c*) the material in which it has cut is very much more easily eroded. If, under these circumstances, the post-glacial cutting at Stanley has been no more than the figure cited above, the amount of post-lacustrine erosion at Millington gorge must have been much less.

Before being lowered by erosion, the drift dam at Stanley had an elevation of about 230 feet. After the ice freed the Little Falls-Paterson outlet, a long, narrow lake must have had a temporary existence behind this barrier, in the valley between Second mountain and Long Hill. Its greatest depth could hardly have exceeded twenty feet. All the lacustrine clay between Long Hill and Second mountain lies below this level, and furthermore most of the surface below this level is clay-covered. There is little doubt that such a lake existed for a time after the great body of the water of Lake Passaic had drained away. It was lowered as the Stanley gorge was cut down, and disappeared when the outlet was cut to the level of its bottom.

*The Little Falls outlet.*—Where it is crossed by the Passaic river at Little Falls, Second mountain is broken by a gap more than two miles wide. The bottom of this gap is nearly flat, and is covered with a coating of till, clay and fine sand, not exceeding ten feet in depth, where now cut through by the river. It is certain that the level of the outlet which Lake Passaic found via Little Falls after the retreat of the ice, had an altitude of not more than 190 feet, and not less than 175.

At West Paterson, the Passaic river crosses First mountain through a gap two miles wide. When the ice had melted back so far as to open this outlet, the river must have crossed this ridge at an elevation of not more than 150 feet, and not less than 125 feet. Since this height is at least 12 feet lower than the height of the lowest swamps in the lake basin, this rocky barrier could not have caused subordinate lakes within the Passaic basin.

*Great Notch.*—Three miles south of Paterson, First mountain is cut by a narrow gap, whose bottom is 303 A. T. Under certain conditions this gap might have served as an outlet for a brief period. Examination of the gap failed to reveal data which could be regarded as proving either that the lake did or did not drain through it at any time.

*The drift-filled gap at Short Hills.*—West of Short Hills the crest of Second mountain is broken by a sag whose bottom has an elevation of 380 feet, an elevation 170 to 200 feet lower than the average height of the trap crest of the mountain. The terminal moraine crosses Second mountain through this sag. Some years since a deep well was bored just below the summit of this sag at an elevation of 370 feet. The well was sunk 200 feet *without reaching the trap rock.* The rock bottom of this gap, therefore, must be below 170 feet A. T. There is good reason to believe that it is much below this figure. A quarter of a mile east of the Short Hills depot, at an elevation of 200 feet, there is a well 200 feet deep. At this depth, that is at sea level, rock was reached. This well is located in the shale valley between First and Second mountains, and is in line with the gaps in Second mountain west of Short Hills, and in First mountain at Millburn. These facts and relations clearly indicate a deeply buried channel across Second mountain at Short Hills, and across First mountain at Millburn, the rock bottom of which at one point between the two trap ridges, is known to be at sea level. If the rock bottom at the gap in Second mountain be no lower than 170 feet—the bottom of the boring—the preglacial stream must have had a fall of 170 feet on the south face of Second mountain. The width of the gap is such as negative this conclusion. It is so great as to indicate that the stream which occupied it was of considerable age. It is probable, therefore, that the bottom of the rock gap in Second mountain is very much lower than 170 feet, the height at which the boring ceased.

It follows, therefore, that the main drainage of the Upper Passaic basin in preglacial times was almost certainly through the Short Hills and Millburn gaps. Manifestly Lake Passaic could not have come into existence until the first of these gaps was closed by the ice and drift.

THE HISTORY OF LAKE PASSAIC.

Something can be inferred as to the preglacial drainage of the lake basin from the gaps in its rim. Through the lowest gap, that at Short Hills and Millburn, the larger part of the preglacial drainage of the Passaic basin doubtless escaped. It is probable that another stream of less size, draining the northeastern part of the Passaic basin, flowed through the gaps at Little Falls and Paterson. The drainage areas of these two basins could have been separated by no more than a low divide, as shown by the present topography.

*The advance of the ice.*—When the ice sheet closed the gap at Little Falls, the drainage must have accumulated in front of the ice in the northern basin referred to above. Any lake which may have been formed at this time must have been small and shallow, for it must soon have overflowed the low divide which separated the drainage basin having its outlet at Little Falls, from that which had its outlet through the Short Hills gap. As the ice advanced, it encroached upon this hypothetical lake, displacing its water and diminishing its area and finally destroying it altogether.

No lake could have been formed in the drainage area of the river which flowed through the Short Hills gap, until after the ice reached that gap and filled it. Then, and not until then, could a lake have existed in the basin south of Morristown. So soon as this gap was closed, water from the melting ice began to accumulate in that part of the basin which the ice did not fill. This was the beginning of Lake Passaic. The water rose until it reached the level of the Moggy Hollow outlet, through which it drained. As already stated, the bottom of the notch in the rim of the lake basin at this point, is 331 feet above tide. During the period when this notch served as the outlet, erosion is believed to have lowered it not more than 25 feet.

*The Madison stage.*—When the ice had blocked the Short

Hills gap, Lake Passaic began its existence. Since the ice of the last epoch had then reached its maximum extension, the area of the lake was at a minimum. The lake seems to have remained at approximately the same level during the time when the moraine and the subaqueous overwash plain which borders it were formed. During this period of maximum level there were formed, in part at least, the high-level shore lines in the extra-morainic basin. To this stage belong the broad, subaqueous overwash plain extending from Chatham to Morristown, and perhaps also the somewhat lower plains near West Summit, the gravel deposits near Bernardsville, Basking Ridge, Lyons, Millington, New Providence and New Vernon, as well as others of less importance. This stage of the lake may be called the Madison stage, from the fine development of the subaqueous overwash plain west of that place. During this period there were doubtless minor oscillations of the water level, due chiefly to varying rates of melting of the ice. Such oscillations of level may perhaps explain some of the minor inequalities in the heights of the different lobes of the subaqueous overwash plain.

*The retreat of the ice.*—As the ice melted back from the moraine, the lake increased in area by successively filling those parts of the basin from which the glacier withdrew. During this period, the lake must have been more or less completely divided into two parts by the moraine, which, for part of its course across the basin, rises above the maximum water level. This barrier did much to prevent débris-bearing icebergs from reaching the extra-morainic basin, and thus limited the time, during which berg deposits could be made outside the moraine, to the period of ice advance.

During the retreat of the ice, an embayment of several miles affected the front of the glacier, where it crossed the basin of the lake. The glacial deltas between Boonton and Parsippany, southeast of Boonton, north of Montville, at Jacksonville, Upper Preakness and Caldwell, were all formed by glacial streams while the ice edge was in the immediate neighborhood. The ice seems to have remained upon the higher ground above and back of these plains, after it had retreated from the lower ground in the same latitude, thus giving rise to the embayment. This is shown (*a*) by the basin-ward slope of the surfaces of the foregoing delta plains, showing that they were built from the highlands; (*b*) by the forward-plunging strata, which, where seen, generally dip towards the lake and away from the highlands; (*c*) by the frequent occurrence at the head of the plains, of bowlder-strewn kames, which mark the position of the ice edge while the plain was forming; and (*d*) sometimes by the forms of the margins of the deltas. Other possible modes of origin were kept in mind as working hypotheses in the field, but were finally abandoned, since they did not harmonize with the facts.

*The Upper Preakness stage.*—At a number of places more or less well-defined terraces and deltas are present at elevations from 65 to 75 feet lower than the maximum water level. These lower terraces are sometimes directly in front of the higher, which then rise from the upper margin of the lower. In other localities the higher are present without the lower, or the lower without the higher. The two are seen in close connection between Boonton and Montville, at Upper Preakness, and west of Haledon. On the assumption that the tops of these lower terraces represent the approximate level of the water in which they were formed, just as it has been assumed that the surface of the subaqueous overwash plain marks the maximum water level, these terraces mark a subordinate stage in the lake's history. This stage may be called the Upper Preakness stage, from the marked development of the delta plain near Upper Preakness. The field relationships are such as to indicate beyond reasonable doubt that *the lower terraces antedate the upper.* The evidence of the greater age of the lower is not equally conclusive at all points, but nowhere is the relationship between the two such as to necessitate the assumption of the greater age of the upper.

We must conclude, therefore, that the front of the ice became deeply embayed as it retreated from the line of the moraine, and that for a time the waters of the lake sank about 70 feet below the Madison level. During this stage the lower terraces and deltas observed in the intra-moraine basin were formed, and perhaps also the gravel beds without the moraine near Madisonville, 80 feet below the maximum water level. The Upper Preakness stage was probably a short one, since the terraces are not of great size and deposits of this character were undoubtedly made very rapidly. In order to account for the lowering of the lake level it is necessary to suppose that the lake had at this time a subglacial outlet. This might readily have been brought into existence as the ice retreated towards the Little Falls gap. There are, however, some difficulties involved in this assumption. These will be noticed later.

*The Montville stage.*—If the higher terraces are younger than the lower, it must be further assumed that the low stage of the lake was followed by a rise of the water approximately to the Madison level. The name Montville is proposed for this stage of the lake. During this stage there were formed the high-level delta plains and terraces north of Parsipanny, near Boonton, north of Montville, at Jacksonville, north of Upper Preakness, west of Haledon and at Caldwell. The ice retreated a little between the Upper Preakness stage and the Montville stage, and the deltas of the latter were built a little back of and above those of the former. In some cases the higher plains reached and partially buried the lower ones. The Montville stage seems to have been a little longer than the Upper Preakness stage. In a few places possible shore-lines have been noted at elevations between those of the Montville stage and those of the Upper Preakness stage, but it has not been possible to correlate them definitely with each other, or to make out their time relationship to other shore-lines. They are best shown on the inner face of the moraine, south of Montville, near Caldwell, and northeast of New Vernon.

If the preceding conclusions as to the relative ages of the Upper Preakness and of the Montville shore-lines be correct, we must conclude that the rise of the water to the Montville level was brought about by the closing of the subglacial outlet. It must be confessed that it is difficult to understand how such an outlet, once established during the retreat of the ice, could again be closed *during the further retreat of the ice*, when its motion was probably diminishing in vigor, and when its rate of melting was very likely increasing, and when it was becoming thinner. Nevertheless, the stopping of the outlet, even under these adverse conditions, seems to be indicated.

*The final draining of Lake Passaic.*—After the Montville stage had endured for a time sufficient for the formation of the glacial deltas which mark that stage, the ice was melted back so as to permit the escape of the lake drainage through the Little Falls and Paterson gaps. The intra-morainic part of the lake was soon drained to the level of the barrier at Little Falls, 175 to 190 feet. Below this level in the area of the Great Piece and Troy meadows, and perhaps in Black meadows and Hatfield swamp, shallow bodies of water may have lingered until the outlet was brought down to this level. Such bodies of water must have existed for a time, if relative levels were the same as now. As deformation of the basin has taken place since the ice disappeared, it may be that these swampy areas were not then lower than the Little Falls outlet. After the Little Falls outlet was established, a small post-glacial lake remained in the extra-morainic basin over the low land between Second mountain and Long Hill, in the valleys of the Passaic and Dead rivers. It was held at 230 feet by the drift barrier at Stanley, through which the river has since cut a passage.

Judging by the meager developments of the shore features of Lake Passaic save in those cases where the supply of material from the glacier was abundant, their indefinite form in many instances, and their entire absence in localities where they might rationally be expected to exist, we cannot but conclude that the entire life of the lake, was, geologically speaking, brief. During its maximum extension, just before its final draining, Lake Passaic must have been about 30 miles long and 10 miles wide at its widest part. It must have had a maximum depth of about 225 feet in the intra-morainic part, and of about 140 feet in the extra-morainic.

The sequence of events outlined above is based upon the assumption that all the drift in the Short Hills gap is late glacial, and that, until the ice reached the line of the moraine, drainage escaped through this gap at the level of the rock bottom. The presence of the thick deposits of (lacustrine ?) clay in the region of the Great Swamp, which by their relationship to overlying deposits, are clearly shown to antedate the moraine and accompanying overwash plain, indicate that a lake may have existed in the Great Swamp area for a considerable period before the ice of the last epoch formed the moraine.

Three hypotheses concerning a pre-morainic lake in the Lake Passaic region may be considered. (1) Some part, perhaps a large part of the drift filling of the Short Hills gap, may belong to an earlier ice sheet which deposited the extra-morainic drift found more or less abundantly about the lake basin and above the lake level. In this case, the inter-glacial drainage may have been through the Little Falls outlet and Lake Passaic may have come into existence, so soon as the ice of the last epoch closed the Little Falls gap. Under this hypothesis, the Great Swamp clays would be referred to this early stage of the lake's history. In this event we must suppose that the ice advanced very slowly, so slowly that a great thickness of clay accumulated before the deposition of the overlying loam, sand, and gravel, which are contemporaneous with the moraine or which but slightly antedate it. The clays north of the moraine, which are similar to lacustrine clays, are also in general at low levels, and so far as elevation goes, may have been formed in such a lake.

(2) We may conceive that the earlier ice invasion wrought such changes in the preglacial topography, that, after its retreat, a low-level lake occupied the area of the Great Swamp, and perhaps also the lowlands northeast of the moraine. In this inter-glacial lake much of the lacustrine clay may have been formed. We may suppose further that the lake was drained during inter-glacial time by the clearing out of the Short Hills gap. In this case we should expect to find the clays overlain by an old soil developed after the lake was drained. Above this old

soil would come whatever deposits were made in the lake basin during the later glacial invasion. So far as known, such an old soil does not exist, but observations are not numerous enough to prove its absence.

(3) The third hypothesis differs from the second only in the assumption that the inter-glacial lake lasted until the later ice invasion, and was continuous in time with the lake formed in consequence of that ice invasion.

The first hypothesis makes the clays, so far as they are lacustrine, entirely late-glacial. The great objection to it is the very long time required for the advance of the ice, in order to permit the formation of so great a body of clay, compared to the brief time of its maximum extension and retreat. The retreat must have been rapid, since the silts and sands correlated in time of origin with the moraine, are not buried by later deposits. The second hypothesis makes most of the clays early glacial and inter-glacial, and seems to demand an old soil separating these deposits from later ones. Such a soil is not known to exist. The third hypothesis makes most of the clays early glacial and inter-glacial, and it demands their transition upward into the later deposits without a break. Sufficient data are not available to permit a decision in favor of any one of these hypotheses.

### DEFORMATION OF THE LAKE BASIN.

The highest shore-lines of Lake Passaic are no longer at a constant elevation with reference to the present sea level. At the southern end of the lake, the highest shore-line has an elevation of 345 feet;[1] at the Moggy Hollow outlet, about 356 feet; at Morristown about 376 feet; at Boonton about 394 feet; at Montville about 398 feet; at Jacksonville, 408-9 feet; north of Upper Preakness, about 412 feet. On the eastern side of the lake the shore-line increases in elevation from south to north. At Mt. Bethel it has an elevation of 350 feet; at West Summit

[1] Elevations in most cases were determined accurately by two men working with a rod and level, from bench marks established during the topographical survey of the state.

probably 367 feet; at Caldwell, 385 to 390 feet; at Haledon it is 405 feet.

These figures show that the shore-line rises from 345 feet to 412 feet from the southern to the northern end of the lake. The shore-lines, however, do not rise most rapidly in the direction of the longer axis of the lake, from southwest to northeast, but rather from south to north. Calculated in this direction, the rise is 67 feet in 25 miles, giving a gradient of two and two-thirds feet per mile. This rise northward is by no means regular. Within short distances, the gradient varies from nearly four feet per mile to less than one foot. In one or two instances, notably along the subaqueous overwash plain, the shore-line, after making all possible allowances, seems to be slightly lower than at points further south and southwest. The differential northward elevation of the lake basin, following the withdrawal of the ice, did not proceed with a constant gradient. It was rather of the nature of an irregular warping and incipient buckling, with the greatest rise to the northward.

The deformation of the shore-lines occurred after the lake was drained, rather than during different stages of the lake. This is shown by the fact that the Upper Preakness shore-line is everywhere about 70 feet below the Montville level, whereas, if any deformation had occurred in the interval between these two stages, their shore-lines would not be essentially parallel.

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# DESCRIPTION OF A NEW SPECIES OF *PETALODUS* (*P. SECURIGER*) FROM THE CARBONIFEROUS OF ILLINOIS.

THE species here described resembles most closely the form described by Messrs. Newberry and Worthen as *Petalodus destructor* (Geolog. Survey of Illinois, 1866, Vol. II., p. 35, Pl. II., Figures 1–3).

The size is large, the extreme length being $56^{mm}$ and the greatest width of the crown $47^{mm}$. It is therefore somewhat larger than the teeth figured by the authors named above; but the difference is not great, and the teeth of the two species may be properly compared.

The width of the crown of *P. securiger* is greater than that of *P. destructor*. The height of the crown of the former, measured from the apex to the lower border of the enamel band on the posterior surface, is exactly that of the tooth figured by Messrs. Newberry and Worthen. Nevertheless, the width of the crown of the latter specimen must be increased by an eighth of itself in order to equal the width of *P. securiger*. The crown of the latter is also less acuminate than that of *P. destructor*. The lateral angles of the two teeth are different. Those of *P. destructor* terminate acutely, while those of *P. securiger* are rounded off. That this condition is not due to wear is shown by the fact that the enamel folds, as they approach the border of the tooth, become directed upward.

The width of the band of enamel folds is also greater in the tooth being described than in *P. destructor*. In the latter, as we find it figured, the width of the band in the middle line of the posterior surface is contained in the distance from the band to the apex of the tooth four times. In *P. securiger* the width of the band is contained in the distance named only three times. In *P. destructor* the band is described as consisting of five or six folds of enamel; in *P. securiger* there are eight or nine distinct folds.

In another important respect *P. securiger* appears to differ from *P. destructor* and all other described species of the genus. The uppermost border of the enamel band stands out boldly from the general surface of the crown on both the anterior and posterior sides of the tooth. On the posterior side there is thus a distinct valley formed above the enamel band. In the section of the tooth figured by Messrs. Newberry and Worthen the lower

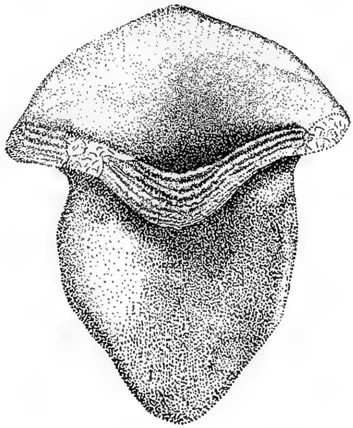

FIG. 1.

border of the enamel band is represented as standing out from the general surface of the tooth on the posterior side of the latter, but nowhere else. The arrangement of the enamel band of the tooth in hand suggests that the cutting edge of the tooth standing in the opposite jaw, and against which our tooth bit, fitted, in the closed mouth, into the valley formed by the band of enamel.

The root of the tooth of *P. securiger* is considerably broader than is that of *P. destructor.* The posterior surface of the root is concave in transverse section at the middle of its length, while it is convex in longitudinal section.

On its posterior face the enamel, for a short distance below the cutting edge, shows a worn surface, where it has come into contact with other teeth.

Dr. Joseph Leidy (Extinct Vertebrate Fauna, p. 312, Pl. XVII., Fig. 3) refers *P. destructor* to his own earlier described *P. alleghaniensis*, and Orestes St. John agrees with the conclusion.

In case this identity is established the availability of two other specific names will have to receive consideration. One of them is *extinctus*. This was proposed by Dr. Leidy in 1855 (Proc. Acad. Nat. Sci. Phila. Vol. VII., p. 414), but later the author essayed to withdraw it in favor of *alleghaniensis*. But there is a still older name which may supersede one or both of the names *alleghaniensis* and *destructor*. In the Amer. Jour. of

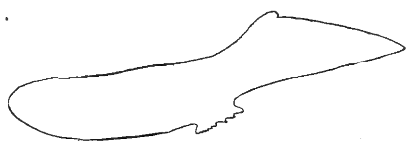

FIG. 2.

Science, 1853, Series 2, Vol. XVI., p. 142, Professor J. M. Safford described and gave two wood cuts of a species of *Petalodus*. On this was bestowed the name *Getalodus ohioensis*, but the error in the generic title is evident. This name and the figure appear to have dropped out of sight. Although Professor Safford's specimen lacked the root, the crown was complete and closely resembles that of *Petalodus destructor*. The angles of the tooth are, however, rounded off like those of Dr. Leidy's figure of *P. alleghaniensis*. The size, if we may depend on Professor Safford's drawing, is more nearly that of *P. destructor*. It is not improbable that Professor Safford's drawings are not wholly accurate and this fact may account for the distance of the enamel band from the apex on what is evidently intended for the anterior face of the tooth. It would be interesting to know whether or not the type of Professor Safford's specimen is yet in existence. In any case, the name must be recognized as that of one of our species of *Petalodus*. Should it also result, as is not impossible, that the species *P. alleghaniensis*, *destructor* and *securiger* shall prove to be one, then it appears reasonable that they shall receive the name *P. ohioensis*. As regards the relationship of *P. alleghaniensis* to *P. destructor* it must be noted that the teeth called by the former name are considerably smaller, the breadth of the crown of the one figured in the "Extinct Vertebrate Fauna" having a breadth of crown of only $20^{mm}$, while the crown of the specimen figured by Messrs. Newberry and Worthen has a width of $42^{mm}$. For the present I am inclined to regard *P. alleghaniensis* and *P. securiger* as distinct species and to refer *P. destructor* to *P. ohioensis*.

Figure 1 represents the posterior face of the tooth of *P. securiger*, while Fig. 2 is intended to present a section through the tooth. However, the anterior face of the root has not yet been freed from the matrix. Two teeth of this form have been brought to me by Mr. Harry Derr, of Chicago, who collected them in the Carboniferous limestone at La Salle, Ill. One of the teeth was considerably broken and parts were missing.

To Professor C. W. Rolfe, of the University of Illinois, I am indebted for information regarding *P. destructor*.

O. P. HAY, PH.D.

FIELD COLUMBIAN MUSEUM,
Chicago, July 12, 1895.

## GLACIAL STUDIES IN GREENLAND. VI.

### The Redcliff Peninsula.—*Continued.*

*The Bryant glacier.*—In a valley about three miles east of the Fan glacier there lies another tongue of the peninsular ice-cap to which the name Bryant glacier has been applied. Like the Fan glacier it is but a short lobe protruding from the ice mantle of Redcliff peninsula on its southerly side. It descends an open valley less than a mile in width, and by estimate less than three miles long. Its course is direct and its slope somewhat greater than that of the Fan glacier, as will be seen from the photographic illustrations, Figs. 31 and 32.

The most striking characteristic of this glacier is the verticality of its face. In this particular it introduces us to the prevailing northern type. Attention has heretofore been called to the curved profile of the terminal slope of the glaciers of Disco Island, and of southern latitudes generally. The Igloodahomyne glacier which we first visited in the northern latitudes does not very widely depart from these. The Fan glacier approaches verticality in its lower face, but its brow is so much curved and the cones and snow embankments along its face covered so much of the vertical part of its front that it falls short of a typical expression of the northern habit. In the Bryant glacier, however, verticality of face reaches a full and characteristic expression. Not only is the face vertical but it is disposed to overhang so that from time to time the upper portion breaks away and falls to the base. This disposition to overhang is doubtless to be attributed partly to the more rapid movement of the upper layers of ice and partly to the more rapid melting of the discolored ice below, the two agencies acting jointly. The verticality is not only a characteristic of the end of the glacier but of the sides. This seems less strange, however, for here we might find a plausible explanation in the undermining of the streams that run alongside the glacier and constitute its main drainage system, and in the reflection and radiation of heat from the adjoining cliffs. But neither of these afford an explanation of the abruptness of the end of the glacier. This terminates upon a flat gravel plain produced by the glacial wash, and no cliff lies in front between it and the Gulf, a mile or two distant. As this glacier has a southern frontage, the phenomenon might perhaps at first thought appear to be due to exceptional exposure to the southerly sun, but the sun is less partial in its favors here than in southern latitudes. During the main melting season it is constantly circling above the horizon and throwing its rays on all sides of the glacier, and, although the southerly sun is more effective than any other, the difference is less than in lower latitudes. Besides, we shall find in the study of other glaciers of the region that eastern and western and even northern exposures present the same characteristics. The explanation seems to lie in the low inclination of the sun's rays and in their impact from all points of the compass in succession. It is obvious that rays of low slant strike the back of the glacier at a very acute angle and easily glance away with little effect. On the edge of the glacier, however, they strike more directly against the surface and hence have greater effect. In addition to this, the slanting rays that impinge on the surrounding surface at low angles are again reflected at like low angles, and hence a much larger proportion of them strike upon the edge of the ice. Thus it appears that a larger *proportion* of the sun's rays fall on the edges of a glacier in high latitudes than upon the edges of a glacier in low latitudes, and it is obvious that it is the *proportional* effect of the sun's rays that determines the contour. For like reasons there is a larger proportional reflection from prominences in the vicinity of the ice, so that, although verticality of face is not dependent on the presence of reflecting cliffs near the glaciers, it is facilitated by them. It will be found in subsequent observations that where promontories of rock rise through the ice-sheet, forming the "nunataks" of the Greenlanders, the ice, in many instances, does not crowd against their sides but is

FIG. 31.—Terminal portion of Bryant glacier seen from the east, showing clean, white ice above and stratified, discolored ice below, with a talus slope at the base. Height of vertical face above the gravel plain in front about 140 feet. In this and the following views the amount of débris in the discolored ice is greatly exaggerated by surface spreading.

FIG. 32.—Middle portion of Bryant glacier seen from the east, showing increased thickness of white ice above and the curvature of the discolored layers below.

melted back, leaving a moat-like ditch between the eminence and the mass of the glacier surrounding it, not unlike the defensive trench of an ancient castle. Whenever the motion of the ice is considerable, however, this intervening space is absent and the ice impinges forcibly upon the base of the prominence.

So striking a feature could not well escape the notice of previous visitors to the region. In the Greeley reports the designation "Chinese Wall" is aptly applied to it. Its significance and especially the internal structure and mode of action which it reveals were not unnaturally overlooked amid the engrossing demands of other interests.

*Stratification.*—This melting back of the edge of the ice, developing a vertical face in the place of the usual slope, is a matter of the utmost good fortune to the glacial student, as it displays the basal organization of the ice and reveals its methods of work to a degree that could scarcely have been anticipated. It is as though a Titan with the blade of a giant knife, one or two hundred feet long, had sliced away the border of the glacier, giving us a vertical section across the end and along both sides. This truncation of the edge reveals a remarkable stratification of the ice and an equally remarkable insetting of rock débris. The stratification of glaciers is by no means an unknown phenomenon, but I doubt whether it had ever been suspected that it reaches an extent and an intimacy such as is here displayed. As will be readily seen from the accompanying photographic illustrations, the ice is not only arranged in layers, but these are subdivided in a very intimate fashion, so intimate indeed in many portions as to pass beyond simple stratification in its usual sense and become lamination. In extreme instances the thin layers number as many as twenty to the inch. By turning to the illustrations (Figs. 31, 33 and 35, in particular) it will be seen that there is a thick stratum of clean, white ice at the top, beneath which there is a zone of ice darkened with much débris, and at the bottom a talus slope formed from a mixture of ice and rock fallen from above, commingled with the residue of snow drifts. The talus slope rises to heights of thirty and forty feet, and occasionally more.

FIG. 33.—Terminal portion of Bryant glacier seen from the west, showing the stratification and lamination of the ice and the talus slope below. Inglefield gulf seen in the distance at the right.

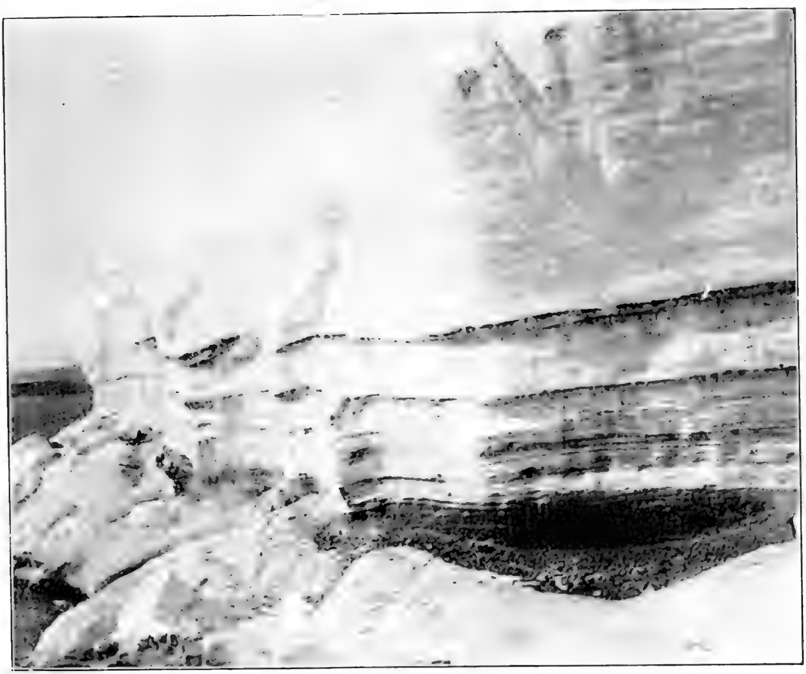

FIG. 34.—Portion of the "Chinese Wall" showing distinctly the stratification of the white ice as well as the discolored portion. It illustrates also the arrangement of the rock débris in definite planes.

The discolored ice above this measures fifty or sixty or even seventy feet, while the white ice above is forty or fifty feet thick at the edge, and rapidly increases backwards. Measurements made with a binocular Locke level by sighting across the extreme front of the glacier from the adjacent slope showed that the discolored ice rose ninety-five feet above the gravel plain in

FIG. 35.—A nearer view of a portion of the front of the Bryant glacier near the middle of the valley, showing the verticality of the face, the stratification of the ice, the insetting of the bowlders, the formation of the talus, and the smoothness of the valley bottom.

front, while the white ice rose forty-five feet above this, making the total vertical height of the extreme front 140 feet.

The stratification is not confined to the discolored portion, although it is only obscurely expressed in the white ice. Nor is the stratification of the two parts identical. Perhaps it may be appropriately said that there are two classes of stratification. The one predominates in the white ice and the other in the discolored. The first consists of an alternation of layers of porous, opaque, white ice with layers of compact, transparent, blue ice. The blue layers are thin, while the

FIG. 36.—Nearer view of the middle of the front wall of the Bryant glacier, showing details of stratification and the trench cut in the face of the glacier and of the talus slope by a small stream descending from the surface of the glacier.

white layers are relatively thick. This form of stratification extends into the discolored portion, but the distinctive stratification of this portion consists of the introduction of layers of rock débris between sheets of ice. In general this débris was found to be confined to very definite planes. In some places there was a somewhat promiscuous scattering of the rock material through the ice, and in exceptional cases considerable thicknesses of ice were freely inset with foreign matter, but as a rule the erratic material was distributed in extremely thin sheets between layers of ice that remained essentially pure. The typical section was therefore made up of layers of pure, clean ice separated by films of rocky débris. The rocky material varied in size from the finest silt up through pebbles and fragments of various sizes to bowlders or blocks of rock several feet in diameter. There was no special assortment of this material. Between the same two layers of ice might be found, here an attenuated film of fine silt,

FIG. 37.—Diagrams illustrating the behavior of the laminæ of the ice in passing embedded bowlders.

a little farther on a layer of sand, or a pebble, or a chip of rock, or all these together, while now and then a bowlder or massive block might be encountered. It was observed that usually these larger pieces centered upon the plane of débris, a portion of their mass rising above it and a portion sinking below it. Where the ice was closely laminated the larger fragments necessarily extended across the horizon of several laminæ, and it was interesting to observe that in many of these cases the laminæ divided, a part bending up and passing over the rock fragment and a part bending down and passing under. In cases where the mass was large, some of the central laminations ended abruptly against the mass and new laminations appeared on the opposite side, while the laminæ above and below were bent around the mass as illustrated in Fig. 37. I observed no cases in which the mass seemed to have descended through the ice, as though carried down by its superior gravity. In such a case it would be presumed to bend the laminæ down with it, or break across them. It appeared, on the contrary, that the larger masses of rock equally with the smaller remained fixed.

The material embraced in the ice was found to consist in large part of indurated quartzose sandstone of a light pinkish-gray color. This appeared to be the sandstone previously described as constituting the second member of the clastic series. It comes out to the surface on the eastern side of the peninsula, forming the very picturesque cliffs of Karnah, and may be conveniently known as the Karnah sandstone. Besides this, there was some reddish sandstone and shaly débris belonging to the other members of the clastic series. There was also present a notable ingredient of crystalline rock, chiefly of the gneissic and granitic types. This constituted a decidedly subordinate percentage of the whole, but it was rendered conspicuous by its nature and is significant in that it indicates the existence of the gneissic series underneath the ice-cap somewhere between this glacier and the center of the peninsula, and it will be recalled that the peninsula is only about fifteen miles across.

By reference to the illustrations it will be seen that the number of layers of débris in the lower part of the Bryant glacier is very large. It is important to observe, however, that the amount of débris appears very much greater than it actually is because of the spreading of the silt over the face of the ice when it was freed by melting. Fig. 38 shows a portion whose layers were upturned at the foot of the glacier. The surface wash was cut away from a belt across the layers and a comparison of this with the rest will show the deceptiveness of the dirty surface. In a similar way natural surfaces that have been washed by streamlets from the surface of the glacier show the true content of débris.

The laminations that bear the débris are not usually continuous for very great distances. The first impression, perhaps, made on viewing the wall of discolored ice is that the more pronounced layers are continuous across its whole breadth, but upon closer inspection it will be seen that the layers thin out and disappear and others are introduced to take their places; even the broader bands are limited in their extent. None of them save, perhaps, the twofold division, appear to pass from side to side of the glacier. This may be verified by comparing the east, the frontal and the west sides as shown in Figs. 31, 35 and 33.

The laminæ are generally plane or slightly undulatory and essentially horizontal, but occasionally they are warped and crumpled; sometimes they are faulted.

The major planes of stratification seem to be essentially parallel with the bottom of the glacier. In detail this is not always true, and theoretically it is probably not accurately true as a generalization—but in a broad sense it appears that the attitude of the layers is controlled by the bottom and not by the top of the glacier. The profile views illustrate this. Apparently the white ice thickens rapidly as we go back from the edge, while the discolored ice at the base probably remains approximately constant in thickness. This seems to me to agree with theoretical presumptions. The melting of the glacier is chiefly at the surface. There is little ground for believing that any considerable amount of interior melting takes place that is not compensated by refreezing. Hence the upper layer must thin out as it approaches the edge of the glacier, while the lower layers remain approximately constant. The ratio, therefore, of the débris-bearing ice to the white ice above it, as seen on the edge, cannot be regarded as applicable to the thicker portions of the glacier back from the edge. At the extreme margin of the Bryant glacier the débris-bearing ice constitutes two-thirds of the section. It certainly would lead us far astray to assume that the débris is distributed through two-thirds of the vertical section of the ice on the summit of Redcliff peninsula.

The drainage of Bryant glacier is essentially the same as that of the two northern glaciers previously described. The waters produced by melting are shed from the back of the glacier in rivulets, very few of which find an opportunity to descend to the bottom through crevasses because of the scantiness of these. The rivulets, however, instead of cascading down the sloping face of the glacier as they were permitted to do in the preceding instances, are forced to project themselves from the overhanging edge as

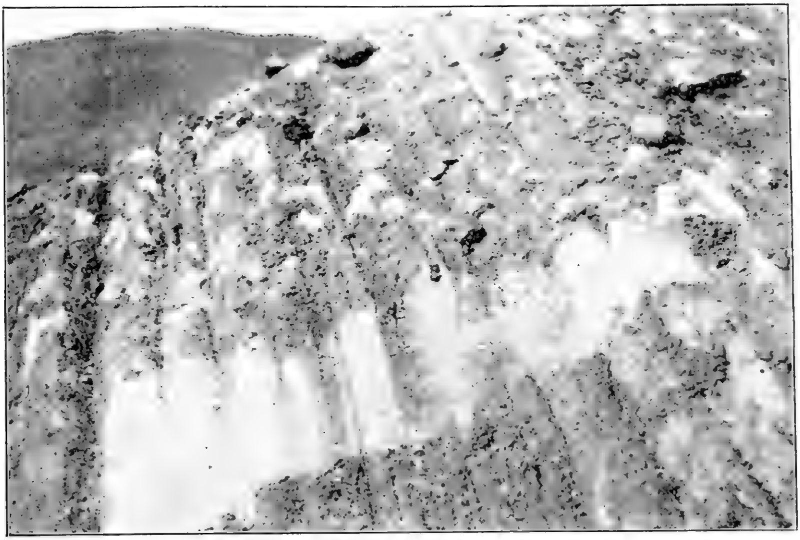

FIG. 38.—A nearer view of the débris-bearing layers which have been curved upwards to a nearly vertical position. From a portion of this the discolored surface has been cut away to show the difference between the real amount of débris included in the ice and the apparent amount deceptively indicated by the surface spreading. It also shows the definite arrangement of the internal débris in layers.

FIG. 39.—A portion of the front of Bryant glacier near the west side of the valley showing the inconstancy of the laminations and the formation of a monument of discolored ice off the face of the wall by the melting or falling away of the ice that once surrounded it.

free-falling little cataracts. Along the sides of the glacier these are gathered into a considerable lateral stream which occupies the trench between the glacier and the side of the valley. At the end of the glacier small streamlets flow away in large numbers but there is no central stream, nor any large central tunnel after the fashion of Alpine glaciers. The lateral streams are usually murky, but the frontal streams are essentially clear.

The plain in front of the glacier is produced by its own drainage and consists of bowlders, cobbles and coarse gravel, with some sand and silt. It spreads from bluff to bluff in a nearly uniform plane. There is no terminal moraine immediately in front of the glacier, unless the talus at its base be so regarded. Between its extremity and the sea, along the sides of the valley, there are some accumulations of erratic material that perhaps represent old moraines, but they scarcely have a distinctive character.

*Ascent to the ice-cap.*—On two occasions we ascended the plateau immediately east of Bryant glacier and went back to the edge of the ice-cap of the peninsula. At first the surface was found to be formed wholly of frost-riven fragments of the sandstone and shale series that constitute the uppermost member of the clastic terrane before described. Here and there an erratic bowlder was seen, but the amount of detectable drift on the surface was very small. At a height of about 1600 feet and at a point perhaps two miles back from the Gulf, moraine-like aggregations of rounded erratics were met. These did not form a sharply defined moraine with a definite outer border, but the transition from local débris was measurably abrupt. As the ascent was continued there was an increase in the amount of drift and the topography became more moraine-like, although it never passed beyond the milder type of morainic hills and hollows. The material was chiefly bowlders ranging from one to three or four feet in diameter. Cobbles and coarse gravel were present, but sandy and clayey constituents were scant. As the edge of the ice-cap was approached streamlets issuing from the border of the ice were encountered and became increasingly frequent. They had brought down with them gravel and sand and by spreading these out had smoothed the surface in a notable degree. Streamlets were abundant on the plateau surface even within short distances of the edge of the valley occupied by the Bryant glacier and seemed to quite ignore its existence. This seems to mean the same thing as the absence of a central stream under the

FIG. 40.—The southern edge of the ice-cap of the Redcliff peninsula a short distance east of the Bryant glacier (which is represented by the lowest white band that reaches the left border of the picture, the valley occupied by it being sunken below the level of the plateau so as to nearly conceal the glacier). The foreground is the gravel plain formed by streamlets issuing from the ice-cap. The snowy slope at the right is the wind-drift border lodged on the edge of the ice-cap. The terminal moraine is barely seen at the top of this, together with a belt of surface wash from a portion of the moraine not seen. In the background at the left is a more distant portion of the ice-cap. View taken looking westward.

valley glacier, viz., that there is little or no gathering together of water beneath the glacier.

The base of the ice-cap was reached at a height of about 2000 feet. It lay perhaps three miles back from the border of the gulf. No measurements of distance were made and this and similar statements in this article are only such rude approximations to the truth as may give a general impression of distances. It was not thought wise to consume precious time in measurements where accuracy had no importance.

The edge of the ice-cap was found to consist of a steep snowy slope rising to a height of about 100 feet, crowned by a terminal moraine, beyond which rose the great dome of the ice-cap. Strangely enough here was a terminal moraine that was not terminal; a terminal moraine with an icy tract outside. This outer tract was in part fresh snow almost perfectly white, indicating that it was a wind-drift accumulation of recent date. At points, however, older discolored snow or ice appeared beneath it and in a few places stratified granular ice of glacial aspect and con-

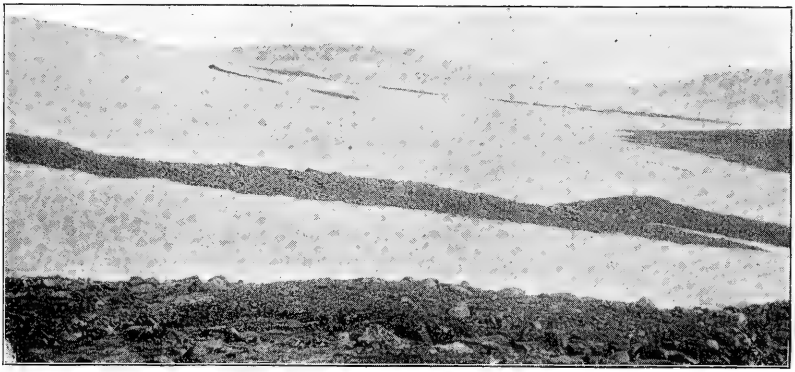

FIG. 41.—Southern edge of the ice-cap of Redcliff peninsula seen looking eastward from a point a short distance east of the Bryant glacier. The débris-strewn portion of the plateau forms the immediate foreground. Beyond this is the wind-drift belt of snow lodged outside the terminal moraine which lies just beyond it in the middle foreground. The dark lines of débris in the center of the picture are also parts of the terminal moraine which pursues a serpentine course controlled by the topography. The white portion in the center and at the left and the dome in the background are parts of the ice-cap.

taining some rocky material was seen. It was not clear, however, that this was not material that had rolled down the steep slope from the moraine above. The phenomenon was at first exceedingly puzzling, but subsequent study and the light which Lieutenant Peary threw upon the subject rendered the elucidation altogether clear. Lieutenant Peary (who had not yet been met) subsequently informed me that the winds of the ice-cap usually flow down its slope much as though they were independent and simply controlled by gravity. It is easy to see that the air in contact with the surface of the ice-cap becomes exceptionally cold.

The high specific gravity thus acquired is apparently sufficient to give it motion down the slope measurably independent of the general movement of the atmosphere, unless the latter is strong, hence the predominance of winds flowing down the slope of the ice-cap in lines normal to its border. By these snow is carried in large quantities over the moraine at the edge of the glacier and is lodged behind it. Thus arises an exceptional snow accumulation on the outer border of the moraine. This is so great in amount as to resist the limited melting of the summer and hence it persists from year to year and becomes solidified to a glacier-like consistency; indeed it may be regarded as a species of fringing glacier. Lieutenant Peary says that it is a prevalent phenomenon, not only around the borders of Inglefield Gulf but on the northeastern side of Greenland so far as reached by him in 1892. This wind-drift border varies in extent from a few rods to half a mile in breadth at the points where I saw it. Where first encountered on the plateau east of the Bryant glacier, it only reached a short distance in front of the terminal moraine. (Fig. 40.) A little to the east it was found to be considerably wider and in an adjacent depression to extend itself as a tongue a mile or so down the valley. Fig. 41 shows a portion of this wind-drift border of relatively flat surface and narrow breadth, as seen a short distance east of the Bryant glacier.

The acclivity of this border where I first encountered (Fig. 40) it was so steep as to make direct ascent difficult, but oblique ascent was found practicable, with a little care. On reaching its summit a sharply ridged moraine was found, the outer face of which was as steep as the material would lie. Indeed, some of the material appeared to have been dislodged and to have rolled down the snowy declivity. Just there the moraine only rose ten or twelve feet above its outer base, though elsewhere it appeared to reach a height of twenty or thirty feet. Beyond the sharp crest there was a descent of a few feet, and then an irregular surface a few rods in breadth. Inside this narrow and apparently shallow moraine and parallel to it, there ran a little brook fed by numerous streamlets from the ice-cap beyond. This brook ran along between the moraine and the ice-cap for some distance to the eastward until it found a low point in the moraine, across which it flowed and became lost in the snowy slope fronting the moraine. It doubtless represents a mode of drainage of some prevalence during the glacial period. Beyond this infra-morainic brook the ice rose with a moderate slope up to the summit plane of the ice-cap.

On neither of my two visits to the ice-cap at this point did

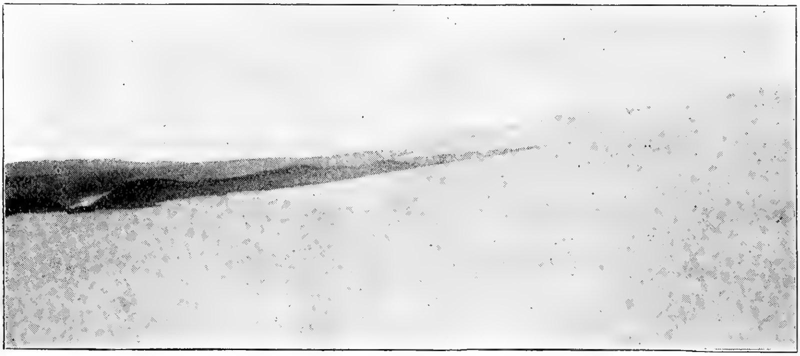

FIG. 42.—A portion of the Redcliff ice-cap seen from a point on the ice-cap looking westwardly, showing the terminal moraine at the left with a glimpse of the snow border beyond and the smooth summit lines of the plateau in the distance.

time permit any considerable ascent of its border. It was estimated to rise one or two thousand feet, and this accords with the estimate of Lieutenant Peary formed on better grounds. The surface of the ice-cap, except in the immediate vicinity of the frontal moraine, was found to be entirely free from débris, except atmospheric dust lodged upon it. No bowlders whatever were seen upon it. Crevasses were absent from the border of the ice-cap, so far as it was traversed, with the exception of mere cracks which did not appear to descend deeply, as they did not absorb the streamlets running over the surface. Dust wells and dirt holes were abundant, usually reaching six or eight inches in depth.

It will be observed that the terminal moraine lay between the wind-drift border and the ice-cap. We were very much struck at first sight with the angularity of the contours of the moraine. It presented the appearance of having been pushed up from beneath. At some points there were sharp conical peaks that gave the impression of direct elevation from below. This appearance was afterwards supported by observations elsewhere and there seemed sufficient grounds for believing that the impression of the method of its formation was correct. It was found that the layers of the ice curved rapidly upward on encountering the wind-drift border and the moraine lodged against it, and that the morainic débris that resulted from its melting was borne on its upturned edge. Under these conditions any motion of the layers of the ice must have pushed upwards the material lodged upon their edges.

The material of the moraine was in general quite angular. There were occasional well rounded cobblestones and some well worn bowlders, while some other fragments were deangulated or rubbed and bruised, in a moderate measure, but notwithstanding these instances, the prevailing character was one of marked angularity. The material was chiefly light colored sandstone of the Karnah variety previously alluded to. Some crystalline bowlders were present. It would appear, therefore, either that the ice-cap was largely underlaid with Karnah sandstone, or else that the débris was chiefly picked up near its border, and of these alternatives the latter seemed best supported by the distribution of the formations and other considerations.

This moraine was seen to reach along the edge of the ice for some miles. To the east it could be seen pursuing a serpentine course along the ice front with a notable snow-drift belt outside. To the west it could be followed for a shorter distance beyond which its presence could not be detected, the ice-cap appearing to come down with a moderate slope to the surface of the plateau without any frontal moraine. But this tract was only seen from a distance and a moraine buried beneath a snow-drift border may have been present.

The ice front showed little evidence of motion. It appeared from the constitution of the wind-drift border that it was the result of several years' accumulations, but it did not appear to be disrupted or disturbed in any observable degree by pressure from the ice-cap beyond. The moraine, pushed up between the ice-cap and the snow-drift border, showed evidences of motion, as already indicated; but this must have been very slow, otherwise the moraine would have been pushed over the wind-drift border or both pressed forward together, of which there seemed to be no evidence. The material rolled along by the little fringing streams that bordered the ice-cap, was found to be rounded up to the very edge of the snow-drift border, and this strengthened the conviction that these little streams had been engaged in their work for some considerable period. Individually they were usually mere little shallow brooklets and the amount of erosion they could accomplish in a single year would be slight. The impression of slow motion and limited vigor was further strengthened by the fact that the water of these little streamlets was clear and free from observable silt. Had the ice been moving at any notable rate, or acting with any appreciable vigor on the angular sandstone at its edge and in its bottom, the issuing streams could scarcely have failed to be silty.

T. C. CHAMBERLIN.

# EDITORIAL.

WHILE polar exploration is less in the minds of the public than it was last year, it is quite probable that the results of the current season will prove more ample. Reports from the north indicate more favorable conditions and there is ground to hope that the exceptional severity of the weather which so seriously interfered with the work last year will be offset by an exceptionally open season. Peary, Jackson and Nansen may all possibly return laden with rich results, though the last cannot certainly be expected, even though he should be ultimately successful. Lieutenant Peary is quite certain to return and there is good reason to believe that the success of his earlier attempts will attend him this season. The expedition which goes to the north to bring him back is under the immediate direction of his brother-in-law, Mr. Emil Diebitsch, a civil engineer, who was a member of the expedition last year. Professor R. D. Salisbury goes as the geologist of the expedition, and, unless circumstances are peculiarly adverse, he may be trusted to bring back much valuable data. His field will be much the same as that of the writer during last season, but it is expected that a larger portion of his time will be devoted to southern Greenland, the purpose being to develop more fully the differences in the effects of latitude which were found to be very notable last year. The expedition is expected to return about the first of October.

Much interest is being awakened in the exploration of the Antarctic regions, and the subject received earnest consideration at the recent International Geographical Congress in London; indeed the discussion of this subject appears to have been the notable feature of the congress. Although the meager reports of the press do not indicate the precise plans recommended, it may safely be assumed that out of the conjoined wisdom of so many experienced explorers the best ideas in polar exploration will find expression in the expedition or expeditions that it is hoped will spring out of the agitation. Dr. Cooke is laboring industriously in the endeavor to organize his proposed Antarctic expedition, but with what success we are not informed. Obviously he is hampered somewhat by the moral effects of the ill success of the Miranda expedition of last season. Altogether there is much ground of hope for important returns at the close of the season and for new enterprises in the early future.

T. C. C.

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The size of this number has been reduced and its issuance delayed by an oversight and by the failure to receive in time the proof of an article whose author is doubtless in the field. As the last numbers have considerably exceeded the standard size and succeeding numbers are likely to do so also, our readers will doubtless generously overlook the shortage of this number.

T. C. C.

## *PUBLICATIONS.*

*Elements of Mineralogy, Crystallography and Blowpipe Analysis, from a Practical Standpoint.* By ALFRED J. MOSES and CHARLES L. PARSONS. 342 pp., 336 cuts, 1895.

The object of this book as stated in the preface is to present in a clear, concise and scientific manner, the nature and uses of minerals and the method for ready and rapid identification.

The regular arrangement of the mineral characters renders it a valuable reference book for one who has but a slight knowledge of the subject, enabling one to turn quickly to the portion he may at any time wish to know, whether this be the physical or chemical properties or blowpipe tests or uses. This is one of the very commendable features of the book, for it is often convenient to turn to these important characters quickly without looking through many pages of detailed description. The book is divided into four parts of which the first treats of the laws, nomenclature and systems of crystallography, and is illustrated by numerous figures. The use of the term *group* as synonymous with *system* is perhaps to be questioned, for while the crystallographic system comprises all forms referable to the same axes, the term group comprises all systems whose forms possess the same number of principal planes of symmetry.

Part II. is a concise treatment of the methods of blowpipe analysis. The chapters on useful tests with the blowpipe, alphabetically arranged, and on qualitative schemes for such analysis will be of special interest to students of mineralogy as affording a quick method of determination.

Part III. is devoted to descriptive mineralogy. While one of the very distinctive and admirable qualities of this book as a practical guide is its conciseness of statement, this feature in the opening chapter of the third part has been carried too far for clearness. The definition of phosphorescence is too comprehensive and for fluorescence is too limited. A student would be apt to confuse the ideas of cleavage and gliding on account of the very brief statement of gliding placed in the section on cleavage. The main portion of this part and over one-half of the book is devoted to descriptions of the various minerals. The economic importance of the minerals is clearly pointed out, then the composition and general description is given, followed by the physical characters, action before the blowpipe, and similar species noted. A list of important localities is also added. The important minerals are printed in ordinary type, while less important ones are printed in small type, thus assisting in the study and reference. The third part of the work will prove of great service to students who wish to acquire a practical knowledge of minerals in a short time, since they are apt to be confused by the mass of detail in the larger works.

Part IV. is entitled determinative mineralogy and contains tables for rapid determination of the common minerals. There are four of these tables, the first containing minerals of metallic or sub-metallic lustre, the second with blowpipe confirmations of the same; the third containing minerals without metallic lustre and their blowpipe tests, and the fourth with the physical characters as confirmation of the minerals of non-metallic lustre.

G. PERRY GRIMSLEY.

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*Memoir of Sir Andrew Crombie Ramsay.* By SIR ARCHIBALD GEIKIE Pp. 397. Macmillan & Co. Price, $4.00.

The biography of so distinguished a scientist as Sir Andrew Crombie Ramsay prepared by so appreciative a friend and so charming a writer as Sir Archibald Geikie could hardly fail to be of interest to geologists and geographers. The author has succeeded admirably in making the geniality and enthusiasm of Sir Andrew apparent, as well as in setting forth the distinguished service which he rendered to the science of geology. The memoir is much more than a mere biography. Sir Andrew was intimately connected with the geological survey of Great Britain for forty years, and an account of his work and of his influence, such as this memoir presents, involves a sketch of the history of the geological survey of the United Kingdom. Not only this, but Sir Andrew's connection with the survey brought him into such intimate relations with other geologists of his own and foreign lands, that his biographer has found it easy to weave into the memoir much general information concerning geologists and geological progress during the period of Sir Andrew's activity.

Portraits of a dozen of Sir Andrew's associates have been introduced into the memoir. These portraits are an attractive feature of the volume and enhance its interest for geologists. A list of the portraits, besides that of the subject of the memoir, is as follows: De La Beche, Logan, Aveline, Selwyn, Bristow, Gibbs, Oldham, Smyth, Jukes, Forbes, Murchison, and Salter. R. D. S.

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*Meteorology—Weather and Methods of Forecasting. Description of Meteorological Instruments and River Flood Predictions in the United States.* By THOMAS RUSSELL, U. S. Assistant Engineer. Macmillan & Co., New York, 1895, pp. xxiii., 277. Illustrations and maps.

The scope of this new work on meteorology is indicated by the title page. As the author states in the preface, the main object of this book is to explain the use of the weather map, where it can be of use for the purpose of making predictions. The method is based mainly on statistics of the observed condition of the air as to pressure, temperature, and humidity of particular types, and the weather following twenty-four hours or more after the occurrence of the type. As a most important aid to this work the author gives a series of twenty-two type weather maps, each representative of about ten cases. Accompanying each of these are maps showing the rainfall (1) for the twenty-four hours preceding the date of the weather map (2) for the twenty-four hours succeeding, and (3) for the time from twenty-four to forty-eight hours after. By the aid of these maps the successful prediction of storms will be greatly aided.

The methods of predicting river heights for some important points along the lower Mississippi and its tributaries are given at some length. Rules and tables are given for computing the rise of floods when data from points higher up the stream are known. Another chapter is given to a brief description of various meteorological instruments, the list of which is quite complete. The principles involved in their construction are considered.

In addition to these topics, "almost everything that is considered to be of interest in relation to the weather is here given. The principal weather changes are described as they occur in various parts of the world in different seasons on land and sea, and their causes narrated so far as known. A collection of facts is given, useful in forming a conception of the phenomena of the atmosphere."

The chief criticism to be made of the book is lack of orderly arrangement and scientific treatment. Long collections of facts are given, which not infrequently have no close logical or causal connection with each other. The book contains a vast amount of information, some of which is so incomplete as to be almost misinformation, arranged on the dictionary or encyclopædia style—interesting reading, but rather disconnected. It is to be feared that a beginner would form a very hazy notion of the science of meteorology, particularly of the broad principles underlying the details of the science from a perusal of it. As a reference book on some points and a storehouse of facts it is valuable to the student. The series of weather maps already alluded to cannot fail to be of great assistance. H. B. K.

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*Air-breathing Animals of the Palæozoic in Canada, up to 1894*, by SIR WM. DAWSON, C.M.G., LL.D., F.R.S. Trans. Roy. Soc. Canada, Section IV., 1894, pp. 71–88.

"Our knowledge of the animal inhabitants of the land in Palæozoic time is very meager in comparison with what is known of marine creatures. There was probably less land in early Palæozoic ages than later. Atmospheric conditions may have been less favorable to breathers in air. Life on land requires a higher nervous and muscular system than those necessary in water, and different means of respiration." Animal life therefore probably originated in the waters. A long time may have been required to introduce the land life. The chances of preservation of aquatic organisms were much greater than were those of terrestrial species. The paucity of land fossils may be accounted for by these less favorable conditions.

The finding of Batrachian footprints by Logan in 1841 was the first indication of air-breathing vertebrates in the Carboniferous rocks. The first discovery of osseous remains of Palæozoic land vertebrates in America was that of *Baphetes planiceps* found by the author in the Pictou coal field in 1850. The first announcement of Devonian insects was from St. Johns, N. B., in 1862 by Hartt. Insects had previously been found in the Carboniferous of Europe, and have since been traced back to the Silurian. The earliest known Carboniferous millipede was *Xylobius sigillariæ*, discovered by the author in Nova Scotia in 1858. Many millipedes have since been found in the Carboniferous and Devonian on both sides of the Atlantic. The first known land snail was found by Lyell and the author at South Joggins in 1851.

This form of land life has since been found in other coal regions in America and in the Devonian plant beds of St. Johns, but not in Europe. Spiders and scorpions were found in the Palæozoic beds of Europe before they were recognized in America.

The known land animals of the Palæozoic of Canada embrace: *Vertebrata*, twenty-six species, all Amphibia; *Arthropoda*, thirty-three species, embracing insects, scorpions and myriapods, and *Mollusca*, five species of pulmonate snails. The author gives a classified list of these land fossils, with notes and brief descriptions of the new forms. Under the head of Vertebrata he observes that no land vertebrates have been recognized lower than the base of the Carboniferous system. Some Devonian fishes may have been endowed with a swimming-bladder capable of being used as an imperfect lung after the manner of the modern dipnoi. We may hope, however, yet to find land vertebrates in the Devonian.

The author adds a very interesting note on two erect stumps of trees recently found by Mr. P. N. McNaughton in the coal series at South Joggins. The hollow of one of these contained the fragmentary remains of nine species of vertebrates, including about thirty individuals. Besides this there were numerous fragments of millipedes, and rather rare remains of *Pupa vetusta.* The second stump contained remains of thirteen individuals, including four or five species. Both stumps occur at considerably lower horizons than the well-known stumps found many years ago by Lyell and the author.

The paper closes with helpful and stimulating suggestions to collectors. T. C. C.

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*Om klitternes vandring*, by K. J. V. Steenstrup (Meddelelser fra Dansk Geologisk Forening, Bianco Lunos Kgl. Hof-bogtrykkeri, Kjöbenhavn, 1894).

Dr. Steenstrup calls attention to some characteristic features of the sand dunes on the west coast of Jutland. He has made out these features partly by observations in the field and partly by study of the topographical charts of the war department. These charts are constructed on a scale of 1 : 20,000 with contour-intervals of five feet, and exhibit well the topographic characters of the sand dunes. The author finds that the original shape of these wind-formed hills, seen in plan, is that of parabolic ridges, which have their concave and open side toward the direction of the prevailing winds and away from the direction of their progression. The middle and most advanced part of the parabola tends to travel faster than the flanks, which are held back more effectively by the protecting growth of dune plants. In fact this center is often blown away entirely, and the flanks then remain as isolated nearly straight ridges which run approximately parallel with the direction of the prevailing winds. Such nearly straight and parallel ridges are therefore not to be regarded as independent formations, but rather as remnants of earlier loop-shaped ridges. The author also observes that the trend of the dune ridges changes in different localities with the changing proportions of the strongest prevailing winds. The direction inland, also, is a little different from the direction near the coast, but the cause for this difference is not yet very clear. It is shown that the dunes, in traveling over the land, do not always leave a deposit along their course. In several places it was noticed that the winds in the rear of the dunes have eroded the ground a few feet below the original level seen in front of the advancing sand. J. A. U.

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*A Great Pre-Glacial River in Northern Canada.*

At the annual meeting of the Royal Society of Canada held in Ottawa on May 15, Professor Robert Bell of the Geological Survey read a paper on the above subject, illustrated by a map which he had prepared as the result of much study and extensive observation in the northern regions. We take the following report from the *Ottawa Journal.* It was, he said, generally conceded by geologists that just before the advent of the glacial epoch, the continent of North America stood at a considerably greater elevation than at present, the difference, according to some authorities, amounting to two or three thousand feet, if not more. The difference was greater towards the south, as compared with the present general altitudes. The inevitable result of this would be to greatly alter the river systems. We should find in northern Canada a wide central drainage area equal to about one-third of the present land surface of the continent, the center of which would be in the region now covered by Hudson Bay.

This great inland sea does not average 400 feet in depth, and it would be all dry land even with a very moderate elevation.

Hudson Strait is much deeper and it would either form a long bay or a river valley, according to the amount of the continental elevation.

Some geologists think that about this time the upper part of the St. Lawrence basin, including all the lakes, excepting Ontario, discharged its waters northward from Lake Superior. But even without this doubtful part the drainage area of this one great northern river would be seven times that of the present St. Lawrence. Judging from the ancient erosion of the valleys and from other considerations, the annual precipitation was at least as great then as now, so that this former river must have been of gigantic proportions compared with any river of the present world.

Its catch-basin would extend from the sources of the Saskatchewan and the Athabasca beyond the Rocky mountains to near the eastern coast of Labrador, and from the Minnesota river in the south to the northern part of Baffin Land and would also include the southern part of the great McKenzie basin. It would flow through the center of Hudson Bay and down Hudson Strait. The former existence of this great river was not a mere speculation as to what might have been, but a necessary consequence of the elevation and change in the slope of the land, and it was proved in detail by a multitude of concordant facts all over the territory involved.

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*Missouri Geological Survey.* Vols. IV. and V., Palæontology of Missouri, by CHARLES ROLLIN KEYES, A.M., Ph.D., State Geologist, pp. 271 and 266. Vols. VI. and VII., Lead and Zinc Deposits, by ARTHUR WINSLOW, assisted by JAMES D. ROBERTSON, pp. xxi. + 763. Jefferson City, 1894.

The issuance in rapid succession of four volumes of the reports of the Missouri Survey indicates a laudable administrative activity. They bring us a grateful relief from the solicitude that was recently felt for the future of the survey. While much of the work of which these four volumes are an expression was done under the previous administration of Mr. Winslow and is to be credited to him and his colaborers, much credit is also due to the administration of Mr. Keyes for their present creditable issuance, as well as for his own large contribution to them.

Volumes IV. and V. relate to palæontology and were prepared by Director Keyes. Volume IV. opens with an introductory chapter on the nature and importance of palæontological data. This is followed by a synoptical description of the formations of Missouri, and a chapter on the biological relations of fossils, these three chapters being preliminary to the descriptions of fossils which make up the remaining six chapters of the volume and the six chapters of the succeeding volume.

The grouping of the descriptions of fossils is biological, the chapters embracing Protozoans and Sponges (IV.), Hydrozoids and Corals (V.), Echinoids and Asterids (VI.), Cystids and Blastoids (VII.), Crinoids (VIII.), Worms and Crustaceans (IX.). These are in the main re-descriptions of species already known, the justification of this appearing in the author's introduction, in which the inaccessibility of the larger part of the original descriptions and the imperfection of some of them is urged. Twenty-one lithographic plates are given to illustrate the fossils described. An appendix containing a stratigraphic catalogue of Missouri fossils and a geological map of the state are added.

Volume V. is practically a continuation of Volume IV. and embraces six chapters relating to polyzoans, brachiopods, lamellibranchs, gasteropods, cephalopods and vertebrates. These are followed by an indexed list of the fossils of Missouri. Twenty-four illustrative plates accompany this volume.

Volumes VI. and VII. relate to the lead and zinc deposits, and are the work of ex-Director Winslow. As in the palæontological part, the separation into two volumes is merely a matter of mechanical convenience, the contents being closely consecutive. The subject is opened with a historical sketch of lead and zinc mining. The treatment is brief, but covers a wide range in time and geographic distribution. The nature of the metals is then discussed, followed by a chapter devoted to their distribution. Emphasis is laid upon the distinction between the diffused and the concentrated conditions, a distinction which is wholly determinative of their economic value, and scarcely less important in the study of their genesis. The ore deposits are classified successively on the basis of their composition, the mode of formation of the constituents, their sources, the forms of the ore body, the attitudes of the ore body, their structures, the natures of the associated substances, the natures of the calcareous rocks, and their geological position. A synoptical description of the lead and zinc deposits of foreign countries and of states other than Missouri occupies two chapters, and gives evidence of good judgment in the selection of the more important data. This is followed by a chapter prepared by James D. Robertson on the metallurgy of the metals, illustrated with cuts of furnaces and other appliances, and accompanied by statistics of production.

The foregoing constitutes Part I. and is preliminary to the special discussion of the Missouri ores and the industry built upon them, which forms Part II. This embraces the history of mining in Missouri, discussions of the physiography of the mining districts and their general geology; a description of the ore deposits, under the heads of distribution, forms, composition, gangues, mineral types, structure and mode of formation, and further statistics regarding the lead and zinc industry.

Part III. is devoted to a detailed description of the mines in which the local occurrence of the ores is set forth with much fullness (200 pages of fine print, admirably illustrated by sections, sketches, maps and photographs).

To the geologist the chief interest of Mr. Winslow's important report doubtless centers in his discussion of the origin of the ores. He points out the grave objections to those hypotheses which postulate the derivation of the ores from solutions rising from great depths. His own opinion coincides in its main features with those of Whitney and Chamberlin respecting the analogous deposits of Wisconsin and adjacent states. He assigns the remote origin of the metalliferous material to the Archæan rocks, whence they were derived by surface decomposition. This material he believes was redeposited by the oceanic waters in the Palæozoic sediments whence it was rederived by surface decomposition and concentrated in the cavities where it is now found. He believes the diffusion of the metalliferous compounds in the Palæozoic sediments was general and rejects the view of Chamberlin that the localization of the deposits was partly due to local enrichment of the oceanic waters corresponding to local richness of the Archæan areas, partly to the courses the oceanic currents followed and partly to the topography of the sea bottom on which the metal-bearing sediments were laid down, aided by a differential distribution of the sea life which gave rise to the agencies of precipitation. He makes the concentration of the ores in the crevices purely secondary, the result of local conditions favorable to concentration. He appears in some slight degree to have misinterpreted Chamberlin's view in that he makes it inapplicable to rocks of different ages. To be sure the discussion of the Wisconsin deposits and the map of the currents were made specifically applicable to the Silurian deposits under immediate discussion, but the map recognizes that the ore deposits are of different ages and the context makes the hypothesis applicable to deposits of other ages. Of course changes in the courses of the currents, changes in the areas of derivation, and in those of deposition must be taken into consideration in explaining the later deposits. If the hypothesis urged by Chamberlin is good at all, it is applicable to all ages, because there must always have been different degrees of enrichment of the oceanic waters in different parts corresponding to the different amounts of metalliferous material brought in from the land and this must have been carried in the direction of prevailing currents. If the inequalities of the sea bottom tended to concentrate metalliferous deposits at one age they should do so at others under similar conditions. Mr. Winslow lays much emphasis upon the degradation of the formations whereby the disseminated metals were removed from their original matrix and brought together in the crevices or cavities in which the ores were accumulated. He justly points out the distinction between this and the narrow views of lateral secretion against which some authors have argued. Perhaps on his own part he is not wholly beyond criticism in the same direction in his interpretation of the views of Whitney and Chamberlin which are scarcely distinguishable from his own in this particular. The ideal diagram on page 548 of *The Ore Deposits of Southwestern Wisconsin*, Vol. IV., Geology of Wisconsin, very sharply emphasizes the function of surface decomposition, conjoined with concentration and segregation below. But this is rather a matter of nice toning and shading of opinion than of important distinctions. The report is much to be commended for its great array of facts which will form a memorable contribution to the science of ore deposits. Mr. Winslow has prepared a list of errata which he will gladly send to any desiring it. T. C. C.

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*Elementary Palæontology for Geological Students*. By HENRY WOODS, B.A., F.G.S. [Cambridge University Press. Macmillan & Co., N. Y.]

This book will supply a want felt in all colleges where historical geology or palæontology is taught. It is something that has been lacking in the English literature on this subject. Though we have great palæontologists and have in our libraries numerous large and well written works on palæontology in various foreign languages and some in our own, students wishing to get a clear idea of the foundation principles of the subject have been obliged either to wade through volumes of technical English works or to materially lessen their interest in the subject by struggling with the difficulties of a foreign language. The author presents in a condensed form the principal structural features of invertebrate fossils, and gives the generally accepted classification, with clear descriptions of the larger groups and principal genera. The book though perhaps too elementary for those taking up the study of palæontology with the intention of devoting considerable time to it, could still be used with profit for some time by such students. Its greatest usefulness will be, however, in aiding those who take up the natural sciences, for general culture only, to get a clear idea of the subject without becoming confused by a mass of details.

J. C. M.

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*Geological and Natural History Survey of Minnesota.* N. H. WINCHELL, State Geologist, 1885–92. Geology of Minnesota, Vol. III., Part I., Final Report, Palæontology, by Leo Lesquereux, Anthony Woodward, Benjamin W. Thomas, Charles Schuchert, Edward O. Ulrich, Newton W. Winchell. 41 plates and 34 figures, pp. lxxv.+474. Published by the state. Minneapolis, Minn., 1895.

This important report opens with an excellent historical sketch of previous investigations of the Lower Silurian formations of the Upper Mississippi Valley by Professors Winchell and Ulrich. Students of the region will find this very convenient in directing them to the literature of the subject not only, but in giving them some indication of the conclusions reached in the works referred to. This is followed by a chapter on the Cretaceous fossil plants of Minnesota by the veteran palæobotanist, Leo Lesquereux. In the introduction to this, attention is called to the remarkably abrupt substitution of the Cenozoic flora for the Mesozoic flora in the midst of the Cretaceous period, and emphasis is laid upon the great diversity of the dicotyledonous forms upon their first appearance, and the lack of any satisfactory explanation of this phenomenon at present. Twenty-three species are described, of which seven are new. This is followed by a chapter on the microscopic fauna of the Cretaceous deposits in Minnesota, with additions from Nebraska and Illinois, by Anthony Woodward and Benjamin W.

Thomas. This is introduced by a description of methods in this relatively new field. Incidentally there is brought out the applicability of such microscopic studies to secondary deposits, such as the occurrence of the microscopic foraminifera in glacial clays. Twenty-nine species are described and fully illustrated. The chapter on sponges, graptolites and corals of the Lower Silurian formations is by N. H. Winchell and C. Schuchert and embraces descriptions and illustrations of nineteen species. This is followed by a chapter on the Lower Silurian bryzoa by E. O. Ulrich, which is introduced by a discussion of terminology, methods of study, classification and geologic distribution. It embraces descriptions of about 150 species, a large percentage of which are new. Twenty-eight lithographic plates, crowded with figures, are devoted to the illustration of this chapter. The final chapter is devoted to the Lower Silurian brachiopoda of Minnesota by N. H. Winchell and Chas. Schuchert. After a brief introduction upon preservation, distribution and terminology—the latter accompanied by very helpful diagrammatic illustrations—an excellent systematic description is given of the brachiopoda represented in Minnesota, exbracing eighty-four forms, amply illustrated. Altogether the volume is a very important addition to the palæontology of the interior. T. C. C.

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## JAMES DWIGHT DANA AND HIS WORK AS A GEOLOGIST.

James Dwight Dana, who for a generation has been our foremost geologist, on the fourteenth day of last April, died at the ripe age of eighty-two years. It is difficult to appreciate how much American geologists owe to the indefatigable industry of this one man; though he has laid down his pen, the results of his labors remain with us, and are wrought into the very foundation structure of American geology. The main events of his busy life have been narrated in many places; one of the most vivid sketches is the one published in the *American Journal of Science*, written by his son. To this we would refer for a clear view of the many-sided life as a whole.

There were certain conditions of birth and early education—certain traits of character—and events in his early life, which in some measure specially prepared him for the career which he so successfully carried out. A few of these may be here recounted as an introduction to this brief sketch of his work as a geologist.

Dana was the son of an active, successful business man; and the qualities of business common sense, industry and economy thus acquired, although he chose to apply them in other than commercial pursuits, were elements of inheritance which contributed greatly to the quality of his greatness and success.

In his boyhood he had the stimulation of a great teacher, whose enthusiasm for natural history tempered by a thorough English culture and education, stirred in him the appetite for investigation and the reverence for the truth, which never left him, but grew with his growth and became the dominating qualities of his character.

Having determined to devote his life to the study and interpretation of nature he chose the most direct ways of fitting himself for the work. He felt the importance of a liberal college education, and entered the Class of 1833 in Yale college, where Silliman was making himself and the college famous for the teaching and encouragement of science. With Silliman he became a devoted pupil of mineralogy, chemistry and geology, but particularly of the first. Silliman's public lecturing began while Dana was in college, and the course of lectures in Hartford in 1834, and the Lowell lectures in Boston in 1835, were the beginning of awakening of the public interest in science throughout America.

Comparing him with others, the influence of this liberal education is seen throughout his writings, in the remarkably philosophical grasp, in the deep insight with which every subject of his investigation was handled, and in the breadth of his interests and his thorough appreciation of the true proportions and relations of things to each other.

He also had the extraordinary advantages of wide travel, which particularly fitted him to be an interpreter of the grander problems of geology, to which in the latter half of his life he gave chief attention. Immediately after graduation he took a cruise on the U. S. Frigates "Delaware" and "United States," across the Atlantic and about the Mediterranean, in the capacity of teacher of mathematics to the midshipmen, but learning and observing meanwhile, studying mineralogy and crystallography inside his cabin, and seeing whatever he could see on sea and land outside. His first scientific paper was written from the U. S. Frigate "United States," in 1834, "On the condition of Vesuvius in July 1834."[1]

[1] See American Journ. Sci. (1) Vol. XXVII., pp. 281–288.

The other and chief voyage was with the United States exploring expedition under Commodore Wilkes, which sailed in August 1838 and reached New York on the return in June 1842. The route took him through the Southern Atlantic, the Straits of Magellan, up the western coast of South America, among the islands of the Pacific, to the western coast of North America, where he was shipwrecked and went overland from the mouth of the Columbia River through Oregon, across the flank of Mt. Shasta and through north California to San Francisco, thence across the Pacific again to the Sandwich Islands, Singapore and around the Cape of Good Hope into the Southern Pacific and thence home to New York.

In this long cruise he acted in the capacity of geologist and mineralogist, but by the failure of others to fill their places, he ultimately became the observer and reporter on all the natural history. The official reports he wrote were three: the first, "On Zoöphytes," 741 pages with a folio atlas of 61 plates, was published in 1846; the second, "On Geology," 756 pages, with a folio atlas of 21 plates, was issued in 1849. The third was "On the Crustacea," in two parts, with a total of 1620 pages and 96 folio plates, and was issued in 1854. A large number of lesser papers and treatises were founded upon facts accumulated during this voyage, or upon investigations carried on in elaborating those observations.

Three lines of investigations, which continued to occupy his attention more or less to the end of his life, were the direct outcome of the experiences of this voyage; these were about 1) Corals and Coral Islands, 2) Volcanoes and the associated problems of mountain making and continental development, and 3) Cephalization; the last topic being incident to the studies made in preparation of the report "On Crustacea." In each of these problems he took keen interest and contributed greatly to their elucidation. His interest in volcanoes led him to make a journey to the Sandwich Islands in the latter part of his life (1887) to see for himself the changes that had taken place, and to compare Kilauea and other volcanoes of Hawaii as they had become, with their condition as observed by him in 1840. As a result of these new studies he wrote "Characteristics of Volcanoes, with contributions of facts and principles from the Hawaiian Islands," 400 pages, in 1890. Much might be said in elaboration of this subject,—the influence of the experiences of 1838–42 in shaping his future investigations and contributions to science—and some of the developments of his geological theories and works will be briefly traced beyond; but space will not here admit the discussion of the equally interesting contributions Dana made to the subject of organic evolution and the correlations between the conditions of life, geological time, and the structure and form of organisms. His studies in the several fields of organisms, minerals and geology made in the earlier, most active period of his life (if there was any time in his life when his activity was abated except by sickness) were an important factor in enabling him to understand nature intimately in her more hidden workings, which by most observers is seen from only one side and therefore but partially comprehended. After returning from the exploring expedition, he spent two years at Washington working on the reports, then he went to New Haven where he resided throughout the remainder of his life.

In the interval between the first two ocean voyages, he was Professor Silliman's Assistant in Yale college, and then produced his first important work, *A System of Mineralogy: including an extended treatise of crystallography with an appendix containing the application of mathematics to crystallographic investigation, and a mineralogical bibliography*. The first edition was of 594 pages and was published in 1837. The title though long gives a concise description of the scope of this book which at once took a first place as a treatise on mineralogy in the English language, and in its successive editions it has not lost its place up to the present day.

That geology was his favorite study is shown by the number of titles in the bibliography. Dividing the list by decades, beginning with 1835, for the first three decades the number of titles is almost equally distributed in the three groups: Geology 37, Mineralogy 34, Zoölogy 38. After 1865, however, but seven papers are strictly mineralogical, and but five were devoted to zoölogy, while of geological papers and books, there are nineteen between '65 and '75, thirty-three between '75–'85, and in the last decade of his life thirty-one, making a total of 120 titles in the geological list, an average of two per year for the whole period of sixty years of his literary activity.

Mineralogy, which first attracted his interest, was early perfected into a system, and after the time of his taking the professorship in Yale college he wrote few special papers on mineralogy, and thereafter turned his attention more and more to geological studies. The 4th edition of the *System of Mineralogy* appeared in 1854 with the fully perfected chemical classification. The 5th edition, which included the complete systematic description of known mineral species, was prepared with the assistance of Professor G. J. Brush, and in the preparation of the 6th edition by his son Edward S. Dana, he was unable to take an active part.

His chief zoölogical works were the reports "On Zoöphytes" and "On Crustacea" of the Wilke's exploring expedition; the former was published in 1846, the latter in 1854. A considerable number of papers were written "On Cephalization," in which he was deeply interested up to about 1866, after that date he produced scarcely anything of purely zoölogical nature.

Geology is a much more complex and miscellaneous science than either mineralogy or zoölogy, and therefore it is difficult to so arrange the facts as to exhibit their relation to any single common principle. But we believe Dana's *Manual* has come nearer to the setting forth of such an ideal system of geology than has been elsewhere attained. The central ideas in this system are: (*a*) the earth a cooling globe,—(*b*) contracting as it cools,—(*c*) differences of depression and elevation of the surface the direct result of the unequal contracting,—(*d*) oceans and continents permanent,—(*e*) trends of shores, of islands and mountains, according to system, and expressive of lines of weakness, and of chief foldings and fractures, (*f*) epeirogenic and orogenic phenomena the direct results of the contracting,—(*g*) climates and currents of the ocean also the effects of changes in elevation of the continents, — (*h*) the separation of the history of the earth into ages by the revolutions at the climaxes in the contraction, when strain and tension came to exceed strength and resistance, and resulted in folding and faulting and local disturbances, and were marked by the greater or less extermination of life, followed by repeopling by, and the modification of the successors, — (*i*) the surface shaping of the continents by ice and water action also influenced by oscillation of level of the continents; and all of these various factors taking a part in producing the present complex condition of the earth's surface.

The earth as a whole was the unit which was before his mind as he constructed this system of geology. As he traced its history he saw in the successive events of geology the marks of the gradual development of a vaporous, then incandescent, and finally hardened, contracting, cooling globe. Others had spoken of geology as a history; but he appears to have been the first to write a manual of geology in English based on this idea. "In history," he commented, "the phases of every age are deeply rooted in the preceding, and intimately dependent on the whole past. There is a literal unfolding of events as time moves on, and this is eminently true of geology." Hence he began his geology with the beginnings, and followed the course of the history of the earth onward.

Again, to Dana the means of measuring the sequence of events was the succession of fossils. "Geology is not simply the science of rocks, for rocks are but incidents in the earth's history, and may or may not have been the same in distant places. It has its more exalted end, — even the study of the progress of life from its earliest dawn to the appearance of man; and instead of saying that fossils are of use to determine rocks, we should rather say that the rocks are of use for the display of the succession of fossils. Both statements are correct; but the latter is the fundamental truth in the science." It was this idea which dominated in his classification of geological formations.

American geologists are all aware that it is from the use of Dana's system that the habit of speaking of geological Periods and Epochs has been acquired. Other manuals speak of formations, systems and étages, of series and groups; rocks being classified as if they were distinguished by some qualities of their own. It is from Dana that we have learned to classify geological formations in relation to the stages of progress in the building of the continents and its local structural features, and to regard rocks as not simply aggregates of mineral matter, but as geological formations bearing a definite relationship to the progress in the history of the earth, and hence as belonging to, and to be defined as of a particular period or epoch. In the first edition of his *Manual* in 1862 the author wrote:

"It has been the author's aim to present for study, not a series of rocks with their dead fossils, but the successive phases in the history of the earth,—its continents, seas, climates, life and the various operations of progress."[1]

The grand outlines of Dana's system of the earth's development are given in a few sentences in his article "On the Plan of Development in the Geological History of North America," first published in the *American Journal of Science* in 1856.[2]

"What then is the principle," he wrote, "of development through which these grand results in the earth's structure and features have been brought about? We detect a plan of progress in the developing germ; we trace out the spot which is first defined, and thence follow the evolution in different lines to the completed result: may we similarly search out the philosophy of the earth's progress? The organizing agencies in the sphere are, 1) Chemical combination and crystallization. 2) Heat, in vaporization, fusion and expansion, with the correlate force of contraction which has been in increasing action from the time the globe began to be a cooling globe. 3) The external physical agencies, preëminently water and the atmosphere, chiseling and

[1] Manual of Geology: treating of the principles of the science with special reference to American Geological History, for the use of colleges, academies and schools of science, by JAMES D. DANA, pp. xvi. + 798, illustrated by a chart of the world, and over one thousand figures, mostly from American sources: Philadelphia and London, 1863.

[2] Am. Journ. Sci. II., Vol. XXII., p. 339.

moulding the surface. 4) The superadded agency of life. Of these causes, the first is the molecular power by which the material of the crust has been prepared. The third and fourth have only worked over the exposed surface. But the second while molecular in origin, is mechanical in action, and in the way of contraction, especially, it has engaged the universal sphere, causing a shrinkage of its vast sides, a heaving and sinking in world-wide movements. Its action, therefore, has been coextensive with the earth's surface through the earth's history" (*loc. cit.* p. 340). On a later page a footnote again refers to this same dominant idea: "I have alluded on a former page to an analogy between the progress of the earth and that of a germ. In this there is nothing fanciful; for there is a general law, as is now known, at the basis of all development which is strikingly exhibited even in the earth's physical progress. The law, as it has been recognized, is simply this:–Unity evolving multiplicity of parts through successive individualizations proceeding from the more fundamental onward" (p. 346).

Notwithstanding all the additions of details and statistics in illustration and elaboration of this idea, we see, up to the last, this is the dominating principle about which his system of geology was built; and the American continent, as its geological features were gradually opened to light, was recognized as the most typical illustration of this system to be found upon the globe. In the last edition of the *Manual* we find these words: "North American geology is still its chief subject. . . . The idea long before recognized [*i. e.*, before 1855] that all observations on the rocks, however local, bore directly on the stages in the growth of the continent, derives universal importance from the recognition of North America as the world's type-continent—the only continent that gives, in a full and simple way, the fundamental principles of continental development."

He was not, however, carried away by theories, his scientific research was always deep, thorough and exact. As he was preparing the report on the geology of the exploring expedition he was not satisfied with simply describing what he saw. He not only made a thorough study of the volcanoes in the islands of the Pacific and on the borders of the South American continent, and Vesuvius and Ætna in Italy (his first scientific paper as before noticed was a letter written from U. S. frigate "United States" in 1834 "On the condition of Vesuvius in July 1834"), but in his investigations of the many questions raised by these observations he also studied the surface of the moon,—and comparison of the already cooled moon and its extinct craters with the present condition of the earth suggested the chief phenomena about which was later elaborated his theory of the earth's development as a cooling, and necessarily contracting globe.

This paper, read before the Association of American Geologists and Scientists in September 1846, "On the Volcanoes of the Moon," suggested the following: "Thoughts bearing on our own planet." 1. If the earth was once a melted globe, it must have passed through the same phases as the moon, with this very important difference, that the whole surface during its progress was subject to the denuding action of waters and from the first had valleys and sedimentary rocks in progress. 2. Certain conclusions regarding the "origin of the mineral constitution of igneous rocks," including the idea that differences in fusibility will determine the mineral combinations, and that "the same igneous rocks may occur of all ages, etc." 3. As to origin of continents "the areas of the surface constituting the continents were first free from eruptive fires. These portions cooled first, and consequently the contraction in progress affected most the other parts. The great depressions occupied by the oceans thus began; and for a long period afterward, continued deepening by slow, though it may have been unequal progress." He cites the evidence of elevations all along the geological history, the presence of marine fossils in elevated upturned strata and the depression of the oceans in the coral islands, quoting the observations of Mr. Darwin, and referring to his own, to be reported on later, in confirmation of these views. The outline of the system is tersely expressed in the closing sentence of this article:

"The principles explained place the general theory of change of level by contraction upon something better than a hypothetical basis, and are believed to explain the actual causes by which the changes have been produced. They correspond moreover with the view that ruptures, elevations, foldings and contortions of strata have been produced in the course of contraction. The greater subsidence of the oceanic parts would necessarily occasion that lateral pressure required for the rise and various foldings of the Alleghenies and like regions."[1]

The theory was further elaborated in the following year in three papers which appeared in the *American Journal of Science* "On the origin of Continents;"[2] "Geological results of the Earth's Contraction in consequence of cooling,"[3] and "Origin of the Grand Outline features of the Earth,"[4] and was finally put into systematic form in his *Manual of Geology*.

The general contraction theory was not original with Dana, as he acknowledged in these papers. He found it advocated by Leibnitz in 1691. Babbage and De le Beche had formulated the general theory of changes of level by contraction and expansion and the rise of continents. Mather, Elie de Beaumont, Lyell and others had made more or less reference to the principle, and M. Constant Provost had published in 1860 his view that the agency of contraction alone will account for the various changes of level which the continental areas have undergone. There were however certain features which were his own, as shown in the following passage:

"The reader will perceive that although the main principles of Provost are sustained by the writer in this and his former paper, the manner in which these principles are carried out, is in some respects a little different, especially in the idea that the oceanic areas have been the more igneous parts of the globe, and for this reason have contracted most; that certain orographic changes over the continents are due to contraction beneath the oceanic regions, and that the fissurings and mountain elevations have for this reason taken place in some instances near the margin of a continent, or near the limit between the great

[1] Am. Jour. Sci. II., Vol. II., p. 355.

[2] Am. Jour. Sci. II., Vol. III., p. 94.

[3] Loc. cit., p. 176.

[4] Loc. cit., p. 381.

contracting and non-contracting (comparatively non-contracting) areas. The efficiency of the cause of contraction has appeared to the writer to be wider and more evident, as the subject has received closer attention; and the study of it very naturally led to modifications of former views."[1]

Thus, it will be seen, that although others had before conceived of the idea of the general effects of contraction, it was to Dana the working hypothesis in the construction of a system of geology.

Although later investigations have added new light for the interpretation of the details of mountain building and earth shaping, a reference to the chief points of the theory, as elaborated by Dana in 1847 will show how much we are indebted to him for a clear exposition of the general principles of the science. In the second article "On Geological Results of the Earth's Contraction" these principles are stated. In regard to the Appalachian Chain, the general structure of which the Rogers brothers had already elaborated, the peculiarities were by them explained as the result of the propelling force or thrust of moving waves of molten material beneath, and the "disrupting tension of the compressed gaseous matter." Mather had previously spoken of the effects of refrigeration of the earth, but he found the cause of the features of the Appalachians in "a paroxysmal elevation and the action of inertia due to the more rapid westward motion of the part of crust lifted up further from the center of revolution." In the article above referred to, Dana wrote, "The principal peculiarity of these plications to which we would ask attention, is the following: the greater abruptness of the northwestern slope of each fold, in connection with the diminution of the undulations to the northwestward; and it will be our endeavor to show that this peculiarity, and the irregularities which exist are necessary results of the action of a force laterally exerted;" and he proceeded to demonstrate how by this power, "a series of folds would be produced each with the inclination steepest on the side farthest from A (the point of resistance); and moreover, these

[1] Am. Jour. Sci. II., Vol. III., p. 179, 1847.

folds would be necessarily most abrupt the nearer they are to A" (p. 184). Further on he gives four chief "reasons why this action should not produce perfectly regular and uniform folds: (1) from a variation in thickness of the bed; (2) from a want of uniformity in the material or its state of induration; (3) from an inequality in the action of the force upon different parts of the line against which it operates; (4) from irregularity in the contraction going on beneath the area." He observed a third principle, viz., that by the effect of gravity alone plication would be produced in much inclined or tilted clayey layers, while the sandy layers unless greatly indurated would settle bodily. A fourth principle is stated thus, "If the material subjected to lateral pressure be not capable of folding, or only partially so, the region operated upon instead of rising into a series of elevations would be raised into one or more ridges of much greater height." A fifth principle is that intruded igneous rocks or dikes may not be the cause, but are rather "a concomitant result of the same general operation." A sixth principle is "the folding of strata by subsidence of the plicated region can be only of small extent." Seventh, he says "the occurrence of volcanoes mostly in the neighborhood of the sea is a necessary result of these principles." The eighth principle is that the grander geological epochs are the direct result of more or less catastrophic periods which would separate, according to the theory, longer periods of comparative quiet, thus forming the transition breaks between the great systems.

While Dana was a consistent uniformitarian, in so far as to interpret past phenomena of the earth's history by the operations of forces such as are now in action, he clearly saw the natural relations of periods of special disturbance of the strata by the reaching of high degrees of tension and their expression in elevation and fractures along lines of tension, and the more quiet periods of chief sedimentation. This principle is better elaborated in the latest edition of the *Manual* than in previous works, on account of the fuller knowledge of the facts finally attained. In the development of the American continent there are recognized, not only long periods of sedimentation and accumulation of strata in synclinoria, but separating these periods of quiet there were revolutions resulting in each case in lifting greater or smaller areas permanently above the surface of the ocean, and the later of these revolutions were the grander, in amount of elevations and mountain making, in fracturing and lava outflows, and in production of volcanoes, because, as his theory explains, of the greater thickness and rigidity of the crustal portion of the earth incident to the secular cooling of the globe.

In the article of 1847 the Appalachian revolution closing the Palæozoic, and what has been subsequently called the Palisade revolution, which terminated the Jura-Trias of the Atlantic border region, are distinctly referred to; and besides these we now know of the Taconic revolution, at the close of the lower Silurian; the Acadian revolution terminating the Devonian in the east; the great Rocky Mountain revolutions terminating the Mesozoic and bringing in the Tertiary conditions in the Laramide elevations, progressing a stage farther in the lifting of the Coast Range region at the close of the Miocene, and finishing its work at the close of Pliocene in the lifting of the Sierra Nevadas. That these more or less catastrophic events were the natural consequences of the continuous uniform cooling and contracting of the crustal portions of the globe, is a corollary of Dana's theory of the earth. As he observed, referring to these revolutions in the last edition of the *Manual*, "the above facts are brought forward to illustrate the grand principle, already admitted by some writers, that such grand crises,—by causing wide emissions of heat and changes of level in the sea, and violent shakings of the globe with its mobile waters,—were in early times a necessary result of the contraction in progress."

Referring to the Appalachian revolution, he wrote, "It is not a matter of surprise that there should have been an abrupt cessation with this event of preëxisting forms of marine life. The period when the effects of dislocation began to be transferred from the oceanic areas to the continents appears to have been the era of this catastrophe, and it was an era of similar changes in various parts of the globe." The forty-eight years of constant study of the new discoveries in geology and testing the theory has shown it to be founded on fundamental truths of geology. The importance of this one, among the causes producing the changes which have taken place in the history of organisms, is a sufficient reason for here making a lengthy quotation from the fourth edition of the *Manual* regarding the application of this theory. Speaking of the disappearances of life at the close of the Palæozoic, the following is written:

"There was no break in the stream of life, but for the most part only seeming interruptions, and many of these owe their prominence in geological history to the culminations and declines of types that were in progress. But it was an epoch of relatively abrupt change, and if chiefly due to the progressive evolution of new species, as has been urged by some geologists, there must have been for the result a great acceleration in such change in consequence of the physical conditions produced by the orogenic disturbances. But the orogenic movements were local and the biologically transforming effects from such a cause should have been confined to the countries where these movements were in progress. The universality and abruptness of the disappearances cannot therefore be so explained. Very much is left for the destructive effects direct and indirect, that is, the exterminations attending the mountain making.

"The causes of the exterminations suggested by the changes are two: (1) A colder climate over the land, and colder waters in the extra-tropical oceans, for the emergence of the eastern semi-continent of North America and of large lands in the other continents could not fail to lower somewhat the temperature of the whole globe. With a lower temperature, the currents from the north sweeping along the coasts would have been destructive to the marine species living in the waters. (2) Earthquake waves produced by orogenic movements. If North America from the west of the Carolinas to the Mississippi Valley can be shaken in consequence of a little slip along a fracture in times of perfect quiet, and ruin mark its movements, incalculable violence and great surgings of the ocean should have occurred and been often repeated during the progress of the flexures, miles in height and space, and slips along newly opened fractures that kept up their interrupted progress through thousands of feet of displacement. The

Acadian upturning took place on the ocean border, and the Appalachian was not far distant from it, Arkansas, moreover, added to the extent of the belt of disturbance. Under such circumstances devastation of the sea border and the low lying land of the period, the destruction of their animals and plants, would have been a sure result. The survivors within a long distance of the coast line would have been few. The same waves would have swept over European land and seas, and there found coadjutors for new strife in earthquake waves of European origin. These times of catastrophe may have continued in America through half of the following Triassic period, for fully two-thirds of the Triassic period are represented by rocks and fossils on the Atlantic border" (p. 736).

Thus the course of the evolution of the life on its surface was in no small way dependent upon the gradual contracting of a cooling globe.

Not only did Dana take this broad and comprehensive view of the whole system of geological phenomena, but he made a thorough and particular study of several of the more difficult problems of American geology; among them may be named the interpretation of the glacial phenomena over New England and the classification of the period for North America—the solution of the "Taconic" controversy, and the associated questions of metamorphism and mountain building.

When the first edition of the *Manual* was issued (1863) there was far from unaniminity of opinion among American geologists as to the agency by which "drift" gravel and bowlders had been spread over the surface of the more northern states of the Union.

Dana interpreted the "drift" and the striations on the surface of the rock to be evidences of glaciation, and he was an earnest advocate of the theory of a great continental glacier, as opposed to the iceberg theory. Although few of the present generation have ever held another opinion, some of us will remember the strenuous defense of the iceberg theory so lately as the meeting of the American Association of Science at Montreal. Professor Dana not only opposed that theory from the beginning, but by his indefatigable personal studies of the surface topography and markings in the Connecticut Valley, and particularly in and about New Haven, as well as with less minuteness, over much of New England and in parts of New York state, accumulated the evidence, which has not only thoroughly proven the glacial theory, but has furnished the greater part of the fundamental facts upon which is built the present classification of the glacial period as given in his *Manual.* To be sure, many other workers have furnished abundant contributions and have greatly elaborated these facts, but when we examine the literature and observe the part Dana took, in formulating the grand outlines as well as many of the particulars of our general theory of the glacial period in America, we find his part in laying the foundation of opinion was far greater than that of any other one man.

His papers in the *American Journal of Science*, beginning in 1863 and not ceasing till the year 1893, are numerous, and are based upon his personal observations in the field. They cover the discussion of each of the important questions which enter into the present theory of the glacial period. Such were: the directions of striæ and their relations to topography, with the establishment of the fact of their local deflection to follow the course of larger valleys, as the Mohawk, the Hudson Valley, the Connecticut River valley, etc.; the floods resulting from the melting of glaciers and the nature of evidence left by them; the absence of marine life in Long Island Sound through the glacial and part of the Champlain period; reindeer of Arctic type in southern New England; depression of land during the melting of the great glacier; damming of streams by ice; and Kames and their relations to the ordinary materials of drift. These, and many others of the particular phenomena of glaciation were built into the definition of the glacial period as he elaborated it from his personal observations.

Even to his last days his interest in the glacial question was keen and wide. In the preparation of the fourth edition of the *Manual*, although confined to New Haven, he made a thorough revision of the chapters on that subject. He realized that outside his quiet study hot controversies were going on among glacialists of different opinions in America, and he took the greatest pains to get from original sources the evidence on both sides. He opened the pages of the *Journal of Science* to discussion of both views. His correspondence was widely extended, and with, I presume, every one of those who had taken a prominent part in the discussions of the past few years. In a conversation with the writer on one of those days, he remarked that one of the chief causes of contrary opinions regarding the division of the glacial period in America was, he believed, due to local coloring resulting from taking either the phenomena of New England and the eastern edge of the glacier, or else those of the western-central region, as the standards of judgment by the two sides in the discussions.

When he had finished the pages on the quaternary for the printers, he remarked that he had reached an explanation of the events which he thought would harmonize the divergent views, and he expressed more than ordinary enthusiasm, and spoke as if, having exhaustively compared all the facts that had been brought forward, he had reached what he believed to be the true solution of the vexing problem.

His explanation of the case, viz., an epoch of extreme advance, which was of great length, with, following, an epoch of first retreat, then halt, in which the deposits of the Lafayette formations were being made on the gulf and eastern borders, and with, third, the epoch of final retreat of the ice from the northeastern plateau, is certainly a comprehensive interpretation of the series of phenomena as a whole, however it may be modified by increasing knowledge. (See *Manual of Geology*, 4th ed., pp. 943–80.)

The clearing up of the confusion involved in Emmons' "Taconic System," was another task to which Professor Dana gave enthusiastic attention. After some thirty years of defense of the system by its friends, against the ineffective attacks of those who were unable to bring convincing proof of its fallacies, Professor Dana entered the field in 1871. The main trouble was that Emmons' interpretation was based upon several false tenets which were then maintained by the best of geologists; and it was necessary to demonstrate their falsity before they could be laid aside. Prominent among them was the belief, that the age of a rock can be determined by its lithological characters. In the absence of fossils, the granular quartz was thus determined to be metamorphozed Potsdam Sandstone, and both Cambrian and Hudson River Slates were included under the name Taconic Slates, and supposed to be of pre-Cambrian age. A second error was the belief that the presence of certain minerals may be relied upon for identifying horizons—and a third point, which though known to be false, was too much trusted in even by those who knew better; viz., that actual succession of rocks in a metamorphozed region is a safe-guide in determining the order of sequence. In 1871 Professor Dana entered the field determined to settle the disputed questions by study of the region itself. "My purpose," he wrote, "was (1) to prove the continuity from north to south of the three associated Taconic formations, the quartzite, the limestone and the slates or schists; also (2) to work out the system of flexures; (3) to ascertain whether the Taconic mountains were generally or not of synclinal structure, as they were made by Rogers, Mather and Hall, and in 1864 by Logan; (4) to settle the question as to continuity from east to west of the limestones of the different north-and-south belts; (5) to apply the evidence from fossils, making them the sole basis for fixing the age of the beds; and finally (6) to use the evidence of the age, thus obtained, for the determination of the age of the hydromica schists, chloritic schists, garnetiferous and staurolitic schists, and other rocks of the Taconic Mountains, and thus test the value of, or give greater precision to, the assumed 'lithological canon' first propounded by Emmons. My work was continued in western New England and eastern New York at intervals from 1871 to the close of the season of 1886." The results of these investigations are continued in a number of papers in the *American Journal of Science*, from 1871 to 1888. Among the more important of them are the following, viz.: "What is true Taconic?" "Green Mountain Geology: on the quartzite" in 1872; "On the Quartzite, Limestone and associated rocks of the vicinity of Great Barrington, Berkshire Co., Mass.," 1872–3; "An account of the discoveries in Vermont geology of the Rev. Augustus Wing; the relations of the geology of Vermont to that of Berkshire," 1877; "The Hudson River age of the Taconic Schists," 1879; "The geological relations of the Limestone belts of Westchester Co., New York," 1880–81; "On the Southward ending of a great synclinal in the Taconic Range," and "The Corlandt and Stony Point Hornblendic and Augitic rocks" in 1884; "Taconic rocks and stratigraphy," 1885, 1886 and 1887; "Lower Silurian fossils from a limestone of the original Taconic of Emmons," 1886; and the final paper of the series, "A brief history of Taconic ideas," in 1888. In addition to the above are "Two atlases, one of Berkshire Co., Mass., and the other of Westchester Co., New York, having on the back the title 'Taconic Rocks,' containing my [his] notes made in the geological survey of these regions," which were specifically bequeathed by his will to the Library of Yale College.

The solution of the problems was not alone Dana's work: the fossils discovered by Wing, Billings, Dale, Dwight, Ford, Bishop, Walcott and others were the evidences which finally redistributed the various members of Emmons' system into their proper places in the standard systems of the Palæozoic already defined. But as we look back over the battle and trace its progress, it is evident that the energy and thoroughness with which Professor Dana attacked the problems, if he did not do all the work, availed much in inspiring and directing the work of others; the bearings and importance of whose discoveries he was often quicker to discern than the discoverers themselves, and always gave full credit to whomsoever it was due. The final paper, "A brief history of Taconic ideas," is an admirable example of the calm judicial spirit with which he was accustomed to rise above all personal prejudices and individual opinions and to define scientific facts as they are.

Two other problems which grew out of the investigations already mentioned were, the interpretation of the partially metamorphosed rocks of the Connecticut Valley, and that of the greenish schists on the western border of the Triassic in southern Connecticut.

Two papers were written upon the first subject, viz.: "On the rocks of the Helderberg era, in the valley of the Connecticut," 1873, and "The Helderberg formation of Bernardston, Mass., and Vernon, Vermont," 1877. The fuller elaboration of the stratigraphy and of the fossil contents were made by Professor B. K. Emerson of the Massachusetts survey. The other problem, about which the paper on "The 'chloritic formation' on the western border of the New Haven region," in 1876, and remarks in the "Geology of the New Haven region," 1870, opened the discussion, was not satisfactorily finished at the time of his death. It involves questions in metamorphism which call for petrographical as well as geological investigation, and whose solution must be left for other workers.

The preparation of the *Manual of Geology* was perhaps the greatest of his contributions to geology; of its value every geologist of America knows. It has done more to unify and codify American geology than any other work, and until very recent years, if we may judge from their literary quotations, foreign geologists have made Dana's *Manual* their chief source of information regarding the geology of America. It has always been characterized by that accuracy, and that fullness of details collected with a rare selective judgment, which has made it for every worker an indispensable handbook. In the last edition, which was finished but a few months before his death, he has combined the results of personal revision by the active workers in the more recently explored fields, with his own full knowledge of the current literature, to make it a complete account of the state of the science at the time of its publication.

In the breadth and richness of his knowledge an equal to Professor Dana is not likely to arise. For the thoroughness and industry which he applied to all his investigations, the fairness with which he treated all with whom he could not agree, the kindness and consideration he showed to all, and the unswerving devotion to the truth, James Dwight Dana will be long remembered by all students of science. His geological contributions to American geology constitute such a fundamental part of our knowledge that so long as the science endures he cannot be forgotten.

HENRY SHALER WILLIAMS.

NEW HAVEN, 1895.

# GLACIAL AND INTER-GLACIAL DEPOSITS NEAR TORONTO.

A LONG line of yellowish white cliffs to the east of the city forms a striking feature of the voyage across Lake Ontario from Niagara to Toronto; and a closer examination of the Scarboro' Heights discloses a most interesting section of the drift. At the highest point the cliffs rise more than 300 feet above the lake, and the thickness of the deposits is probably considerably greater than this, for the solid rock nowhere crops out in a distance of twenty miles. Along many parts of the Heights, which are in all nine and a half miles long, reaching from a point three and a half miles east of the River Don to the mouth of Highland Creek, the undermining action of the lake provides for a constant series of fresh exposures; and at other points the deep V-shaped valleys of small streams, afford almost as good sections. From Scarboro' westwards to Toronto also, the cuttings for railroads and streets, and the ravines of the Don and its tributaries display more or less complete sections of the drift, some of them more than 150 feet in height.

The Scarboro' Heights were an object of interest to engineers and geologists more than forty years ago as the source of the sand which, driving westwards along the lake shore, is arrested by the current of the River Don, thus forming the island which protects the harbor of Toronto;[1] but no serious geological study appears to have been made of them except by Dr. George Jennings Hinde, who published an admirable account of them in 1878.[2] The results of his observations seem little known, probably from the fact of their having been published in a journal not very widely circulated and at a time when glacial studies did not

[1] Reports on the Improvement and Preservation of Toronto Harbor, Prof. Henry Youle Hind, p. 1; Sandford Fleming, p. 15; Appendix to Canadian Journal, 1854–5.

[2] Glacial and Inter-glacial Strata of Scarboro' Heights, Can. Journ., 1878, p. 388, etc.

attract so much attention as they now do, since the rise of a body of able and ardent glacialists in America as well as the Old World.

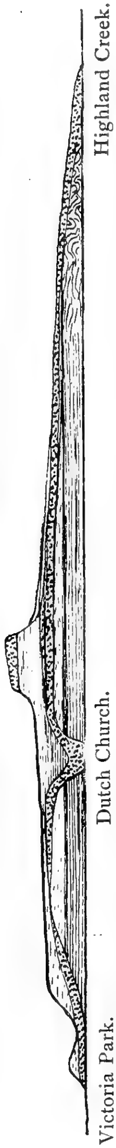
The inter-glacial beds of the Don have been described briefly by the present writer[1]; but beyond these two papers little has appeared as to the drift in this part of Ontario. It seemed so difficult to correlate the results obtained from these two localities only a few miles apart, that it was decided to connect the two by a careful study of the whole ground. This has now been carried out with tolerable completeness, and it is proposed here to give a short account of the results. In doing the work great assistance has been received from the authorities of the Grand Trunk and Canadian Pacific Railways, who provided profiles of all the lines near Toronto; from the city engineer, who provided maps; and from several specialists who have determined fossils obtained from inter-glacial beds; and I desire to express my heartiest thanks for their great kindness.

It will be well to begin with an account of the Scarboro' Heights which afford the thickest and most complete section in the region. For this my own observations, which in general accord well with those of Dr. Hinde, will be made use of chiefly.

The drift deposits show themselves first, after a long stretch of gravel beach, about three and a half miles east of the Don, as a low cliff of stratified sand and sandy clay, below which blue till appears. The first outcrop is just west of Victoria Park, and the escarpment, which is only ten or fifteen feet high at the beginning, rises rapidly, after a break caused by the valley of a stream, to one hundred and sixty or eighty feet. About three and a half miles east of the Park the cliff suddenly rises to a height of more than 300 feet, but soon drops down to its old level, after which it sinks gradually to a height of twenty or thirty feet, six miles farther east, where it is interrupted by the valley of Highland Creek.

At its best exposures the escarpment displays, beginning at the level of the lake, about ninety feet of stratified clay, followed

[1] Inter-glacial fossils from the Don Valley, Am. Geol., Feb. 1894, p. 85, etc. In this paper references are given to the literature on the subject, which is very scanty.




Section at Scarboro' Heights, 9½ miles long and 300 feet high.

by fifty feet of stratified sand, covered by a bed of till varying from forty feet to nothing in thickness. Three miles from Victoria Park this layer of till suddenly dips down to the lake, thickens to sixty or seventy feet, and rises as suddenly a quarter of a mile farther east. The hollow left on its surface is filled with stratified clay to a depth of ninety feet, and this is followed, where the escarpment is highest, a half mile farther east, by from seventy to one hundred feet of stratified clay and sand, capped by twenty or thirty feet of an upper till. About one hundred feet of stratified sand overlying the western end of the lower sheet of till, should perhaps be correlated with this, though possibly of post-glacial age. These sands thin out to nothing where the upper stratified clay shows itself. The accompanying diagram, in which the heights are exaggerated tenfold, will give a general idea of the section and make a more elaborate description unnecessary. It will be noticed that the lower bed of till dips down to the lake at each end of the section; while the upper till, forming the surface of a table land which comes out to the escarpment for a short distance only, is cut off abruptly at each end.

Examining the members of this section in ascending order, we find at its base a series of bluish-gray clays rising out of the lake. They lie perfectly horizontal, are often finely laminated with sandy partings, having sometimes twenty laminæ to an inch, but at other times forming beds several feet in thickness. Narrow bands of flat green concretions of impure carbonate of iron occur at various levels; and at others thin layers of peaty matter. Some beds of clay richer than others in plant food may be followed long distances by the eye as bands of rich, green vegetation, while other parts are bare.

The peaty matter varies from a mere film to a thickness rarely greater than half an inch, and is made up sometimes chiefly of mosses, but more commonly of fragments of bark, wood and twigs, waterworn and mingled with flakes of mica. Quite seldom one may find a larger knot or broken branch, but never trunks of any size. From these insignificant peaty layers Dr. Hinde obtained three species of diatoms, a chara, five mosses, Bryum, Fontinalis, Hypnum commutatum, H. revolvens (?) and another species of hypnum, spores of lycopodium, pieces of pine and cedar wood, portions of leaves of rush, etc., and seeds of various plants. Among animals he found two or three species of Cypris, a Planorbis and a Zonites (doubtful), as well as the elytra of beetles.[1] The insect remains were submitted to Dr. Scudder, who reports as follows:[2]

"Among the material . . . . . . was a considerable number of the elytra and other parts of beetles, an assemblage, indeed larger than has ever before been found in such a deposit in any part of the world, and they are mostly in excellent condition. Twenty nine species have been obtained, some of them in considerable numbers. Five families and fifteen genera are represented; they are largely carabidæ, there being six or seven species each of Platynus and Pterostichus and species also of Patrobus, Bembidium, Loricera, and Elaphrus. The next family in importance is the Staphylinidæ, of which there are five genera, Geodromicus, Arpedium, Bledius, Oxyporus, and Lathrobium, each with a single species. The Hydrophilidæ are represented by Hydrochus and Helophorus with each one species; and the Chrysomelidæ by two species of Donacia. Finally a species of Scolytidæ must have made certain borings under the bark of juniper.

"Looking at them as a whole and noting the distribution of the species to which they seem to be most nearly related, they are plainly indigenous to the soil, but would perhaps be thought to have come from a somewhat more northern locality than that in

[1] Can. Jour. 1878, p. 399.

[2] Fossil Insects of North America, Vol. II., Tertiary, p. 40.

which they were found; not one of them can be referred to existing species, but the nearest allies of not a few of them are to be sought in the Lake Superior and Hudson Bay region, while the larger part are inhabitants of Canada and the northern United States, or the general district in which the deposit occurs. In no single instance were any special affinities found with any characteristically southern forms, though several are most nearly allied to species found there as well as in the north. A few seem to be most nearly related to Pacific forms, such as the Elaphrus and one each of the species of Platynus and Pterostichus. On the whole, the fauna has a boreal aspect, though by no means so decidedly boreal as one would anticipate under the circumstances."

It will be seen that this remarkable assemblage of insects is of great importance in coming to a conclusion as to the climate of the time when these deposits were laid down; and Dr. Scudder's wide experience in regard to the geographical range of North American insects gives special value to his views on the subject.

By washing, drying, and examining with a lens peaty matter from Scarboro' the present writer has succeeded in obtaining a large amount of additional material, consisting of wing cases and other parts of the chitinous armor of insects, all of which has been submitted to Dr. Scudder, who has very kindly consented to determine them and thus add to the data available for judging of the climate.

A considerable number of determinable parts of plants, such as leaves, seeds, mosses, etc., obtained in the same way, was sent to Dr. Macoun of Ottawa. The small collection of mosses was forwarded by him to Mrs. E. G. Britton of Columbia College, New York; and I am much indebted to both of them for the trouble they have bestowed on the determinations. Dr. Macoun gives the following list of the species determined by him in the material sent: Larix americana (?), Abies balsamea, Salix, alder, Carex aquatilis and C. utriculata, Equisetum, Oxycoccus vulgaris and vaccinium uliginosum. Of the last two he is quite certain.

Mrs. Britton determines the mosses as follows: Limnobium palustre (?), L. montanum (?), Hypnum lycopodioides (?), H. aduncum, H. fluitans (?). Professor Penhallow of Montreal has determined two specimens of wood from Scarboro' as probably Picea nigra.

It will be noticed that the plants obtained by myself differ considerably from the list given by Dr. Hinde, perhaps because taken from different levels in the clay. Doubtless the number of species could be greatly added to by careful search.

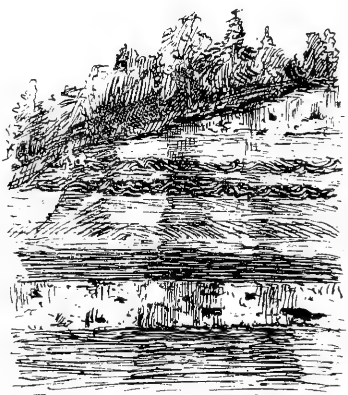
Looking at the plants as a whole Dr. Macoun is of opinion that the climate was like that of the northern part of the Gulf of St. Lawrence or southern Labrador, cool and wet. He states that all the species are represented in the herbarium of the Geological Survey at Ottawa by specimens from the regions mentioned; and thinks that the deposit was formed in a pool surrounded by trees, such as we find in our northern woods today. Dr. Macoun's conclusions regarding the climate as determined from the plants correspond fairly well with those of Dr. Scudder; so that the question may be looked upon as settled. There are, however, no evidences of the action of ice. Dr. Hinde remarks the complete absence of pebbles or bowlders from these clay beds, a point which the present writer also has been struck with, suggesting no transport and dropping of materials by floating ice. One may infer from the uniform lamination and fineness of the clay that it was deposited in quiet water some distance from the shore. Leaves and bits of bark and mosses drifted in by the wind or brought down by a stream gradually waterlogged and sank along with the slowly settling flakes of mica and fragments of insects. It appears that forest fires raged in Ontario then as now, for fragments of charcoal or of chips charred on one edge are not infrequently found mixed with quite uncarbonized woody material. This, of course, does not necessarily imply the presence of man; for doubtless many fires have originated by natural causes, such as lightning.

Resting conformably on the clay we find about fifty feet of fine, yellowish or grayish sand, sometimes having thin layers reddened with garnets or blackened with magnetite. Very marked transverse bedding is often observed, indicating more troubled water than during the deposit of the underlying clay. Some parts of these sands contain many nut-brown concretions of a much rounder form than those from the clay. A large number of these were broken, but only two or three contained traces of vegetable matter or portions of insects as a nucleus. Peaty matter may be found in small amounts in the sand, and at a few points fresh-water shells were found along with the concretions, Sphærium striatinum and Succinea obliqua, according to determination of Mr. C. T. Simpson. The Succineas seem almost too fresh and well preserved to be of inter-glacial age, but they are found nowhere except in the sand beds below the lower till, and the evidence of their age seems pretty conclusive.

The beds just described were deposited in water having a level at least 140 feet above that of the present Lake Ontario; and they may have been considerably thicker than we find them now, for there is clear evidence that they were greatly eroded before the overlying till was spread out. At the Dutch Church not only the sands but the stratified clays also were cut through by a stream valley, for we find the bowlder clay filling a hollow that reaches below the level of the lake. Hinde supposes that the ice of the glacier ploughed out this deep valley; but there is no reason to suppose that this portion only should have been excavated by the ice front while the same materials were left untouched on each side. The bedding of the clay is scarcely disturbed right up to the contact with the till, which would be impossible if the snout of the glacier had ploughed its way through, but is intelligible if it simply filled a preëxisting valley.

The till which follows is of the usual description, a blue calcareous clay charged with polished and striated pebbles of limestone and black Utica shale, with a few Laurentian bowlders. This bed of till is continuous from end to end of the section except at a point about one mile and a half east of Victoria Park, where probably by subsequent erosion, it is thinned out to nothing for about 300 yards. There is a deep hollow in the till at the Dutch Church, where it dips down to the lake, perhaps an original depression of its surface, now filled with ninety feet of stratified clay, very like the lower beds, but more calcareous and apparently free from fossils and concretions.

At the point where the upper terrace comes out to the shore these stratified clays are covered conformably by a series of stratified sands with some clay beds, in all seventy feet thick. Several of these beds at different levels are remarkably crumpled and contorted, while the beds immediately above and below appear quite undisturbed. They have perhaps been folded by



Upper part of Section at Scarboro' Heights, showing two upper layers of till and the crumpled strata. After photograph by Dr. Ellis.

the grounding of ice floes, and in appearance they remind one of examples figured in *Geikie's Great Ice Age.*[1] No fossils have been obtained from these inter-glacial beds.

The upper till, which overlies the country to the north of the Scarboro' Heights, forming a gently rolling table-land, described by Professor Chamberlin in conversation as a mild form of moraine, is seen at this section to consist of yellowish-brown clay with well striated pebbles and larger stones, fragments of black Utica shales, often falling to pieces, limestones apparently of Trenton age, and archæan rocks, such as gneisses. It differs from the lower till in being somewhat more sandy, and especially in hav-

[1] P. 271–2.

ing been greatly weathered, some parts at the bottom alone showing the original blue color of the clay.

West of this highest part of the escarpment a series of rather coarse, cross-bedded, stratified sands and gravels, in which no fossils have been found, overlies the lower till, at first in a a thin layer, but rapidly thickening as the bed of till descends toward the lake near Victoria Park, where it expands to a thickness of more than one hundred feet. Hinde looks on these sands and gravels as post-glacial, but similar deposits a few miles to the west and north are covered by the upper till; and at a cutting on the Scarboro' street railway a little north of the Park crumpled strata of the kind previously referred to are well exposed, suggesting an inter-glacial age for these beds. However up to the present their position must be looked on as not positively settled.

A comparatively thin layer of coarse gravel and well-rounded stones, followed by loamy soil covers these sands and forms the surface of the Iroquois terrace.

From the description just given it will be seen that at the Scarboro' Heights there are two beds of till separated by a deposit of unfossiliferous stratified clay and sand amounting in thickness, if we add the depth of stratified clay at the Dutch Church to that of sand and clay at highest points a little farther east, of 160 feet. Below the lower till the fossiliferous sands and clays have a depth of at least 140 feet, their lower limit being covered by the lake. Dr. Hinde assumes a third till below the lower clay, nowhere exposed along the Scarboro' escarpment, but cropping twelve miles to the west at Humber Bay, where till overlies the Hudson River shales, and is covered by stratified clay not unlike that at Scarboro'. The Humber clays, so far as I have observed, do not contain peaty matter nor the plate-like concretions of clay-iron stone; however, they are so far separated that the conditions under which they were deposited may have differed greatly from those at Scarboro'.

Whether the underlying till be found or not, there is every reason to think the lower Scarboro' sands and clays inter-glacial; for they contain a series of minerals including garnet, magnetite, hornblende and biotite, thoroughly characteristic of Laurentian rocks and not found in the adjacent Hudson River or Utica shales. The transport of these materials for a distance of not less than seventy miles is best accounted for by glacier ice.

The extent of these deposits has not yet been worked out in detail, though the lower stratified clay was apparently widespread. Twenty feet of clay very like it, containing thin layers of peaty matter, may be seen on the shore of Lake Ontario four miles to the east of Highland Creek, here also covered by a bed of till. Exactly similar clay occurs about four miles to the northwest of Victoria Park in the brickyards of Messrs. Price and Logan. The exposures are excellent, one presenting a face of sixty feet; and the top of the clay, which rises about one hundred feet above Lake Ontario, is covered with a few feet of stratified sand. One finds the greenish plate-like concretions, and peaty matter containing mosses, pieces of bark and wood, elytra of beetles, flakes of mica, etc., just as at Scarboro'. The layer of till is wanting at these brickyards, but is found a few hundred yards farther north near the corner of Danforth avenue and Greenwood lane.

If we include the Humber clay in the series, this lacustrine deposit has a length of twenty two miles, by a breadth of at least one and one half miles. Omitting the Humber beds, it has been traced for about sixteen miles.

The upper, unfossiliferous clay from the Dutch Church seems also very widely distributed. It may be found as suggested by Dr. Hinde, in the north of Toronto (formerly Yorkville), where it is used to make gray brick. It seems to occur also at the Don Valley brickworks, and other points along the Don ravines. Similar stratified unfossiliferous clays making white or buff or gray brick occur at various points a few miles to the north and west of Toronto; and beds very like them underlying an upper till are well exposed on the lake shore between Newcastle and Newtonville, more than forty miles to the east. The upper unfossiliferous clays appear then to be even more widely spread than the lower peaty clays, though one can hardly make sure that the deposits at all the localities mentioned were laid down in the same body of water and at exactly the same time.

The inter-glacial deposits on the Don, best shown at the brickworks owned by the Messrs. Taylor, were described a year ago,[1] but will be referred to again, giving the results of a careful reinvestigation under better conditions.

When it was examined in the preparation of the paper referred to, the quarry consisted of two parts, a lower one showing about forty feet of drift, including nearly three feet of till resting on Hudson River shale, twenty-five feet of stratified sand with one or two clay beds, and, above this, ten feet of stratified clay making red brick. A slope of grass extended from this part of the quarry for about one hundred yards to the upper portion, where about forty feet of stratified clay making buff brick were to be seen, the top of the exposure reaching almost to the level of the plain formed by the Iroquois beach of Spencer. The part covered with grass was stated by the men at work in the quarry to consist of the same clay as that worked for buff brick, and was included with the upper stratified clay in the section given. About a third of a mile northwest of the quarry, the Davenport Ridge, a morainic tract of gently rolling highland, composed of somewhat sandy till containing bowlders and striated stones, comes to a sudden stop and forms a cliff fifty to seventy feet high at the Iroquois beach. That the Davenport till stretched much farther south before the Iroquois water had encroached upon it is clear, not alone from the steep cliff, but from the immense bowlders scattered over the terrace, evidently left behind when the finer materials were washed away by wave action. Such bowlders lay on the surface just above the quarry, until removed a year ago. The fact that the upper stratified clay of the quarry may be traced here and there up the ravine to the north, until, about half a mile above the brickyard, it underlies the till of the Davenport ridge, confirms the conclusion.

The Davenport ridge is a continuation of the mild moraine

[1] Inter-glacial fossils from the Don Valley, Am. Geol. Vol. XIII., February 1894, p. 85–95.

forming the upper plateau at Scarboro', the two being separated only by the deep bay-like depression of the Don Valley; and it seemed to me probable, last year, that the layer of till overlying the shale at the brickyard was a continuation of the lower Scarboro' till, which sinks beneath Lake Ontario near Victoria Park three or four miles to the east. This implied that the fossiliferous beds at the Don, with the overlying stratified clay in which no fossils occur, were equivalent to the upper, unfossiliferous beds at Scarboro'. This spring, however, new excavations at the brickyard have completely overturned this theory by disclosing a thick bed of till in the slope formerly covered with grass. This overlies the fossil-bearing strata which correspond, therefore, to to the lower, fossiliferous bed at Scarboro', so far as position is concerned.

At present the quarry presents the following section, as measured by aneroid and steel tape:

| | Feet. |
|---|---|
| Soil and stratified clay, making buff brick (unfossiliferous) | 43 |
| Till (partly covered with grass) about - - - - | 35 |
| Stratified clay with peaty matter, making red brick - | 13 |
| Stratified sand with some clayey beds (fossiliferous) - | 24 |
| Till - - - - - - - - | 2 |
| Hudson River shales, about - - - - - | 60 |

The Hudson River shales rise about thirty-five feet above the level of Lake Ontario. At the Don Valley brickworks we have, then, a lowest till resting on the rock and overlaid with fossiliferous beds; a second till corresponding to the lower Scarboro' till; but no uppermost till, though one probably existed before the formation of the Iroquois beach, and the upper stratified clay passes beneath the upper till at the Davenport ridge a half-mile away. So far as I have observed the three tills are nowhere all disclosed in a single section; but a shaft sunk through the Davenport ridge or the highest part of the Scarboro' Heights would probably cut through all three.

Since the paper on the Don fossils was published three new localities have been found in the same valley; one of them, which was opened to give employment to the convicts at the gaol near by, proving especially interesting; since thin layers of matted deciduous leaves occur in it. One of these localities is at the shore of a pond a mile above the brickyard, so that the fossil-bearing sands and clays have been shown to extend for three miles along the valley of the Don. Judging by the position of these beds with reference to the lake, the stream in which they were formed had a much more rapid fall than the present sluggish river. The lowest fossil bed in the upper part of the valley

Quarry at Taylor's brickyard, Don Valley, Toronto. The section shows the Hudson River shale; the lowest till resting on it (dark); the fossiliferous stratified sand and clay; the middle till just beneath the grass at the staging; and the upper stratified unfossiliferous clay in the much foreshortened upper quarry. The photograph is by Dr. Ellis, of the School of Practical Science, Toronto.

is about forty feet above the lake; at the Convict Cutting ten or fifteen feet; while at the cutting for the Don improvements, near the mouth of the present river, fossils were found several feet below the level of Ontario.

The localities most productive in fossils are the brickyard and the Convict Cutting, and a brief description of them may be of interest. At the brickyard unios, retaining their dark epidermis and having the valves united, are often found embedded in a few inches of blue clay immediately overlying the till. The sands above this contain more or less waterworn unios, pleuroceras, sphæriums, etc., while the overlying stratified clay beneath the middle till holds a little peaty matter, but nothing well enough preserved to be determinable.

At the Convict Cutting, too, the unio bed is disclosed, but some stratified, sandy clay beds in the upper part of the section have proved much more interesting, that patient collector, Mr. Townsend, having obtained from them a large number of leaves, among which he thinks are leaves of the oak, beech and willow. It is very difficult to preserve these leaf fragments, since the clay dries up and the brown traces of the outline and veining shrivel up and become almost unrecognizable.

Up to the present the unios have proved the most important finds along the Don. They include the Unio phaseolus, U. clavus, U. pustulosus, U. pustulosus, var. schoolcrafti, U. occidens (?), U. luteolus, U. undulatus, U. rectus, U. trigonus, and U. solidus. The other shells obtained are Sphærium striatinum, Pleurocera subulare, P. elevatum, an undetermined species of the same genus and a single specimen which may be P. pallidum, Physa ancillaria and Amnicola limosa. I am indebted to Dr. Dall and his assistant, Mr. C. T. Simpson, for the determination of the above species, all of which occur at the brickyards and several of them at the other points. A few other fossils, including one or two species of ostracods, a number of elytra of beetles and one or two teeth, the latter found by Mr. Townsend, have been obtained at the Convict Cutting with the leaves, but have not yet been determined.

The plants include fragments of tree trunks, leaves, a very few mosses and chara. The specimens of wood have been determined by Professor Penhallow of McGill to be Fraxinus quadrangulata, Quercus obtusiloba, Ulmus americana, Maclura aurantiaca and Picea sitchensis (?). Some leaves sent from the Convict Cutting he considers to be of willows and poplars. Professor Penhallow had previously found in material sent by Mr. Townsend from the Don Improvements, Asimina triloba, Ulmus racemosa, Taxus baccata and a new maple leaf, which was named Acer pleistocenicum.[1] In respect to the woods, Professor Penhallow says that they are usually badly decayed, but that he has referred them to the nearest living species.

If we compare the inter-glacial fossils of the Don with those of Scarboro' we find them surprisingly different. Up to the present only one species of animal, Sphærium striatinum, a form having a wide range, has been shown to be common to both localities. It will be of great interest to learn if Dr. Scudder finds insects from the Convict Cutting the same as those from Scarboro' or not. No two trees are undoubtedly alike, though Picea nigra of Scarboro' is not far removed from Picea sitchensis of the Don; and willow leaves of undetermined species have been found in both places.

It will be remembered that both the insects and plant remains of Scarboro', in the opinion of such good authorities as Dr. Scudder and Dr. Macoun, point to a cool climate like that of Lake Superior or Labrador; while the Don fossils, on the other hand, point equally conclusively to a climate as warm as that of Toronto at present, if not considerably warmer. The numerous unios, some of them no longer found in our lakes, though common farther south in the Mississippi drainage system;[2] the forest trees including three species (Asimiana triloba, the osage orange and Fraxinus quadrangulata) now belonging to the portions of Ontario along Lake Erie and the states to the south,[3] hint at a climate very far from glacial, probably comparable to that of Ohio at present.

There seems no doubt also that both of these deposits are inter-glacial and included between the same sheets of till; though the lowest till is out of sight below the lake at Scarboro'. These two series of beds can hardly have been formed contempora-

[1] Bull. Geol. Soc. Am., Vol. I., p. 328.

[2] C. T. Simpson, Proceedings U. S. National Mus. Vol. XVI., pp. 591–5.

[3] Dr. Macoun, Forests of Canada, Trans. Royal Soc. Can., Sec. IV., 1894, p. 11.

neously; one must have preceded the other; but which came first is not easy to decide.

One might assume that the Scarboro' clays were formed first, a cold climate continuing for a long period of time after the departure of the earliest ice sheet; that the water was drained off or the land elevated afterwards, and the Don of those days excavated its comparatively wide and deep valley apparently not greatly different from the present one. Meantime the climate had become warm, and southern forms of life pushed their way northward and occupied the river and its shores until the second advance of ice destroyed them. This hypothesis seems to agree with many of the facts, particularly if Dr. Hinde is correct in his belief that the stratified clay resting on till near the mouth of the Humber is a continuation of the fossiliferous Scarboro' beds. The quite similar clays at Price's brickyard would then be a remnant of a wide sheet of such lacustrine deposits afterward eroded by the Don. There is an appearance of interbedding of a thin layer of the peaty clay at the Taylors' brickyard with the bowlder-clay above; while the upper fossiliferous beds at Scarboro' were much eroded before this sheet of till was laid down, facts which perhaps point in the same direction. If this hypothesis be correct the Don beds, being much later than those of Scarboro', may somewhere be found resting unconformably on their eroded surface. Up to the present, however, no such section has been observed.

On the other hand one might suppose that the Don beds are the older; that after the till was laid down there was a sudden change of climate, and that southern forms of life quickly followed up the retreat of the ice-sheet as it vanished under the action of warm sun and winds. The fact that Mississippi unios lived and died right on the unweathered surface of the blue till at the brickyard fits best with this assumption. If there had been a long period of erosion before they arrived, one would expect to find the till weathered brown and its enclosed pebbles of shale crumbled to pieces, instead of being fresh and sharply striated. Taking this view, the layer of peaty clay just beneath the middle till at the Don is the equivalent of the ninety or more feet of peaty clay at Price's brickyard and Scarboro'; and one might expect to find the unio bed, or its equivalent as to climate, beneath the level of the lake at Scarboro'. It should, however, be observed that up to the present no species has been shown to be common to the peaty beds of the Don and those of Scarboro', except one ubiquitous shellfish. It may be that future excavations will settle which hypothesis is correct; if, indeed, some entirely different interpretation may not be put upon the facts described.

Two very interesting articles have appeared recently, one by Professor Chamberlin in the JOURNAL OF GEOLOGY, the other by Mr. Warren Upham in the *American Geologist*, referring to the succession of glacial deposits in America, and mentioning the Toronto inter-glacial beds in that connection. Professor Chamberlin gives the "Toronto Formation" tentatively an independent position as the possible equivalent of Geikie's Neudeckian,[1] and places it in the interval between the Iowan and Wisconsin sheets of till. Mr. Upham places the Toronto inter-glacial beds in a somewhat similar position, but looks upon them as only in a limited sense inter-glacial, "since they lie between deposits of glacial drift; but they seem better referred to moderate oscillations of the ice boundary during its general retreat after the Iowan stage, that is, to a time during the Wisconsin or moraine-forming stage rather than to distinct glacial epochs."[2] He supports this view by a statement as to thinning out of the beds of till between Scarboro' and Toronto, suggesting the nearness of the ice border; and finds the deposits "quite inexplicable on the hypothesis that these till formations record great readvances of the ice, as either to the Iowan stage or to the Wisconsin moraines."[3]

In regard to the thickness of the sheets of till it may be mentioned that they vary greatly in this respect within short

[1] JOURNAL OF GEOLOGY, Vol. III., No. 3, pp. 273–275.

[2] Am. Geol., Vol. XV., No. 5, p. 289, etc.

[3] Ibid., p. 290.

distances both at Scarboro' and along the Don, but by no means always in the sense of thinning out towards the west. For instance, the middle till, the lowest visible at Scarboro', is there generally less than thirty feet thick and for a mile or more scarcely averages five feet in thickness; but at the Dutch Church, where the subglacial débris has been crowded into a deep valley, it reaches a maximum of seventy feet. The same bed of till at the Don brickworks is thirty-five feet thick, and a little farther south, between the Winchester street bridge and Danforth avenue, is apparently ninety feet thick.

The upper till at Scarboro', so far as I have measured it, runs from twenty to thirty feet in thickness; but at Moore Park Station, less than a mile north of Taylor's brickyard it is forty-five feet thick, and at York Mills, three or four miles northwest, is nearly sixty feet in thickness.

In reality the difference in thickness of the drift at Scarboro' and the Don is due rather to the greater or less development of the inter-glacial beds than to the thickness of the till.

If these inter-glacial deposits were formed during slight oscillation of the ice margin, one would suppose that drifting ice floes or even bergs would have been active on the waters of the time, transporting bowlders and other materials, which should be imbedded in the clays and sands of the lake bottom; but neither Dr. Hinde nor the present writer has been able to find stones of any kind in the 140 feet of fossiliferous beds at Scarboro'.

The case of the Alaskan glaciers cited in the article mentioned[1] is in reality not at all analogous to the conditions prevailing at Toronto during the earlier inter-glacial time. In Alaska the Japan current brings comparatively warm moist air right up to latitude 60°; while the highest mountains in North America rise a few miles inland, their icy flanks intercepting the moisture-laden winds from the Pacific and causing a tremendous snowfall in a region where the snowline is only 2000 feet above sea level. If Mt. Fairweather, Mt. St. Elias and Mt. Logan were leveled,

[1] Ibid., p. 278.

how long would the Malaspina and other Alaskan glaciers hold their ground?

At Toronto during one part of this inter-glacial time we had a climate, judging by the flora and fauna, far milder and drier than that of Alaska; and, nothing that can be called a mountain rises between this and Hudson Bay. The inter-glacial time was long enough not only to allow of the deposit of the thick beds of sand and clay that have been described, but to allow the great body of water in which they were formed to be drained to a depth of one hundred and fifty feet, and the new land surface to be deeply eroded. At the Dutch Church, for instance, a valley was dug a mile in width from edge to edge and a quarter of a mile wide at the lowest level exposed by Lake Ontario.[1] All of this must have demanded time and plenty of it. Can any one believe that meantime, while elms and oaks and maples, not to mention the papaw, were growing along the Don, the ice-field, with no lofty slopes to supply gathering ground for névé, was lurking a few miles off, ready to advance and overwhelm the deciduous forests?

It has been pointed out in a previous paper that Toronto lies not more than 500 miles from Hudson Bay or 700 from the center of Labrador, with no mountains intervening.[2] There seems no more reason to assume that a great ice-field existed within those distances while the Don fossils were being buried than there is to assume it at the present day. As a whole, then, the evidence at Toronto seems to support strongly the theory of Geikie, Chamberlin and others as to the distinct ice ages separated by mild inter-glacial times.

The unfossiliferous clays and sands lying between the middle and upper sheets of till and having a thickness of at least one hundred and sixty feet at Scarboro', and of forty at Toronto, indicate a second recession of the ice. The absence of fossils, the presence, though rarely of angular striated pebbles in the clay, and the corrugated and crumpled beds here and there found among the upper sandy layers suggest a cold, perhaps

[1] See Section of Scarboro' Heights.

[2] Am. Geol., Vol. XIII., p. 92.

Arctic climate, implying perhaps only a long recession of the ice, not its complete removal. The upper part, consisting of cross-bedded sand and clayey sand, seems quite widespread, for similar beds lying between the rolling surface of till and a lower sheet of till have been found on a branch of the Don seven miles north of the city, at Pickering twenty miles northeast, and on the lake shore near Newcastle forty miles to the east. It may be that fossils giving a hint as to the climate in this inter-glacial period will be found at some time. The tooth of a mammoth was found last summer on the Don eight miles north of the city at a point where the stream flows over the middle till and cuts away banks showing stratified sand and in some cases the uppe till also, but the fossil may be post-glacial rather than inter-glacia in age. The same holds of two mastodon teeth found several years ago, one on the Don, the other in a sand pit two or three miles east of the city.

If Professor Chamberlin is correct in assigning the fossiliferous beds of Toronto and Scarboro' to the interval between the Iowan and Wisconsin ice ages;[1] then the upper stratified beds imply a still later ice age, separated probably by a shorter and less genial inter-glacial time than the former one. It is however possible, as suggested by Professor Chamberlin, for the beetle-bearing beds of Scarboro' in case they should prove to belong to a lower horizon than the Don beds, that the fossiliferous beds near Toronto are of Aftonian age, *i. e.*, belong between the Kansan and Iowan sheets of till; and that the upper beds represent the interval between the Iowan and Wisconsin ice sheets. The former supposition seems to me the more probable, since there is some likelihood that the mild morainic sheet forming the Davenport ridge and upper Scarboro' Heights runs out in the neighborhood of Toronto, and hence cannot be continuous with the Wisconsin sheet to the southwest. Until the till sheet lying to the north and east of Toronto has its western boundaries traced this point cannot be settled.

A long halt in the retreat of the last glacier, if not a recru-

[1] JOURNAL GEOLOGY, Vol. III., No. 3, p. 273, etc.

descence of glacial conditions after another interval, is indicated by the great morainic loops stretching from Trenton westwards to Lake Huron and passing (as the Oak ridges) about eighteen miles north of Toronto.

The post-glacial history of the region near Toronto has not yet been satisfactorily worked out, though one episode, that of the Iroquois water as described by Dr. Spencer, has left its mark very distinctly in the old beach to the north of the city, and must have had considerable importance as regards the formation of surface deposits.

Much of the somewhat loess-like fine clayey sands of the Humber valley may turn out to be post-glacial; and Dr. Hinde supposes that the upper hundred feet of sand and gravel at the west end of the Scarboro' cliffs are of the same age; but my own observations incline towards an inter-glacial position for these thick and widespread but greatly eroded deposits. Similar sands occurring at York Mills and other points north of the city are undoubtedly covered by the upper till, which may simply have been removed from the more southern parts near the lake. Unprotected by a layer of till these sands are easily attacked by wind and water and superficially rearranged, so that their original structure and relationship becomes obscured.

Of course the Don and Humber with their tributaries have formed in the lower sluggish parts of their courses alluvial deposits of clay and sand that are evidently modern, and in some instances are added to by every spring flood.

The succession of events since Pliocene times in the vicinity of Toronto may now be reviewed in order to bring to a focus the results of the observations described in this paper.

No Pliocene deposits have been found in this region, supposing the earliest advance of the ice to indicate the end of the Pliocene; but the lowest till forms a carpet over the eroded surface of the Hudson River shales. At the time the earliest glacier advanced the Scarboro' region formed a valley whose hollow is now below the surface of Lake Ontario, and there were low hills where the Don and Humber valleys now exist, the highest observed level of the shale being about eighty feet above the lake at Lambton Mills on the Humber.

The retreat of the ice was followed by a rise in the water of the lake to a level at least 150 feet above the present lake, depositing that depth of clay and sand upon the unweathered till. The Scarboro' water, as it may perhaps be called, was then drained off to a point below the present lake level, and at some points erosion took place to a corresponding depth. It is possible that the climate became warmer during this period of erosion and that the Don beds were deposited afterwards.

At the time of the second glacial period the topography of the region had greatly changed. The Scarboro' Heights already had an elevation of 150 feet, while valleys reaching the present lake level had been cut by Highland Creek and the Don, as well as by the Dutch Church stream, which now has no equivalent. The retreat of the second ice-sheet was followed by a rise of the water to a height of 280 feet above the present lake, the water being cold and lifeless, and bearing ice floes.

Once more the lake was drained, at least partially, and erosion went on, for the upper till is found at a sand pit near the corner of Bloor and Christie streets in Toronto at a level of about 120 feet above the present lake. Either the period of dry land was short, giving no time for the cutting of deep valleys, or the level of the lake of those days was considerably above the present Lake Ontario. The contour of the land at the end of this inter-glacial period is more difficult to settle than in the former one; but it is tolerably certain that the Scarboro' Heights had almost their present height, and that the Don valley was much shallower than at present, if it existed at all.

The retreat of the third ice-sheet was followed as before by a rise of water, Lake Iroquois reaching 160 feet above the present lake to the north of Toronto, and about 190 at Scarboro'. After the draining of Lake Iroquois it is probable that the surface of the country presented much the same rolling swells of till as are now found north and east of Toronto; for, in general, erosion has gone on to a moderate degree only, except where the more powerful streams have cut out picturesque ravines, such as are seen along the Don and Humber.

It is probable that at the end of the first inter-glacial period the topography had almost as old an aspect as at present, indicating as long a time for erosion as has elapsed since the last ice age; but the dry land stage during the second inter-glacial period was apparently much shorter. The length of time during which high water lasted during the two mild periods must have been very great to allow the immense sedimentary beds to be deposited at Scarboro' and elsewhere, 150 feet thick in the earlier period and 160 in the later. The Iroquois high water stage after the last ice age was probably much shorter, since it has left much smaller sedimentary deposits.

It is a notable fact that each ice-sheet advanced apparently during a time of low water, and was followed by a stage of high water; whether this is to be accounted for by assuming an ice dam at the foot of the predecessors of Lake Ontario, or a change in the level of the land surface caused by the loading and unloading of its ice burden, it is very unlikely that the sea has extended inland so far as Toronto since glacial times. The numerous marine animals found as fossils lower down on the St. Lawrence and Ottawa would hardly have stopped short without reaching the Iroquois bay, if that had been a body of salt water, in communication with the Gulf of St. Lawrence.[1] However, no fresh water forms have been found on its beach, so that the evidence is only negative.

The Scarboro' beds give very instructive evidence as to the comparatively slight erosive power of glaciers. Except near the east end of the section, where, as suggested to me some time ago by Mr. J. B. Tyrrell, the ice front began to rise upon the higher ground during the second advance and crumpled and contorted the clay beds, there is no very striking disturbance even of the stratified sand, though here and there portions of the sand

[1] Two marine shells have been picked up on the Iroquois beach, but, as suggested by Dr. Dall, to whom they were submitted, they have almost certainly reached that position by human agency.

are tilted out of place. The upper layer of till rests in some places on crumpled beds of sand, but more often one sees little trace of disturbance. One might almost describe the till as a lubricant allowing the ice-sheet to glide easily over the inequalities of the surface.

A. P. COLEMAN.

# ORIGIN OF CERTAIN FEATURES OF COAL BASINS.

WHILE the general theory of the formation of coal has long been worked out and accepted, it cannot be said that the details of the process are as yet altogether understood. Numerous puzzling phenomena are constantly encountered in all coal regions. In some regards Iowa is a particularly good field in which to work out certain of these points. The coal seams here are relatively thin and lie near the surface. The region has not been disturbed by mountain-making forces. The seams, with one or two exceptions, are not of great areal extent as is common in certain other fields, but are usually quite limited. Indeed it is frequently possible to find the whole of a seam in a single exposure and to be able to trace it readily from one limit to another. Thus the coal beds are reduced to the lowest terms and so become miniature representations of larger coal basins. They serve as models and present opportunities for investigation of certain phases of their structure which in larger basins have been obscured.

In the following paper an attempt is made to explain a few of the different questions which arise in the study of coal beds. The observations were made on the beds of the Iowa-Missouri field alone, and the explanation is only offered as true of certain of these beds. Whether it is of value in other fields or not cannot be told; to workers elsewhere it may perhaps be of suggestive interest.

There is probably no peculiarity of the coal seams of this region which is more constant than what has been called their basin character. In any individual bed the coal is not everywhere of the same thickness; neither does it all lie at the same level. These two variations have usually a constant relation to each other, it being commonly true that the thinner coal is found at the higher points in the seam and the thicker lies in the lower intermediate regions. The exceptions to this rule are rare and are usually found either where the rise is slight and covers a small area or where the coal is of an impure or bony character. In all the greater differences the coal thins towards the rise.

These lower lying portions of the coal beds are usually called by the miners "swamp coal" or "basin coal" and it is in these swamps or basins that the thicker and more productive portion of the beds lie. In many cases these basins have been traced considerable distances, maintaining the general character of a trough with coal thick at the center and thinning on each side. The area they cover is usually quite irregular. In a few cases the bed underlies a broad circular area thinning quite regularly as it rises in all directions from the center. More usually the length in one direction is much the greater, instances being known where areas of workable coal only about 100 yards wide have been traced nearly a mile. They do not run in direct lines but curve often in an intricate and irregular manner. They are not confined to any one locality but are found in such widely scattered regions as Scott, Keokuk, Jasper, Marion and Lucas counties. Indeed they are present in nearly every region in the state in which coal is mined and are largely sought for by operators. They seem to be more abundant and more irregular in character in the lower horizons. The general character of such a coal basin is represented in Fig. 1, a composite section. On the one side the coal rises twenty feet in a distance of 320, thinning from six to four feet. On the other hand it rises sixty feet in 400 and thins from six to two feet. These two instances are taken from a large number which might be given. The rise of sixty feet is rather unusual, the variation being more frequently from twenty to forty feet. In mining, neither the total variation in elevation nor in the thickness of the seam is usually learned, since so soon as the coal becomes too thin for profitable mining it is rarely traced farther.

A number of these cases have been examined and the relations between the amount of rise and the decrease in thickness determined. The cases examined yield a series of ratios varying from 1:6 to 1:30. The greater number fall between 1:10 and 1:16, so that the average may be taken as lying between these figures.

In connection with these basins usually a considerable number of small slips or true faults are found. These rarely have a great throw though in a number of instances they parallel each other, forming a step fault with an aggregate throw of considerable extent.

Frequently these slips parallel the basins. In some cases cracks or veins filled with calcite also run in a parallel direction. Another peculiarity often observed is that the slips do not run

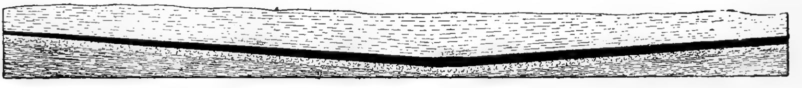


FIG. 1.

clear through the coal; more usually they come in from the top but disappear before reaching the bottom. This, however, is not confined to the most pronounced basins, but it is also frequently found in those coals which have a true bedded character, such as the Mystic coal.

In discussing the origin of these basins it will be convenient to consider separately the lines now formed by the top and the bottom of the coal. Considering first the latter the resemblance to the cross section of a valley is at once seen to be striking. This is well brought out in the figure of the Vanderberg mine, a small slope about three miles south of Pella on the Des Moines River. Fig. 2 represents the conditions at this point. The Saint Louis limestone here forms an almost continuous outcrop some distance along the river. It rises to a height of thirty or forty feet. At the place in question the coal lies undisturbed at a level at least fifteen feet below two contiguous limestone outcrops only a few feet distant. It is evident that this coal was formed in a depression in the limestone, and the relations exhibited on the ground show just as clearly that this was a basin of erosion. There is no evidence of disturbance or faulting. The limestone ledges of the two opposite sides of the basin may be as directly correlated as those on opposite sides of a modern stream. In working the coal in this mine, which is merely a small country bank, it has been found that the coal dips toward the present river. Thus it seems that this vein was laid down in a small gully or ravine opening out into some larger basin, the margin of which was located approximately along the present course of the Des Moines.

In these and other cases it is at once seen that the lower line

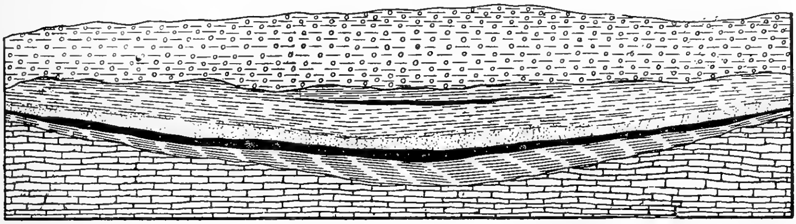


FIG. 2.

is the cross section of a previously existing ravine. There is no reason to doubt that a similar statement would hold in a great number of the remaining cases. In all places where there has been an opportunity to examine the underlying rocks this has been found to be true. In a majority of the other cases known the coal horizon lies undoubtedly above an unconformity of erosion, and the underlying rocks are known to have suffered erosion sufficient to account for just such outlines. Not all, however, are known to be so located. In a few instances similar basins are found in seams which so far as known do not overly any unconformity. In the veins which lie high up in the coal measures the coal often has a rolling or undulatory character, differences of twenty to twenty-five feet in elevation being not uncommon. In such cases there is not always a constant rule as to the thinning of the coal over the higher points. It is only as the basins are traced out to their limits that the rule appears to hold. These minor changes can readily be accounted for by the secondary changes induced by the consolidation of the immediately underlying strata. In other instances, as for example the "second seam" in the Eureka mine at Des Moines, the usual rule holds true.

If we conceive the coal seam at the time of its formation, we would have essentially what may be seen in any modern peat swamp. The loose vegetal matter lies under the water completely covering the irregularities of the bottom and rising to a practically uniform level a short distance below the surface of the water. In the process of change by which the vegetal matter is transformed to coal it loses a considerable percentage of gas and water so that the relative percentage of carbon increases in regular order from wood to anthracite.

Bischof in studying these changes calculated the total loss which takes place in the change of wood into coal. He assumed that the change had taken place by three processes:

1. By the separation of carbonic acid and carburetted hydrogen.
2. By the separation of carbonic acid from the elements of wood, and by oxidation of hydrogen by external oxygen.
3. By the separation of carbonic acid and water from among the elements of wood.

Under these three assumptions the wood lost as follows: (1) 78 per cent.; (2) 58.3 per cent.; (3) 45.5 per cent.

It is readily seen that with so great a loss of material there must be a corresponding decrease in volume. As the gases escaped, a process yet in operation in the deeper mines of other regions, the strata settled. The amount of this settling may be arrived at as follows.

In the coal basin figured above it will be seen that at one point the floor of the coal bed is sixty feet above the lower portion adjoining. At the time of the deposition of the vegetal matter both these points were covered to a considerable depth, the loosely compacted material rising probably to an even level. It is evident that at that time there was sixty feet of material less over the high than the low point. The whole mass became so deeply buried that the pressure of the overlying beds may be assumed to have been equal at both points. This assumption is especially safe since the two points are but a short distance apart. As the matter yielded to this pressure, it decreased in bulk until in the end it assumed the thickness now seen. The fact that the character of the coal at both points is similar confirms the assumption that the conditions and pressure at both points have been the same. It thus becomes evident that the original difference of sixty feet in the thickness of the vegetal matter ultimately gives a difference of four feet in the thickness of the coal; or that each foot of coal now present occupies one-fifteenth the vertical space which it originally filled. This ratio has been calculated for a number of cases in Iowa and is found in a major portion of instances to lie between one to ten and one to fifteen. Thus the rule is reached that in the process of consolidation Iowa coal seems to have been reduced to from one-tenth to one-fifteenth its original bulk. It should be remembered in comparing these estimates with those made in other fields that the Iowa coals have not been subjected to the action of mountain-making forces. There has been no lateral pressure, and the vertical pressure has probably been comparatively slight.

The changes due to this compression would be slight in the beds under the coal. To the degree in which they were soft and unconsolidated they would themselves be amenable to the same pressure. As a matter of fact they were only slightly affected. The fire clay immediately under the coal, if thick, frequently shows the greatest changes. It was of course subject to irregularities of deposition and hence varies in thickness. When the strata consolidated the fire clay was more unyielding than the coal so that a greater thickness of fire clay is marked by a "horseback" or ridge pushed into the coal. Changes in the thickness of the coal bed would not greatly affect the underlying strata except to the slight degree in which they may at times have lessened the pressure on the fire clay. The effect of such a decrease would correspond to that now seen in "creeps" which are due to a similar cause.

In the coal bed itself the effects of the settling may be seen in the small slips or faults which are encountered. As the coal became older and less plastic it was able to resist the pressure for a considerable time. Finally the accumulated force would cause it to yield, and this yielding would take the form of a series of slips or of cracks along its edges rather than of a gradual unbroken deflection. Since the lower beds were more largely resistant the faults do not often extend far into them and frequently do not even extend to the bottom of the coal.

In the beds above the coal the effects of this action must be large. The shales which lie immediately over a coal seam are frequently quite badly faulted. This is usually more evident in bituminous than in argillaceous shale. This is probable due to the fact that just in proportion to the degree with which they are charged with bituminous matter they would themselves undergo the same loss and other changes which occurred in the coal. In general, however, shale accommodates itself readily to pressure. Limestones and sandstones prove more unyielding and break with sharp fault lines into the underlying coal beds.

One of the most important results of these changes and the one which gives them their deepest economic significance is the part which such a change in a coal seam would play in inducing the deposition of overlying seams. Starting with the conception of a coal swamp as a low-lying coastal marsh it will be seen that any irregularity in the surface which makes an inreaching basin will afford better opportunities for the formation of a coal seam since it will give a better—more protected—area for the growth of plant life and will shield the deposit from the incursion of currents. The influence of such preëxisting irregularities is believed to be seen in the coal seams already described, as for instance that at the Vanderberg mine. Now if there be a sufficient cause for the prolonged and gradual subsidence of the area, the ideal conditions for the formation of a coal seam would be present. It must be evident that in the course of such secondary changes in a coal body as has been sketched above there would be, unless sedimentation were active, an area over each coal basin which would become depressed. For a considerable time this area would continue to sink. This action would be very slow and probably long continued. As a rule the strata covering coal seams are shales and are indicative of slow and even deposition. If then a coal basin be formed and coal be deposited in it, that coal in the process of solidification would, provided the general subsidence of the region continued, thus give rise to conditions favorable to formation of a second seam above it. This second or upper seam would repeat to a greater or less extent the irregularities of the first. The inequalities in the thickness of the upper seam would probably not be so great as in the lower seam.

From the above it follows that if in working a coal seam — where the general conditions are the same as in the Iowa field — a marked basin character is found, it is indicative probably of one of two things. Either the coal lies above an unconformity and the irregular character of the coal is the expression of that fact, or it may lie above another coal seam and its irregular distribution may have been conditioned by the equal settling of the lower bed.

How far this may aid in prospecting for coal seams cannot now be said. It must not be forgotten in applying it that there are many beds other than coal which undergo important secondary modifications in thickness. The influence of underground waters in washing out underlying strata and thus producing irregularities in the position of overlying beds may also perhaps need to be taken into account. In at least one instance, however, there is confirmation of the reality of the process sketched above.

In the region around Des Moines there are a number of mines which have at different times worked two seams of coal separated by thirty-five to forty feet of shale. The maps of these mines have usually been very imperfectly kept and levels are only occasionally available. In the Eureka mine the second seam is now being worked. The first is a thin seam which has no value. The third lies about forty feet below the second and has been worked out. In both the second and third seams the basin character is a prominent feature. *It is found in working the second seam that the thicker low-lying coal overlies the areas from which the swamp coal was taken in the third seam.*

The opportunities for thus testing the truth of this theory are, in this field, quite rare since only a very small number of the mines ever work more than one seam.

H. FOSTER BAIN.

IOWA GEOLOGICAL SURVEY,
May 25, 1895.

# PREGLACIAL GRAVELS ON THE QUARTZITE RANGE NEAR BARABOO, WIS.

## WITH SUGGESTIONS AS TO THEIR CORRELATION.

At a number of points on the east bluff of Devil's Lake, and about half a mile from it, at an elevation of 1560 to 1580 feet, A. T., there are traces of gravel differing radically from any other surface formation known in this part of the State. These traces are, in general, very meager, consisting of scattering pebbles only. They may be seen along the crest of the south face of the east bluff for a distance of 80 rods or more, and along the path leading down from the summit of the bluff, in the vicinity of the Devil's Doorway. This path leads over the talus slope of the quartzite range, and the well-rounded pebbles of chert, flint and light-colored quartz are in striking contrast with the purple quartzite blocks over and among which the pathway leads. The pebbles along the path are clearly in secondary positions, having come down from the crest above.

There is a single point, a few rods north of the upper end of he path referred to, where the same sort of gravel may be seen to exist in considerable quantity. The crest of the ridge is here somewhat broad and flat. On its surface a well was dug some years since, and at the site of the excavation, the gravel was found to have a depth of 16 feet, and to rest directly upon the firm surface of the quartzite.

The gravel thrown out in the digging referred to has been subjected to the weathering of many years, but its character does not appear to have been perceptibly modified. It is made up wholly of quartzose material, consisting principally of chert, flint, vein-quartz, and silicified fossils. A glance suffices to show that the larger part of it was derived from limestone formations. In size, the constituents of the gravel range from tiny pebbles to cobbles, three, four, and even five inches in diameter. The pebbles, especially the smaller ones, are for the most part thoroughly well rounded, though there are occasional conspicuous exceptions. For example, a silicified fossil, such as a fragment of an orthoceras, is now and then found, the form of which is almost perfectly preserved, showing that rounding was not in all cases carried to an extreme degree. Many of the larger pebbles or cobbles are less completely smoothed than the smaller ones, but even these are rarely angular. All, or essentially all, show distinct evidence of having been subjected to very considerable wear. On the whole, the constituents of the gravel are as thoroughly rounded and worn as the constituents of any gravel of similar materials which the writer has ever seen.

Another characteristic of the gravel is the extreme smoothness of its pebbles. While the subangular forms are still retained in some cases, the surfaces even of the subangular pebbles are almost uniformly smooth. Not only this, but many of them, have a sort of gloss or polish which is very unusual, and which could only be acquired by pebbles of extreme hardness.

Among the silicified fossils which enter into the gravel as constituent pebbles, there were found representatives of the following groups: orthoceratites, gastropods, brachiopods, crinoids, bryozoa and corals. The following forms are recognizable:[1] *Astrocerium venustum* Hall, *Favosites niagarensis* Hall, *Fenestella* cf. *termiceps* Hall, *Callopora* cf. *elegantula* Hall, *Retepora* sp. indet., *Zaphrentis* cf. *turbinata* Hall, crinoid trochites, gen. indet., *Orthoceras junceum* Hall. Of all the determinable species, five belong to the Niagara of Wisconsin, and one to the Trenton or Galena.

The quartzite surface immediately beneath the bed of gravel was not seen by the writer, but by those who dug the well it is said to be much worn and polished. Its surface also is said to be marked by very notable pot-holes. This statement can readily be believed, since the surface of the quartzite at various points in the vicinity is seen to be so marked. At one point, at the very crest of the south face, a pot-hole was found about

[1] The determinations were kindly made by Dr. E. C. Quereau.

eighteen inches deep, and about eight inches in diameter. When found, this was nearly filled with soil, but on removing the soil and the vegetation which grew in it, there was found at the bottom of the hole a small amount (a pint or so) of gravel, identical with that at the site of the well.

The fact that the surface of the quartzite on which the gravel under discussion rests, is market by pot-holes, suggests that the latter were developed when the former were deposited. The pot-holes have been observed before, and have been ascribed to glacial streams descending from the surface of the ice. But the surface where the observed pot-holes and gravel occur is beyond the reach of the ice of the last glacial epoch, and in this region, the ice of earlier glacial epochs is not known to have reached farther west than that of the last. The drift limit, as well as the ice limit in this region, is of exceptionally clear definition, so that it seems certain that the pot-holes are not *moulins*.

It cannot be supposed that the gravel and the pot-holes are the product of glacial waters operating beyond the edge of the ice, first, because the crest of a high ridge where the gravel and pot-holes are, is not the place where extra-glacial waters would run, and, second, because the gravel itself is radically unlike the glacial gravels of the surrounding country, both in its lithological constitution and in its physical condition. If similar materials enter into the constitution of the glacial drift at all, they do so in very subordinate measure. It is incredible that running water, working upon the glacial drift of the region, could bring out of it chert, silicified fossils, quartz, etc., without the slightest admixture of any of the many other constituents which make up the larger part of the drift of the region. The lithological constitution of the gravel is such as to make it altogether certain that it is not glacial, or aqueo-glacial.

The physical condition of the gravel is hardly less conclusive than its lithological constitution, against its glacial or aqueo-glacial origin. The pebbles are rounded and smoothed to a degree altogether beyond that which characterizes the comparable materials of the stratified drift. When the position, the relation, the constitution and the condition of the gravel are duly considered, there is no escape from the conclusion that it is preglacial.

This preglacial gravel at this elevation and in these surroundings, is surely a striking fact, although it may not now be possible to define its exact significance. It might be thought to be either, first, a remnant of gravel deposited along the course of a former stream, and therefore very local, or, second, a remnant of a formation which was once widespread. Between these two hypotheses it should be possible to decide, if sufficient data are available. While relevant data are less complete than could be desired, they are sufficient to constitute a strong presumption in favor of the latter hypothesis, although the pot-holes, considered by themselves, might seem to point to the opposite conclusion.

It is well known that high-level gravels have a wide distribution in the Mississippi basin south of the limit reached by the ice of the Pleistocene period. Such gravels are well known at various points in the southern part of Illinois, Indiana and Missouri, in Arkansas, Kentucky, Tennessee and in the states further south. Comparable gravels are widespread in the West. In the South these gravels have sometimes passed under the omnibus name Orange Sand. They have sometimes been regarded as of recent (Pleistocene) age,[1] though in late years they have been regarded more commonly as pre-Pleistocene.[2] It is not to be understood that all the gravels within the general area here referred to are of the same age. Reference is here made especially to the high-level gravels, as distinct from those which occupy the lower lands and the valleys. According to our present interpretation, the gravels which are found capping the hill tops and the high-level plains within the general area specified, represent an older (pre-Pleistocene) formation, while

[1] DANA, Manual of Geology, Fourth Edition, p. 964, and UPHAM, American Naturalist 1894, pp. 979–988.

[2] CHAMBERLIN and the writer; Am. Jour. Sci., Vol. XLI., pp. 359–377; 1891. McGEE; The Lafayette formation, Eleventh Annual Report U. S. G. S. CALL; Arkansas Geological Survey, Annual Report for 1889, Vol. II. SMITH; Report on the Geology of the Coastal Plain of Alabama, 1894.

much of the gravel which occupies the lower lands and the valleys of the same general area, represents a younger formation derived from the older. It is also believed that the valleys and lowlands in which the latter class of gravels are found, were developed by subaërial erosion from the plains on which the high-level gravels occur, after the latter were laid down.

The northward extension of these high-level gravels of the south has never been determined. It has long been known that they reached as far north as Pike and Hancock counties, Illinois.[1]

In August, 1891, a paper was read before the Geological Society of America,[2] in which attention was called to the existence of certain isolated and hitherto unknown beds of high-level gravel, lying farther north than most of those previously known, and believed to be their equivalent At that time the gravel had been found at various points as far north as Adams county, Illinois, where it was found to underlie the glacial drift. Where the new finds of gravel were made, in Calhoun, Pike and Adams counties, the beds occur, as in the earlier known localities, on the crests of high hills or ridges, or on high plateaus, positions which clearly indicate that the formation was deposited long before the surface had assumed its present topography. Since the gravel underlies the glacial drift of this region at but a few points, and these the most elevated, and since its materials do not enter into the constitution of the glacial drift in any large quantity, there is no room to doubt the conclusion that the high-level gravel of western and southwestern Illinois had been largely removed by erosion before the glacial drift was deposited. Since the amount of erosion involved is large, affecting not only the gravel but also the underlying indurated strata, and since the overlying drift belongs to the earlier part of the glacial period, there is little room to doubt that the gravel is preglacial, and, therefore, according to the commonly accepted standard of classification, pre-Pleistocene.

[1] Geol. Surv. of Ill., Vol. I., p. 331, 1866; Vol. IV., p. 37, 1870.

[2] SALISBURY; Bulletin of the Geol. Soc. of Am., Vol. III., p. 183, 1892.

The gravel of Adams county is 175 to 200 miles north of the northernmost point where the high-level gravel has any considerable areal development. Within this distance, however, gravel is known at many points. At all these points its constitution, its physical condition, and its geological and topographical relations are such as to leave little room to doubt that the existing beds are to be correlated with each other, and that they are the erosion remnants of a once continuous formation, which extended over southern Illinois, reaching at least as far north as Adams county.

The study of the high-level gravels of adjacent states had at that time (1891) left no room to doubt their correlation with the similar formations of Illinois. It is confidently believed that the gravels on the crest of Crowley's ridge in Arkansas, and its continuation northward into Missouri, are parts of the same formation which once covered the southern portion of Illinois, and considerable parts of Kentucky and Tennessee. To the south, this formation probably extended to the gulf. Its extreme eastward and westward borders, as originally developed, have not been determined, but in both directions the extension was great. In Indiana it is known to have reached as far east as Perry[1] county. The possibility should be recognized that these high-level gravels may not all belong to one formation, although the remnants thus far referred to in Indiana, Illinois, Missouri and Arkansas are so similar in constitution and in all their relationships as to raise a presumption in favor of this view.

At the time of the reading of the paper cited above, the gravel had not been found at any place north of Adams county, Illinois. In spite of this fact, it was believed that the formation once extended further north since its materials, so it was thought, were to be recognized as minor constituents of the glacial drift at various points as far north as Rock Island county. If this identification be correct, it means that at the time of the deposition of the drift in Rock Island county, remnants of this preglacial gravel formation were still in existence as far north as that point. The localities in this county where material

[1] Bull. Geol. Soc., Vol. III., 1892, p. 186.

derived from the pre-Pleistocene chert gravel were thought to enter as constituents into the drift, are 100 to 125 miles north of the northernmost point in Adams county, where the formation is known to occur *in situ*. At many intermediate points, similar materials were found in the glacial drift. Quantitatively they are unimportant, and their absence is more common than their presence. Their occurrence and distribution in the drift are such as would have resulted had erosion remnants of the high-level gravel existed when the ice invaded western Illinois.

In the paper referred to it was stated that certain limited beds and scattered remnants of hitherto unexplained quartzose gravel were known to exist within the driftless area of Wisconsin, and the suggestion was hazarded that these gravel remnants were very likely to be correlated with the gravels further south. The remnants of gravel in Wisconsin occur at various points from Crawford county on the south, to Dunn county on the north. Wherever known, these remnants occur on the crests of ridges and the summits of isolated hills. Not only this, but they are found on the summits of the highest elevations of the region within which they occur. They often consist of nothing more than scattering pebbles, though beds a few feet in thickness are known, the most considerable being near the village of Seneca in Crawford county. The gravel is here composed almost wholly of quartz.[1] As at various points further south, the gravel is here cemented by iron oxide into a firm conglomerate. The average depth does not appear to be more than five or six feet, but it has been penetrated to very much greater depths at one or two points. The exceptional depths are thought to represent the fillings of fissures, which affect the underlying rock.

Had gravel remnants similar to those of the driftless area existed in western Illinois at the time this region was glaciated, they would have contributed to the drift of their respective localities, just such material as it has been observed to contain. They would have made considerable contributions where they were considerable, and meager contributions where they were

[1] STRONG, Geology of Wisconsin, Vol. IV., p. 88.

meager. The facts, (1) that the pre-Pleistocene gravel exists in the form of widely separated erosion remnants south of the drift-covered country; (2) that isolated remnants of it are known to exist at several points beneath the drift, as many as 125 miles north of the southern limit of glaciation (Adams and Hancock counties); (3) that the glacial drift here and there at various points for 90 miles further north (Rock Island county) contains gravel which might well have come from remnants of the northern extension of the same formation; (4) that remnants of similar gravel occur in the driftless area, where there has been no chance of destruction or burial by the ice; and (5) that the gravel in all these situations has the same topographical habit, all point to the conclusion that they are parts of a once wide-spread and continuous gravel formation.

The gravel on the east bluff of the Devil's Lake is about 60 miles east of the gravel of Crawford county. It is about 150 miles northeast of that part of Rock Island county where similar gravel is a local constituent of the glacial drift. The topographic situation of the gravel is the same as that of all the widely distributed remnants further west and south, to which reference has already been made. In its constitution and other physical characteristics, the Devil's Lake bluff gravel is so similar to that of the region farther south (Adams county, Illinois, etc.), that it could hardly fail to recall the southern formation to one who had seen it in southern Illinois, Missouri and Arkansas. The geographic and topographic position of the Devil's Lake gravel, as well as its constitution and physical condition, make it altogether rational to infer that it may have been connected with the isolated beds of similar material already referred to, and that, as originally developed, the formation of which the existing beds are but remnants, had a much greater extension than has heretofore been recognized. If the gravel on the bluff east of Devil's Lake be a remnant of an extensive preglacial gravel formation, it becomes a matter of much importance to fix its age.

Limited occurrences of somewhat similar gravel or ferruginous conglomerate are known in southeastern Minnesota, and have been referred, with some doubt, to the Cretaceous.[1] On the other hand, its relations are so uncertain as to have led to the suggestion that it may represent a remnant of the Oriskany sandstone.[2] It is clear that if its relations to the underlying strata do not preclude its reference either to the Oriskany or to the Cretaceous, they do not preclude its reference to the Tertiary. Since it is overlain by glacial drift only, it would not seem that there is anything in its relations to superior strata to preclude its reference to the Oriskany, the Cretaceous, or the Tertiary. Similar gravel in Fillmore county is unhesitatingly referred to the Cretaceous,[3] because of its association with certain clays containing Cretaceous fossils.

The topographic relations of the gravel and conglomerate of Minnesota here referred to, are the same as those of similar deposits in the driftless area of Wisconsin, and the suggestion is here renewed that they probably go together, and that they are very likely to be correlated with the high-level gravels further south.

Conglomerate which may be found to belong with the gravel and conglomerate of Minnesota, Wisconsin, Illinois, and regions further south, is known to exist at Rockville, Iowa. This was referred to by McGee[4] in 1879, as belonging to the glacial series.

In the Devil's Lake gravel there is nothing, so far as known, to fix its age. It rests unconformably on Algonkian rock, and it is evidently preglacial. It contains silicified fossils, which seem to have been derived chiefly from the Niagara limestone. Internal evidence, therefore, does not prohibit the reference of the gravel to any period between the Niagara and the Pleistocene. If this gravel is to be correlated with the gravels of southern Illinois, it is doubtless late Tertiary. On the other hand, there is no inherent evidence which precludes its reference to the Cre-

[1] Final Report Geol. and Nat. Hist. Surv. of Minn., Vol. I., pp. 305–309.

[2] Loc. cit., pp. 355–6.

[3] Loc. cit., pp. 307–11.

[4] Geological Magazine, Vol. VI, 1879, p. 360–1.

taceous,—the reference which Professor Winchell has suggested for the high-level preglacial gravels of southern Minnesota. Assuming that the Minnesota gravel referred to is Cretaceous, and comparing the Devil's Lake gravel with that of Minnesota alone, this would perhaps seem to be the most natural reference of the Wisconsin beds.

It is not beyond the range of possibility that some of the gravel beds here mentioned are Cretaceous, while others are Tertiary. The gravel beds of Minnesota and Crawford county, Wisconsin, resemble each other much more closely than either resembles the Devil's Lake bluff gravel. The Devil's Lake gravel, on the other hand, is strikingly like that of the areas further south, and on the ground of physical likeness would be classed with it, rather than with the beds of Crawford county, Wisconsin, and of southeastern Minnesota. It is distinctly recognized, however, that physical likeness is not a safe criterion from which to draw important conclusions. Both in Crawford county and at Devil's Lake, the gravel is unaccompanied by the clay and sand beds which are present in Minnesota, and on the basis of which the Cretaceous correlation was suggested. At various points in western and southern Illinois, on the other hand, clay exists immediately beneath the gravel; the same is true in some parts of Missouri. So far as known, no determination of the age of the clay of these regions has been made, nor is it known that the clay and the overlying gravel belong to the same period. So far as association with clay is concerned, the gravel of southeastern Minnesota would seem to belong with the gravel of western Illinois (Pike and Adams counties). Manifestly little weight can be attached to this association, on the basis of present knowledge.

There is some reason for believing that there may be both late Tertiary, and older (possibly Cretaceous) gravel formations south of the Ohio River. The gravel between the Cumberland and the Tennessee Rivers, exposed in the deep railway cut, may represent a formation much older than the gravel of Adams county, Illinois, or of Crowley's ridge, Arkansas. It is not to be looked upon as impossible, therefore, that both Cretaceous and Tertiary gravels may have extended as far north as Wisconsin. If so, it is possible that remnants of both still exist, though until we have positive evidence of two formations, the presumption is in favor of but one.

Whatever the age of the Devil's Lake gravel, its topographic position is full of significance. It occurs on one of the highest points of the state. Within the driftless area, where such gravel as this might have escaped destruction if it ever existed, there is, we believe, but one other point so high as that on which the gravel occurs. This is the Blue Mounds. On the crests of these mounds, corresponding gravel is not known to occur, though they have never been examined, so far as known, with this point in view.

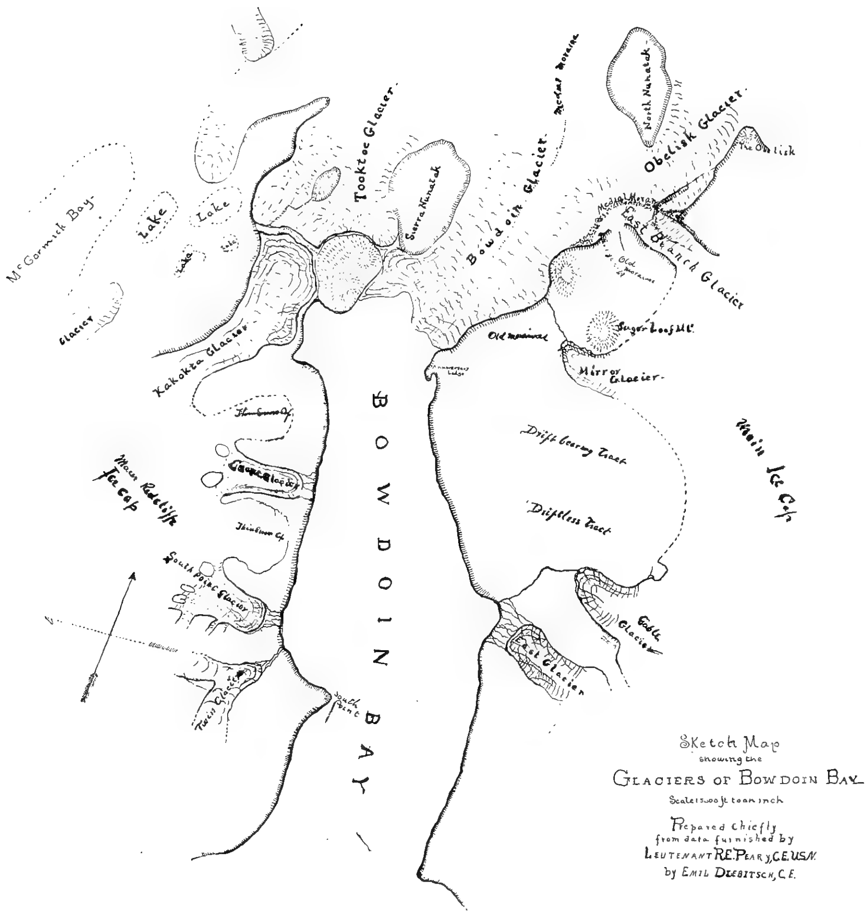
It is clear that the gravel could not have been deposited in its present position, since the existing topography was developed. The ridge on which it occurs is about 700 feet higher than the Barbaoo River to the north, and about 800 feet higher than the Wisconsin River to the south, and, what is still more significant, it is 500 or 600 feet above the general level of the extensive drift-covered sandstone plain which surrounded it. Since the gravel is not glacial, there is but one interpretation possible concerning the topographic conditions and relations at the time it was deposited. At that time the surface on which it occurs was not higher than its surroundings. This fixes the age of the gravel in terms of erosion. It was deposited before the quartzite ridge was isolated, that is while the Potsdam and later formations still reached the top of the harder quartzite.

The amount of erosion which has been accomplished since the gravel was deposited is, therefore, very great. It should be noted that this erosion is not measured simply by the excavation of valleys on either hand to the depth of 700 and 800 feet respectively. Since the gravel was deposited, the general surface of the surrounding country has been cut down to the extent of 500 to 700 feet, disregarding the heavy drift deposits which have helped to build it up again. This building up process was considerable, for there can be no question but that in this region glacial deposition greatly exceeded glacial erosion. The quartzite range is not simply an inter-stream ridge; it is an elongate monadnock standing up out of a very extensive peneplain. The amount of erosion necessary to isolate it was much greater, and demanded a very much longer period of time than would have been necessary simply to cut valleys 700 or 800 feet deep. Looked at from this standpoint, one is inclined to think that the age of the gravel may be as great as Cretaceous. On the other hand the total amount of erosion which has taken place in the upper Mississippi basin since the deposition of the gravel is but a fraction of that which is believed to have taken place in some parts of the west in late Tertiary and post-Tertiary time.

Although the topographic relations of the gravel do not enable us to fix its age in the accepted terms of geological chronology, they seem to bring out the general fact that the present physical features of the upper Mississippi basin are of later origin than has been generally supposed. This is especially true if the gravel shall prove to be Tertiary, and the balance of evidence seems at present to favor this interpretation.

There is still another direction in which the gravel bed at Devil's Lake is of interest. The fossil content of the gravel, as well as the greater quantity of chert, indicates that it was derived in considerable part from the Niagara limestone. It has long been believed that the Niagara limestone of Wisconsin, now confined principally to the eastern margin of the state, once extended much farther west, over regions whence it has been removed. The constitution of the gravel affords an interesting confirmation of this belief, and seems to indicate that the Niagara may have had even a greater extent than has been supposed, for it can hardly be doubted that, when the gravel was formed, the limestone either overlay the quartzite, or existed at some equally high point in the immediate vicinity. Not only this, but the presence of one fossil, *orthoceras junceum*, which, so far as known, can be referred only to the Trenton or Galena, suggests that one or both of these formations also once passed over the quartzite ridge, or at least that they were once at equally high points in the immediate vicinity. If these formations once covered the quartzite and were overlain by the Hudson River shale, the Niagara limestone, which, in Wisconsin, immediately succeeds the Hudson River shale, must have originally lain very high above the crest of the quartzite range. If the Trenton lay upon the quartzite directly, and if it and the succeeding Galena and Hudson River formations had their usual thickness, the base of the Niagara could hardly have been less than 500 feet above the the top of the east bluff at Devil's Lake. If the St. Peters sandstone and the lower Magnesian limestone overlay the quartzite beneath the Trenton, the base of the Niagara must have been still higher.

R. D. SALISBURY.




Sketch Map showing the Glaciers of Bowdoin Bay.

# GLACIAL STUDIES IN GREENLAND. VII.

THE REDCLIFF PENINSULA.—*Continued.*

*Glaciers on the East Side of Redcliff Peninsula.*—The Fan and Bryant glaciers that have been previously described represent the group of ice tongues which protrude from the *mer de glace* of Redcliff peninsula on the south. A group of similar tongues push out toward Bowdoin Bay on the east, and two of these will now be described, the South Point glacier and the Gnome glacier. The general aspect of the east side of Redcliff peninsula is shown by the accompanying photographic illustrations. Together the two illustrations form a panoramic view. The point of observation is the border of the main ice-cap on the east side of Bowdoin Bay. The foreground is the edge of the plateau on which the main ice-cap lies. The depression that traverses the middle of the view is the valley occupied by Bowdoin Bay. The flat snow field beyond and the nearly level sky line show how truly the peninsula is a plateau and how far the glacial phenomena are different in general aspect from the Alpine type. At the extreme south lies the Twin glacier. Just north of it, but scarcely shown in the view, is the South Point glacier. At the left of the lower view lies the Gnome glacer. At the right hand of the lower figure the plateau may be seen to fall away to the low neck that connects it with the mainland. The geographic relations of these features may be seen by reference to the accompanying map of Bowdoin Bay and vicinity.

*South Point Glacier.*—This is a lobe of the peninsular ice-cap occupying a short valley notched in the edge of the plateau. Its width was estimated at one mile and its length at two. It descends from the plateau rather abruptly, as is the fashion of the valleys of the region. The ice as it makes its descent to the valley is interrupted by three islands around which it flows and from which it carries away medial moraines. These moraines,

FIG. 43. General view of the south portion of the Redcliff peninsula, showing its snow-cap and the location of Twin and South Point glaciers. The point of view is the edge of the main ice-cap east of Bowdoin Bay, and the direction of view south-west. The immediate foreground is the wind-drift border of the main ice-cap which had been freshened and extended by a recent snow-fall. The main foreground is the edge of the plateau which extends backwards under the main ice-cap. The depression in the middle of the view is the valley occupied by Bowdoin Bay. Beyond lies the Redcliff peninsula. The Twin glacier occupies the valley at the left. The South Point glacier occupies a valley that begins a little to the right of the center of the view and extends towards the left, emerging at a point a little to the right of the Twin glacier where a small part of the glacier is seen. The horizontality of the summit plane is worthy of special note.

FIG. 44. General view of the north portion of the Redcliff peninsula, showing its snow-cap and the location of the Gnome glacier. Point of view the same as in Fig. 43, of which it is the complement. At the right the surface descends abruptly to the low ground that connects the peninsula with the mainland.

however, curve outwards to the sides of the valley before they reach the end of the glacier. At least one lateral glacier joins the main one on the south, bringing in an additional moraine, but this is also carried to the side of the glacier before advancing far down the valley. On the south side also there is an interesting "hanging" glacier descending very steeply from the summit of the plateau. This may be seen in Fig. 45. This

FIG. 45. View of the extremity of South Point glacier from a point on the north side of the valley looking southwesterly. The point of the glacier at the left is near the center of the valley, and a face similar to that turned toward the observer is presented beyond this point looking southeast. The dark band at the bottom is the talus slope and the bowldery layer of the glacier. The rather sudden change in the upper surface slope of the glacier is probably due to a terrace of rock extending across the valley and appearing at the edge of the glacier at the right. By a little care it will be seen that the bedding lines on the face of the glacier are continuous with those on the upper surface. The little steeply-descending glacier on the face of the snow-capped plateau in the background is the "hanging" glacier referred to in the text.

little glacier, however, is wasted and stayed at the foot of the steep slope before it is able to join the larger glacier. The measurements of its slope indicate that it reaches an inclination of twenty to thirty degrees in its steeper parts, but, singularly enough, it was not greatly crevassed, not even where it bent over the brow of the plateau.

South Point glacier stops short of Bowdoin Bay by perhaps half a mile. The interval is occupied by gravelly and bowldery wash forming a sloping plain. On this the end of the glacier rests, except at the north edge, where it descends a rock terrace. There is a notable dropping down of the upper surface not far back from the end of the glacier, and this stretches well across

FIG. 46. Portion of the front wall of South Point glacier near the center of valley, seen looking southwesterly. The upper portion is nearly pure ice, but shows the stratification well. The dark ice at the upper edge of the talus slope is the bowldery layer mentioned in the text. The material of the talus is chiefly derived from this. The blocks of ice on and at the foot of the talus slope are masses detached from the glacier.

the valley, as seen in Fig. 45. It suggests that this rock terrace extends far out under the ice in the bottom of the valley. Owing to this or some other cause the glacier's upper profile is less symmetrical than those of the Bryant and Fan glaciers.

The most interesting feature of the glacier is its frontal edge. The view shown in Fig. 45 partially illustrates its character. It was taken from the northeast, looking obliquely across the axis of the glacier. A view from the southeast would show a very similar face and the two combined would make up the extended terminal curve of the ice lobe. Fig. 46 is a nearer view in the middle of the valley, and Fig. 47 is a still nearer one on the

FIG. 47. Portion of front wall of South Point glacier near center of valley, seen looking northwesterly. The dark shading brings out prominently the stratification of the upper part, which is obscure in most of the views presented, because of the light color of all parts. The dark layer at the base and the talus slope are continuous with those of the preceding figure.

southeast face, looking in the reversed or northerly direction. These views, particularly Fig. 47, show the pronounced stratification of the glacier, the presence of débris between the layers, the development of a vertical and even overhanging face, and the formation of a notable talus slope in front. The stratification is much the same as that of the Bryant glacier, but more regular and pronounced in the upper portion where the débris is slight. It is worthy of note that these lines of stratification appear upon the upper surface also and may be traced consecutively from this surface to the vertical face, as illustrated in Fig. 45. The lines which represent the outcropping of the layers on the surface form sweeping curves more or less concentric with the frontal edge of the glacier. By differential melting of these layers little steps or terraces are formed, which sometimes become somewhat pronounced. This phenomenon was observed on other glaciers.

As in the preceding glaciers—indeed in all the glaciers of Greenland that were seen—the upper part was found essentially free from débris, while the basal part was well inset with rock rubbish of various kinds. Along almost the whole face there was a layer twelve or fifteen feet thick at the upper edge of the talus slope that was so thickly inset as to be almost black with débris (Fig. 46). A part of this blackness, however, is attributable to the illusive effects of the surface wash. Much of the débris of this layer was coarse. Large bowlders were abundant, but all grades were present down to fine clay. When freed by melting it constituted a very coarse, stony till. Many of the fragments were rubbed, bruised, scratched or polished in typical glacial fashion. The assemblage of rock species was unusually interesting, embracing gneissic and igneous rocks and the gray and red sandstones. The walls of the valley and doubtless its bed were formed of the gneissic series into which had been intruded igneous dikes. Among these were some of a markedly green rock of diabasic aspect that was capable of receiving and exhibiting glacial markings with unusual facility. The sandstone series capped the plateau and formed the nunatakes at the head of the valley in the main. The distribution of the formations seemed to favor the view that the débris of the very bowldery layer above described was introduced at the cataract at the head of the valley.

The melting out of the débris of this bowldery layer at the frontal edge of the glacier was the chief cause of the formation of the pronounced talus slope shown best in Fig. 46. Its height varied from thirty or forty feet downwards. It gave the glacier the appearance of resting on a pedestal. This appearance was, I think, with little doubt representative of the real fact in part, but it was also certainly true that the ice extended below the upper edge of the talus slope. The true bottom of the glacier was below its apparent bottom. I succeeded at points in tracing the ice under the talus at least half way down the slope. where the ice was uncovered under the talus its layers were curved upward at high angles, due I suppose to the relief of pressure above and to the resistance of the talus in front (Fig. 48). The concealed ice was less thickly set with débris than

FIG. 48—Diagram intended to illustrate the probable curvature of the layers of ice under the talus in front of the glacier.

the layer above. If there were no other instances than this it might be questioned whether the pedestals on which so many of these northern glaciers seemed to rest were not illusions induced by misinterpretations of slopes of superficial talus derived from special débris-burdened layers of ice that happen to come out at some distance above the true glacial base, but the platforms of débris left by the retreats of some of the glaciers seem to show that there were true pedestals in some cases at least.

Inspection of the face of the glacier, as shown in Fig. 47, shows that certain of the layers of ice jut out over others very sharply. This was found to be a very common phenomenon, not only here but in most of the glaciers of the region. It gave the impression, at first sight, that the upper layers had been thrust forward over the lower ones. If this were the true interpretation, it would be a matter of radical value for it would indicate a mode of motion that has not, I believe, been recognized as a function of glaciers. It became, therefore, in the highest degree important to ascertain whether such was the real nature of the phenomena, or whether the impression was an illusive one. It was very obvious from an inspection of the face of the glacier than wherever débris was embedded in it the radiant energy of the sun was caught and converted into sensible heat and melting was thereby promoted and so the darkened portions of the ice became sunken. From this obvious and very general fact, the suggestion arose that the overjutting layers were due to differential melting faciliated by the débris in the under layer. Observation showed that in most cases the under layer was darkened with débris and that it was therefore disposed to melt more rapidly than the overjutting layer which was usually white and free from débris. There was further evidence of like import in the fact that in some cases—indeed in many cases—the overjutting cornice when traced right and left was found to disappear simultaneously with the disappearance of the débris in the under layer. It cannot be supposed that there would be differential motion that would correspond accurately with the débris in the layers, although there might be a genetic connection between the formation of the layers and the introduction of the débris. Furthermore, in some instances the overjutting portion was too restricted in length and too sharply limited to accord with the hypothesis of differential motion. On the other hand, when it was found that the overjutting layers extended for long distances and that the projection reached two or three feet, and in some cases eight or ten or even fifteen feet, the hypothesis that the phenomenon was due simply to the superior melting of the underlayer seemed unsatisfactory if not untenable.

It occurred to me that if the upper layer moved over the lower layer, rock fragments at the junction of the two layers would give rise to fluting of the under surface of the upper layer as it was forced over it, and that perhaps evidence might be found along this line which would demonstrate the supposed mode of motion. I found upon the south side of the South Point glacier a very pronounced case of overjutting reaching an extent of two to three feet in which the junction plane between the upper and lower layers was corrugated and was marked by a thin line of earthy and rocky material. The corrugations were not unlike those of the zinc facing of a washboard, except that they were on a much larger scale. I not only found that the débris layer was corrugated, but that for some inches below there were blue laminations of clean ice that were corrugated harmoniously with it. I succeeded in following these backward into the ice sufficiently to show that they were not simply superficial. Presumably they extended some distance along the junction plane. This phenomenon, it will be observed, is not precisely

FIG. 49.—Diagram illustrating the phenomena of faulting and drag as seen on the south side of the South Point glacier.

that suggested above, but it has a bearing upon the interpretation of the fluted under surfaces of overjutting layers that were observed in very pronounced development in some of the glaciers yet to be described.

An observation was made on the south side of the glacier that bears upon the same question. On each side of a fracture plane extending obliquely across the ice layers, the laminations were bent toward the plane just as they are in the phenomena of faulting and drag (Fig. 49). There seemed no ground for doubt that there had been motion along the plane of fracture and that the ends of the laminations next to it had been bent backwards by the friction of the two faces. Similar phenomena were observed in several other places.

At another point upon the south side of the glacier there was a wide band of débris-set ice that zigzagged in a very irregular way from the summit of the ice cliff to its base. Fig. 50 is a representation of a sketch made upon the ground. The point at which this appeared was near the extremity of one of the medial moraines, and it seemed probable that this dark zigzag tract represented the junction of the two parts of the glacier that had united on the lower side of one of the nunataks before described; in other words the two glaciers, instead of fusing, flowed side by side, crowding upon each other mutually and developing this zigzag line of junction. In addition to this very notable and unusual distortion, and in addition to the faulting and drag there were, at not a few points, twisted and contorted laminations indicating varying stresses and differential rates of motion.

FIG. 50.—Sketch intended to illustrate the remarkable zigzag course of a dark layer thickly set with pebbles and bowlders on the south side of the South Point glacier. The upper line of the sketch represents the upper edge of the wall of the glacier and the bottom its base.

On the south side of the glacier a stratum was observed thickly set with bowlders in very much the same manner as the stratum that formed the talus in front. The aneroid indicated that this was about 400 feet higher than the débris layer in front. Its distance back from the front unfortunately was not measured, nor was it traced continuously along the side and shown to be identical with the layer in front, but there seemed little ground to doubt that it was the same, and if so, it is worthy of note as indicating the rapid descent of the débris-bearing layer harmoniously with the descent of the entire glacier. The upper edge of the glacier was measured at a point not far above this and found to be about 550 feet above the base in front.

In respect to the interesting question of recent change in the extent of the ice, the evidence of the South Point glacier seemed very clear so far as it went. It has been remarked that between the glacier and the bay the valley was occupied by glacial wash. In the middle and northern half of the valley this was recent, but in the southern portion there was a terrace elevated from ten feet upwards that was much older. It was very notably weathered and covered with vegetation in the scanty fashion of the region. In particular the bowlders were covered with lichens and were roughened and exfoliated by weathering in a way that indicated considerable antiquity. While comparisons with southern latitudes are liable to error because of the different climatic conditions, it may give some impression of the evidence of aging in the present case to compare these weathered and lichen-covered bowlders with the ruins of mediæval ages. Very possibly, however, they may not exceed a century in age, or even reach that. This older terrace extended to within 100 feet of the present edge of the ice, indeed, at the southeastern curve of the glacier where it turned away from the side of the valley, there was little more than room for the talus slope and the lateral drainage stream between the ice and the old valley débris. In harmony with this evidence, the talus slope of the valley cliffs on the south side, for the most part, was ancient, although somewhat disturbed and freshened at some points near the ice. It would appear, therefore, clear that the glacier has not, within recent times, advanced notably beyond its present position. It may, of course, have been advancing from some point of greater retreat, and may be even now advancing. The sharpness of the talus slope and the fact that it is no greater than it is, is best explained by supposing that the glacier is advancing with exceeding slowness upon the débris which is gradually accumulating at its front.

*The Gnome Glacier.* This is a smaller glacier occupying a narrower valley. It is only about 1800 feet wide, measured at a point above the terminal slope, according to Lieutenant Peary. It is closely beset with walls of gneiss on either hand, but judging from the erratics which it carries it reaches back to the sandstone series. Red sandstone covers the cliff on the north. The plateau on either side of the valley in which the Gnome glacier lies is capped with a thin stratum of ice, which, at some points, creeps out to the edge of the plateau, from which it falls in broken masses or extends itself downward in little hanging glaciers. On the south side the edge of the Gnome glacier is quite extensively covered with fallen ice and débris from this source. The foot of the talus slope of the cliff on the north side is in close contact with the border of the glacier and indeed, in portions, has been carried away by it.

The Gnome glacier stops short of Bowdoin Bay by only a few rods, its terminal base lying but little above the sea level.

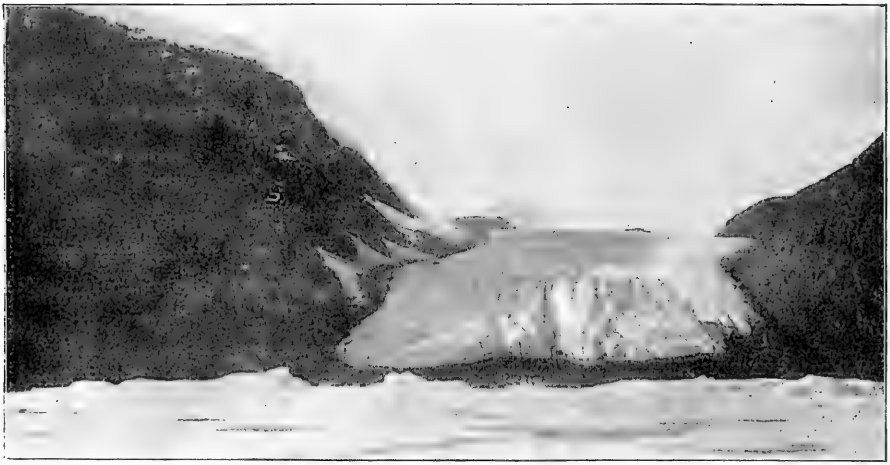


FIG. 51.—The Gnome glacier, seen from the ice of Bowdoin Bay. The dark layer at the base of the glacier and the talus slope are not distinguishable from the surrounding surface. Nunataks are partially shown at the head of the valley where the ice descends from the plateau. The steep border of the ice about them makes them appear as depressions.

It has an abrupt terminal face much like that of the South Point glacier. The upper portion consists of a thick stratum of nearly pure ice, showing indistinct lamination, the middle portion, of alternating dark and light ice, while the lowest exposed portion consists of a dark layer thickly inset with bowlders similar to the dark bowldery layer of the preceding glacier. Below this there is a similar talus slope but of greater height. The day of our visit was sunny and exceptionally warm, and the bowlders were being loosened from the dark stratum of ice and were falling at short intervals, rendering the ascent of the talus slope imprudent, and its height was therefore not measured. This was by far the most notable exhibition of activity seen in connection with any of the northern glaciers that end upon the land. In no other case during our visit was the loosening and falling of débris more than a rare event. The material contained in this bowldery stratum is in part very coarse, masses of rock several feet in diameter being not uncommon. As in the case of the South Point glacier, the talus slope here conceals the base of the glacier, and it was not ascertained how much of the talus slope represented a subglacial accumulation and how much merely a superficial concealment of the glacier's base. It was observed here, as in the preceding case, that the lamination of the ice under the talus slope stood at high angles, and had its strike approximately parallel to the face of the glacier, and this seems to be the prevalent fact in similar cases.

The laminæ of the ice are frequently twisted and distorted, and horizons of faulting and overthrust appear to be common, but they were inaccessible to close observation. The outjutting layers sometimes project two or three feet beyond those below. It would seem from the unconformity of the bent and crumpled layers that shearing action had taken place.

There are no abandoned moraines on the front or sides of the glacier. The sides of the valley showed some freshening and disrupting above the present edge of the ice, indicating that it had recently stood somewhat higher, but beyond this there was no evidence of any recent difference in extension. Beyond the exceptionally rapid melting of the face at the time of our visit there were but limited signs of activity.

T. C. CHAMBERLIN.

# THE CLASSIFICATION OF THE UPPER PALÆOZOIC ROCKS OF CENTRAL KANSAS.[1]

CONTENTS.



## INTRODUCTION.

Recent studies of the geology of eastern central Kansas, in connection with the preparation of geologic maps of that region

[1] Published by permission of the Director of the United States Geological Survey.

for the United States Geological Survey, have acquainted the writer with interesting facts in reference to the description and classification of the Upper Palæozoic rocks of Kansas.

The early geologists of the state, Hawn, Swallow, Meek and Hayden engaged in a spirited controversy, not only in regard to the correlation of the geological formations of this part of the state, but also as to whom belonged the honor of first announcing the discovery of the Permian rocks in Kansas. Major Hawn stated that his first impression that the rocks in question might be of Permian age was obtained from a letter written by Mr. Meek, September 3, 1857.[1] On January 19, 1858, at the request of Meek and Hayden, a record was made at the Smithsonian Institution in which is mentioned "forms indicating Permian both in Kansas and the region of the Black Hills."[2] In determining the date of the first scientific publication of the discovery of Permian fossils in Kansas neither of these records should be considered. The first public announcement before a scientific society of the identification of Permian fossils in Kansas was made by Professor G. C. Swallow in a letter read by Professor B. F. Shumard before the St. Louis Academy of Science, on February 22, 1858.[3]

[1] Am. Jour. Sci., 2d series, Vol. XXVI., p. 188; *ibid.*, Vol. XLIV., p. 38. Trans. Acad. Sci. St. Louis, Vol. II., p. 511.

[2] Am. Jour. Sci., 2d series, Vol. XLIV., 1867, pp. 38, 39. See *ibid.*, Vol. XXVI., 1858, p. 188, and Trans. Acad. Sci. St. Louis, Vol. II., p. 511.

[3] See Trans. Acad. Sci. St. Louis, Vol. I., pp. 111, 112. The letter, which was dated February 18, contains the identification of several species collected by Major Hawn. Professor Swallow states: "I can have no doubt that the rocks are Permian, since the proof is very conclusive to my mind. . . . . All of the described fossils, with perhaps two exceptions, are identical with Permian species of Russia and England, while all of the new species appear to be more nearly allied to Permian forms than to any other." At the same meeting a portion of a paper by Professor Swallow and Major Hawn was read, entitled "The Rocks of Kansas, with descriptions of new fossils from the Permian formation in Kansas territory." The reading of this paper was concluded at the following meeting on March 8 (Trans. Acad. Sci. St. Louis, Vol. I., pp. 112, 113; and pp. 173–197). An abstract of the paper was read at the Baltimore meeting of the American Association for the Advancement of Science, May, 1858, and appeared in the Am. Journal of Science, November, 1858 (2d series, Vol. XXVI., pp. 182–188). Also published in Proc. Am. Assoc. Adv. Science, Vol. XII., 1859, pp.

Apparently the first published announcement of the Permian age of the Kansas fossils was a letter from Professor G. C. Swallow to Professor J. D. Dana, dated February 16, 1858, and printed in the March number of the *American Journal of Science and Arts*[1] Swallow mentioned some ten European Permian species; these or closely allied species he had identified in Major Hawn's collection and he stated "I can but feel that the above is sufficient to justify us in the decision that they are *Permian.*"

On March 2d, Professor James Hall read a paper by Meek and Hayden before the Albany Institute, describing a small collection of fossils "from near the mouth of the Smoky Hill fork of the Kansas River" concerning which is the statement: "We think there is scarcely room to doubt that it [the formation] is of Permian age."[2] A letter from Meek and Hayden making brief mention of the discovery was read the same day before the Philadelphia Academy of Natural Sciences.[3]

After reviewing the various statements referring to the discovery of Permian rocks and fossils in Kansas, it appears that to Professor Swallow belongs the credit of first announcing the fact before a scientific society and publishing a notice of the discovery in the leading scientific periodical of the country.[4]

214–221, where Professor Swallow says, "The Coal-measures occupy a belt along the eastern end of the territory, extending westward as far as Fort Riley. West of the Coal-measures the Permian strata are developed over a wide zone stretching across the territory from north to south" (p. 220).

[1] 2d series, Vol. XXV., p. 305*.

[2] Trans. Albany Inst., Vol. IV., p. 76. The paper is entitled "Descriptions of new organic remains from northeastern Kansas indicating the existence of Permian rocks in that territory," pp. 73–89. This paper was noticed in the May number of the Am. Jour. Sci. (2d series, Vol. XXV., p. 442).

[3] Proc. Acad. Nat. Sci., Philadelphia, Vol. X., pp. 9, 10.

[4] Professor Hayden stated that extras of the Albany Institute paper were distributed two days after it was read, so that the paper "was actually published on the 4th of March;" but he seems to have been in error in stating that the March number of the American Journal of Science, which contained Professor Swallow's letter, was issued "between the 4th and 10th of March" (Am. Jour. Science, 2d series, Vol. XLIV., 1867, p. 38, f. n.).

The Proceedings of the Albany Institute for March 2, 1858, following the remarks

TOPOGRAPHY.

The region under consideration is a belt of country varying in breadth from fifty to seventy-five miles, extending across the state from south to north in an approximate northerly direction. Topographically, it is a region with high hills which generally have rounded slopes capped by escarpments of massive limestone and flint. The valleys are narrow, and the landscape as a whole presents an appearance quite at variance with the preconceived idea of the plains of Kansas. As my knowledge of the country increases, I am led to see the resemblance that it bears, in miniature, to the Colorado plateau of the west [Utah and Arizona]. Its topographic features appear to be similar to the Ozark uplift of southern Missouri which has been well described by Nason as follows: "While at the base of these steep-sided hills we cannot escape the feeling that we are among mountains. A climb up the slope dispels the idea however. Instead of a commanding view from the summit of the divide we look forth upon what in the distance appears to be a plain stretching away on every hand. The mountain crests rise to the same level as far as the eye can reach."[1]

This elevated tract of land known as the "Flint Hills" crosses the southern boundary of the state on the line of Cowley and Chautauqua counties and then extends in a northerly direction with a breadth varying from twenty-five to forty miles. A view from the summit of the divides reveals an extensive plateau in which the streams have eroded many small valleys, leaving numerous mesas and other interesting topographic features due to the alternation of layers of flint and massive limestones with shales and shaly limestones. Along the valleys of the rivers and

of Professor Hall upon Mr. Meek's paper, contain the following statement: "Mr. Gavit called attention to the fact that, in the last number of Silliman's Journal, Professor Swallow makes a similar announcement as to the identity of certain fossils of Nebraska with those recognized as Permian" (Trans. Albany Inst., Vol. IV., p. 248). Finally, Professor James D. Dana wrote me: "I have no doubt that the number for March, 1858, was out and off by the 1st [of March] if not before" (Letter of March 28, 1895).

[1] Geol. Surv. Missouri, Vol. II., 1892, p. 86.

larger streams and extending well up toward the heads of their branches are numerous trees; but on the upland of the plateau nothing appears save the native prairie grass. At numerous points are extensive views of most interesting landscapes which are especially beautiful when clothed with the bright green grass of early summer.[1]

As the summer advances the grass is frequently turned brown by the hot, dry weather so that during August and September the ground is parched and barren, and it is not at all strange that the early explorers of Kansas described the region as a "desert." Professor Broadhead has called attention to some of the interesting topographic features of this region and has suggested that it "might appropriately be termed the Permian Mountains."[2] In a recent paper Professor Haworth has admirably described the topographic features of eastern Kansas, and concisely stated that its terraced topography is due to "a condition which seems dependent principally upon the more or less regular occurrence of alternating heavy beds of soft shales with light beds of harder limestones and sandstones."[3] The professor also speaks of the beauty of the scenery[4] along the Kansas River and the "magnificent bluffs"[5] which line the upper part of its valley.

[1] Among other places the writer would especially mention Blue Mount at Manhattan, looking up the canyon of the Kansas River, which presents a scene of surpassing beauty. Fine views may also be obtained at various places on the southern side of the Kansas River between Manhattan and Junction City; at numerous places in Wabaunsee county south of Alma and southeast toward Eskridge; in Chase county southwest of Cottonwood Falls, on the southeastern side of Cottonwood River, and in the southern part of the state in the eastern portion of Cowley and western portion of Chautauqua county.

[2] Trans. St. Louis Acad. Science, Vol. IV., Pt. III., 1883 (?), p. 484. Again, on page 491, occurs this statement: "The group of the Permian Mountains forms an interesting study, the strata are easily traced, and the scenery afforded is very fine and the views very extensive." An abstract of this paper was published in the Am. Jour. Science, 3d series, Vol. XXII., 1881, pp. 55–57, and the above quotations appear on pp. 55 and 57 respectively.

[3] Kansas Univ. Quarterly, Vol. II., 1894, p. 134.

[4] *Ibid.*, p. 131.

[5] *Ibid.*, p. 134.

*Principal rivers.*—Two river systems have cut approximately east and west valleys through this plateau, nearly at right angles to the trend of its flint ridges. The Smoky Hill and Kansas Rivers have cut the valley in the northern part of this range, while the Cottonwood River has eroded a similar valley through its central part. The great value of these two valleys in determining the character and stratigraphic relations of the geologic formations composing the upper Palæozoic and lower Mesozoic rocks of Kansas was early appreciated, consequently these two great sections are classics in the literature of the Permian and Permo-Carboniferous rocks of Kansas. In a recent article the writer has discussed the geology of the Kansas River section, particularly from Manhattan to Junction City; identified and correlated as far as possible the various beds of that section as described by Meek and Hayden, Swallow, and Hay, and given lists of fossils which characterize the various divisions of the section.[1] The present paper proposes to consider in a similar manner the classic section of the Cottonwood Valley and in addition, to define briefly the formations into which the writer has divided the upper Palæozoic rocks of Kansas.

*The Cottonwood River valley.*—About seven miles below the city of Emporia, the Cottonwood River enters the Neosho and reaches the Arkansas River near Fort Gibson in the Indian Territory; consequently the Cottonwood River forms a part of the great drainage system of the Arkansas. For more than twenty miles from its mouth, to a point near Ellinor, the Cottonwood River flows through a broad, fertile valley with low hills in the distance. But above Ellinor it rapidly narrows, except where tributary streams enter it, to a valley one or two miles in width, lined on both sides with steep hills which are generally capped by a prominent escarpment of massive limestone or flint. This type of valley continues westerly as far as the junction of the South Cottonwood River with the Cottonwood, two miles west of Marion; and for some forty miles along the main line of the

[1] Kansas River section of the Permo-Carboniferous and Permian Rocks of Kansas, Bull. Geol. Soc. America, Vol. VI., pp. 29–54.

Atchison, Topeka & Santa Fé Railroad from Ellinor to a point near Peabody. The bluffs on the southern side of the river are generally higher and more continuous than those on the northern side. This is well shown in the bluff extending from the vicinity of Cottonwood Falls southwest to Florence, where for a distance of twenty-three miles there are but two decided breaks, one of which occurs at Clements formed by Coyne Branch, and the other at Cedar Point where Cedar Creek enters the Cottonwood. From the northern side of the valley different prominent strata of limestone are seen forming terraces near the summit of the bluff. This is especially noticeable along the bluff from Cedar Point to the summit opposite Florence. A similar bluff, but higher and steeper, extends for twenty miles along the south side of the Kansas River, from Manhattan to Junction City, broken only by the two valleys formed by McDowell and Clark Creeks. As far as my observation goes, the southern bank of many of the streams in this part of Kansas is steeper than the northern, and Professor Haworth tells me that such a statement applies in a general way to all the rivers of Kansas.

## DESCRIPTION OF THE GEOLOGICAL FORMATIONS.—THE WABAUNSEE FORMATION.

In the classification of the rocks into formations, primarily for use in areal geology, it has been the general intention to include in a formation a series of strata, which may be characterized by their fossils and which have similar lithologic characters.

In the lower valley of the Cottonwood, as well as along the adjacent portion of the Neosho, are several rather massive beds of limestone between which are calcareous, argillaceous and arenaceous shales with an occasional thin stratum of coal. The limestones of this formation cap the low bluffs along the river valley to Ellinor, where a higher limestone, known as the Cottonwood, appears near the top of the bluff, which, dipping westerly, is carried nearly down to the level of the river about one and one-half miles west of Strong City; then begins to rise again until it reaches the top of the high bluff 200 feet above the river at Elmdale. As a result of this folding the Wabaunsee formation extends thirteen miles farther up the Cottonwood River to the vicinity of Clements.

This series of limestones and shales is well exposed along the Neosho River below and above Emporia, and especially to the north, in the eastern and northern portions of Wabaunsee county. There are excellent outcrops in the bluffs along Allen, One Hundren and Forty-Two Mile, and Elm Creeks in the northern part of Lyon county; on Elk, Dragoon and Mission Creeks in southern and eastern Wabaunsee county, and particularly on Mill Creek in the northern part of the county; and on the bluffs of the Kansas River from Wabaunsee to the vicinity of Ogden in Riley county. I have considered the base of this formation as defined by the top of the Osage coal horizon,[1] and the top by the base of the massive limestone known locally as the Cottonwood, Alma and Manhattan limestones. Mr. Charles R. Keyes has proposed the name Missouri formation for the upper Coal Measures of Iowa and Missouri,[2] but did not clearly indicate the upper limit of the formation. The deposits forming the upper coal measures of Kansas are principally of the same age as those in northwestern Missouri, and, if we consider the Osage and Silver Lake coal horizon as the upper limit of the Missouri formation in Kansas, then the Wabaunsee formation will directly succeed the Missouri formation. The formation covers one-half of Wabaunsee county and,

[1] This is near the line of division between the upper Carboniferous and Coal Measures of Professor Mudge. The Professor states that the dividing line between these formations "is not clearly defined or easily fixed . . . . . Plants and coal are the best evidences, and even these are not strongly marked" (First Bien. Rept. [Kans.] State Board Agri., p. 71, and see p. 86 for place of the Osage coal). Professor Mudge, however, did not understand the northern and southern extent of this horizon, as was shown later by Professor St. John (Third Bien. Rept. [Kans.] State Board Agri., p. 585) and Hay (Eight *ibid.*, p. 132). Finally Professor Haworth has shown that on the Kansas River the Silver Lake Coal, 125 feet above the Topeka, is the equivalent of the Osage Coal (Kan. Univ. Quart., Vol. III., pp. 304, 305 and Plate XX).

[2] Iowa Geol. Surv., Vol. I, 1893, p. 114. *Ibid.*, Vol. II, 1894, Plate III, and p. 137. Missouri Geol. Surv., Vol. IV, Pal. Mo., Pt. I, 1894, p. 82.

on account of the excellent exposures along nearly every stream in the eastern and northern portions of the county, I would propose that it be called the *Wabaunsee formation.*

*Early geologic explorations.*—The rocks of this formation along the Kansas River, especially from Mill Creek westward, were carefully examined by Meek and Hayden in the summer of 1858, and a paper describing the geology of the region traversed appeared the following January.[1] During the same summer Dr. Newberry studied this series of rocks as exposed along the Santa Fé road, on his return from the Ives exploring expedition of the Colorado River of the West, from Santa Fé to Fort Leavenworth, crossing the Neosho River at Council Grove.[2]

In the summer of 1859 Dr. Newberry again crossed the same formations as exposed along the route from Independence, Mo., to Santa Fé on his way to join the Macomb exploring expedition and described to some extent the rocks and fossils found along Dragoon Creek and on the high ground to the west.[3]

*Palæontology.*—The calcareous and argillaceous shales frequently contain numerous specimens of fossils representing a

[1] Proc. Acad. Nat. Science, Philadelphia, Vol. XI., p. 8; see particularly pp. 14 and 18. A part of this paper including the "general section of the rocks of Kansas valley" appeared in the Am. Jour. Sci., May, 1859 (2d series, Vol. XXVII., pp. 424–432).

[2] Dr. Newberrys's observations on this trip were published in 1861 in the Report upon the Colorado River of the West, explored in 1857 and 1858 by Lieut. Joseph C. Ives. Geological Report by Dr. J. S. Newberry, Chapter X., Geology of the route from Santa Fé to Fort Leavenworth, p. 102. See particularly pp. 110–115. Meek and Hayden's "General section of the rocks of the Kansas Valley" from Manhattan to the Cretaceous is copied on pp. 112–114.

[3] Report of the Exploring Expedition from Santa Fé, New Mexico, to the junction of the Grand and Green Rivers of the great Colorado of the West in 1859, under the command of Capt. J. N. Macomb, with Geological Report by Professor J. S. Newberry. See Chapter I., and especially pp. 16–21. Although Dr. Newberry's report was finished in 1860, it was not published until 1876, but in his Prefatory Note of June, 1875, we find these words: "Precisely as written in 1860." A brief account of this trip appeared in the September number of the Am. Jour. Science, for 1859 (2d series, Vol. XXVIII., pp. 298, 299) where Dr. Newberry states that "from Wellington to Cottonwood and Turkey Creek the Permian was constantly found in the hill-tops, but the valleys were excavated down to the Carboniferous" (p. 298).

considerable number of species; but in the massive limestones the number of species and individuals is usually smaller.

From the exposures of shales and limestones on Mill Creek, the following species were obtained, which are arranged in the order of their relative abundance and may be considered the characteristic fossils of the formation:

1. *Chonetes granulifera*, Owen.
2. *Productus* (*Marginifera*) *splendens*, Norw. and Pratt.
3. *Productus semireticulatus*, (Martin) de Koninck.
4. *Productus cora*, d'Orbigny.
5. *Spirifer* (*Martinia*) *planoconvexus*, Shum.
6. *Fusulina cylindrica*, Fischer.
7. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea*, (Shep.) Keyes.
8. *Pugnax uta*, *Marcou* (Marcou) Hall and Clarke.
9. *Productus nebrascensis*, Owen.
10. *Hustedia mormonii*, (Marcou) H. and C.
11. *Septopora biserialis*, (Swallow) Waagen.
12. *Rhombopora lepidodendroides*, Meek.
13. *Spirifer cameratus*, Morton.
14. *Pinna peracuta*, Shum.
15. *Phillipsia scitula*, Meek and Worthen.
16. *Derbya crassa*, (Meek and Hayden) H. and C.
17. *Meekella striato-costata*, (Cox) White and St. John.
18. *Chonetes Flemingi*, (according to Keyes) Norw. and Pratt.
19. *Allorisma Geinitzii*, Meek (?)
20. *Campophyllum torquium*, (Owen) Meek?
21. *Chonetes glabra*, Geinitz = *C. lævis*, Keyes.
22. *Productus symmetricus*, McChesney.
23. *Spiriferina kentuckensis*, Shum.
24. *Enteletes hemiplicatus*, (Hall) H. and C.
25. *Dielasma bovidens*, (Morton) H. and C.
26. *Orbiculoidea nitida*, (Phillips) H. and C.
27. *Myalina subquadrata*, Shum.
28. *Allorisma subcuneatum*, M. and H.
29. *Aviculopecten occidentalis*, (Shum.) Meek and Worth.

30. *Straparollus* (*Euomphalus*) *subrugosus*, Meek and Worth. = *S. catilloides*, (Con.) Keyes.

The bluffs along the Kansas River near Manhattan afforded me the following additional species:

31. *Fistulipora nodulifera*, Meek.
32. *Fusulina cylindrica*, Fischer, var. *ventricosa*, M. and H.
33. *Lingula umbonata*, Cox.
34. *Orbiculoidea manhattanensis*, (M. and H.) H. and C.
35. *Nuculana bellistriata*, Stevens, var. *attenuata*, Meek. (?)
36. *Dawsonella Meeki*, Bradley (?)
37. *Lophophyllum proliferum*, (McChes.) Meek
38. *Cladodus mortifer*, Newberry and Worthen.

In the lower part of the formation, from exposures along the Kansas River below the mouth of Mill Creek and extending to the vicinity of Topeka, the following additional species were obtained:

39. *Bellerophon sublævis*, Hall.
40. *Myalina Swallovi*, McChesney.
41. *Allorisma* (*Sedgwickia*) *topekænsis* (Shum.) Meek.
42. *Myalina perattenuata*, M. and H.
43. *Productus punctatus* (Mart.) Sowb.
44. *Allorisma* (*Sedgwickia*) *Geinitzii*, Meek.
45. *Edmondia ovata*, Meek.
46. *Schizodus curtus*, M. and W.
47. *Nuculana bellistriata* (Stevens) Meek.
48. *Allorisma granosa* (Shum.) Meek.
49. *Macrodon tenuistriata*, M. and W.
50. *Modiola* (?) *subelliptica*, Meek.
51. *Productus pertenuis*, Meek.
52. *Edmondia aspinwallensis*, Meek.
53. *Entolium aviculatum* (Swallow) Meek.
54. *Solenomya radiata*, Meek and Worth.

As will be seen from the above fauna this formation clearly belongs in the upper part of the Carboniferous to which system these rocks have generally been referred.

*Meek and Hayden's classification.*—In Meek and Hayden's paper of 1859 it was proposed to divide the upper Palæozoic rocks into the Permian and Permo-Carboniferous.[1] They did not indicate precisely this line of separation, but it seems probable that their Permo-Carboniferous division included the upper part of the Wabaunsee formation.[2]

*Newberry's classification.*—It is evident that Dr. Newberry in his early explorations regarded the rocks of this formation as belonging to the Carboniferous, for he stated in 1860 that "at Dragoon Creek [probably on the Santa Fé trail in the southeastern part of Wabaunsee county where the upper part of the course of Dragoon Creek is eroded in rocks belonging to the Wabaunsee formation, while the upper part of the bluffs belong to the overlying formation] we reach the extreme summit of the Carboniferous formation, and first meet with those which may be regarded as distinctly Permian."[3]

[1] Also see the following statement of Meek and Hayden: "We are inclined to the opinion that the entire series, from near the top of the Lower Permian of Professor Swallow's and Mr. Hawn's section, down even lower than the horizon where they draw the line between the coal measures and the lower Permian, should be regarded as intermediate in age, and as filling the hiatus between the Permian and upper coal measures of the Old World. . . . This intermediate series might be very appropriately termed the Permo-Carboniferous group, to indicate its relations both to the Permian and Carboniferous rocks" (Am. Jour. Science 2d series, Vol. XXVII., January 1859, p. 35).

[2] See PROSSER: Bull. Geol. Soc. Amer., Vol. VI., p. 51, and notice the line of separation indicated with a question on p. 53. The authority for this statement may be found in Hayden's article in the Amer. Jour. Science, 2d series, Vol. XLIV., 1867, p. 37, where he states that "Meek and Hayden regarded the beds . . . . down so far as to include most, if not nearly all, of Professor Swallow's Lower Permian, as an intermediate connecting series between the Permian and Coal Measures, which, if worthy of a distinct name at all from the latter, should be called Permo-Carboniferous."

[3] Rept. Explor. Exp. 1859, Macomb, p. 19. It is not clear from the context whether by "Permian," Dr. Newberry meant the base of the Permo-Carboniferous, or the base of what he called "true Permian;" but the former seems to have been his interpretation, for on p. 16, in enumerating localities containing numerous fossils, he mentions "Permo-Carboniferous at Dragoon Creek and Wilmington" [name of southeastern township of Wabaunsee county, with town of same name in the southeastern corner on Soldier Creek] and "true Permian on the hill-tops east of Council Grove [which would be some twenty miles southwest of the Permo-Carboniferous localities], and on Cottonwood Creek." Also in describing the region toward Council Grove is the statement that "over a considerable area in this vicinity the highlands are occupied by what may be considered true Permian strata, while the valleys of all the water-courses are exca-

At this time Dr. Newberry clearly recognized the difficulty of separating the Carboniferous and Permian systems by any sharp line, and he said, "From this interlocking of the Carboniferous and Permian faunæ, it is evident that the line of separation between the two formations must continue to be debatable ground; and as there is, in fact, a group which contains a mingled fauna—in truth, a Permo-Carboniferous group—we must introduce this new member into the geological series, or fix upon some conventional line which shall form the boundary between the summit of the Carboniferous and the base of the Permian formations."[1]

*Comparison of the Wabaunsee formation with Swallow's section.*—Professor Swallow in his Preliminary Report on the Geology of Kansas divided the rocks of eastern Kansas into 256 beds which were referred to the Quarternary, Tertiary, Cretaceous, Triassic, Permian and Carboniferous systems.[2] In his section the rocks which we have referred to the Wabaunsee formation were described from exposures occurring principally along the Kansas River, Mill Creek and adjacent country. As the limits of the Wabaunsee formation have been indicated, it includes the rocks from the top of Swallow's bed, No. 154, up to the base of bed, No. 80. The greater part of the formation belongs to the upper part of the Carboniferous system of Swallow, which he called "Formation *a*—Coal Measures," including the larger portion of his "Stanton Limestone series" and all of the following series in ascending order, "Chocolate Limestone" and "Upper Coal series." In addition to the above rocks the Wabaunsee formation includes the four beds forming the base of Swallow's "Lower

vated to and into the Permo-Carboniferous, or, as I have called them, Upper Carboniferous strata" (p. 20). Again he says, "the Permian magnesian limestones occupy the general surface, but are cut through by the valleys of the draining streams. Below them are exposed strata containing *Orthisina umbraculum; Productus Calhounianus;* spines of a species of *Archæocidaris*, regarded by Professor Swallow as identical with *A. Verneuiliana*, King; a small *Athyris*, and a *Rhynchonella;* all of which belong rather to the Carboniferous than to the Permian fauna" (p. 21).

[1] *Ibid.*, p. 20.

[2] Prel. Report, Geol. Survey, Kansas, 1866, section of the rocks in eastern Kansas, pp. 9–29.

Permian," Nos. 84–80, to which he assigned a thickness of forty-two feet, and claimed that on Mill Creek the base of the Lower Permian was separated from the Carboniferous by unconformability.[1] In general it is not difficult to identify the beds which Swallow referred to the Permian, but those of the Carboniferous are not as clearly defined. Swallow gives the total thickness of the beds which I have included in the Wabaunsee formation as 546 feet, while from my estimate of the exposures along the Kansas River the formation has a thickness of probably 575 feet.

As stated above, the greater part of this formation consists of a series of limestones alternating with argillaceous and calcareous shales which it is not necessary to consider in detail in this article. The upper part of the Wabaunsee formation is more important in reference to the geological classification of these rocks, since the line drawn by Professor Swallow separating the Carboniferous from the Permian occurs forty-two feet below its top. Professor Swallow considered bed, No. 84, of his section, which he named the "dry bone limestone," the base of his Lower Permian; next above came bed No. 83, composed of "bluish-brown marls, one foot;" then No. 82, the "Cotton rock, five feet," above which was No. 81, composed of thirty-one feet of shales and marls which is the top of the Wabaunsee formation. These shales are capped by a massive limestone, six feet thick, called bed No. 80 by Swallow and named the "*Fusulina* limestone" on account of the abundance of this fossil. Professor Swallow states that beds "Nos. 82, 83 and 84, are sometimes represented by a bluish-gray and buff porous magnesian limestone, . . . . containing numerous Permian *Acephala* and *Zaphrentis* and small *Spirifer*," and he gives the locality as the Cottonwood.[2]

This limestone is in general very prominent in the bluffs along the Cottonwood River from the vicinity of Ellinor to within

[1] See section on p. 16, and the following statement on p. 44: "Nos. 85–95, from the sections near Manhattan are not found in the Mill Creek sections, where No. 84 rests directly upon the Fusulina shales, No. 96."

[2] *Ibid.*, p. 16.

three miles of Clements. A mile west of Strong City it is carried below the surface by a synclinal fold, but it reappears west of Simmons Creek three miles west of Strong City, where it forms a prominent ledge on the northern side of the valley which is conspicuous from the Atchison, Topeka & Santa Fé trains. It also forms a prominent ledge on the southeastern bank of the river below and above Elmdale, as well as on the northwestern side, some distance from the river until within four miles of Clements, where it becomes more conspicuous on the Blackshere ranch (Sec. 12, 20 S., 6 E.). This ledge, a massive bluish-gray stratum in places seven feet or more in thickness, frequently breaks on the edges into large blocks, with sharp angles and rough, jagged surface, which usually weather to a color not dissimilar to that of bleached bones, hence the name "dry bone limestone" is not especially inappropriate. Professor Swallow repeatedly stated that the limestones all through the rocks which he called Permian were strongly magnesian and regarded their chemical composition as an important character in separating the Carboniferous and Permian systems. The professor was in error in this particular and must have considered the limestones to be magnesian from their general appearance since a chemical analysis of them fails to reveal magnesia in any considerable amount.[1] This erroneous view in reference to their chemical composition was noticed by Professor Mudge,[2] and the error is very evident from an examination of the table of

[1] This is well shown by the following analysis of a specimen of the "dry bone limestone" from Manhattan, by Mr. Warren Finney, who kindly analyzed a series of these limestones for me:

| | | |
|---|---|---|
| $SiO_2$ | 2.34 | per cent. |
| $Fe_2O_5$ | 0.03 | " |
| $CaCO_3$ | 97.46 | " |
| $MgCO_3$ | 1.02 | " |
| $Al_2O_3$ | trace | |
| | 100.85 | " |
| $CO_2$ | 44.34 | " |

[2] First Bien. Rep. [Kansas] State Board Agri., 1878, Geology of Kansas, p. 70, where in describing the Permian and Upper Carboniferous he said, "Some of the lime has been called magnesian, but analysis has failed to show, in more than a single

"Analyses of Kansas building stones" prepared by Dr. S. W. Williston for the Columbian Exposition.[1]

Professor Swallow claimed that the main reason for drawing the line of separation between the Carboniferous and Permian at the base of the "dry bone limestone" was the fact "that the Permian fossils come down in force to this line and but few go below, while a few species only of Carboniferous fossils are found above it."[2] In beds, Nos. 82, 83 and 84, I have found but few fossils and those are not especially Permian types, while it will be shown that in the Cottonwood shales of the succeeding formation there are abundant specimens of characteristic Carboniferous species. The small *Spirifer* mentioned by Professor Swallow in this limestone on the Cottonwood[3] is *S. cameratus*, Morton which I have not found at a higher horizon.

*Comparison with Haworth and Kirk.*—In the paper describing the Neosho and Cottonwood River sections by Professor Haworth and Mr. Kirk, this limestone is called No. 12, and its extent is well shown along the Neosho River from five miles above Emporia to Dunlap. It is also accurately noted on the Cottonwood from the vicinity of Ellinor to Strong City, but it was not recognized on its reappearance three miles farther west.[4]

THE COTTONWOOD FORMATION.

Succeeding the Wabaunsee formation is a massive yellowish to light gray limestone with a maximum thickness of six feet capped by yellowish calcareous shales fourteen feet thick which together have been called the Cottonwood formation.[5]

*Geologic section of the Cottonwood formation.*—The thickness of the formation is about twenty feet, and it is well exposed in the

instance, over 5 per cent. of magnesia." This statement is not correct for the limestones of the Permian, but well expresses the chemical composition of the lower limestones.

[1] Mineral Resources, U. S., for 1893, pp. 563–565.

[2] Prel. Rep. Geol. Surv., Kansas, p. 44.

[3] *Ibid.*, p. 16.

[4] Kan. Univ. Quart., Vol. II., pp. 112, 113 and Pl. IV., Figs. 2 and 3.

[5] PROSSER: Bull. Geol. Soc., Amer., Vol. VI., p. 40.

Fox Creek quarry and bluff, one mile west of Strong City. At this locality there is the following section:

No. 4. Blocky limestones from 1′ 6″ to 2′ in thickness separated by shaly partings. This bed is referred to the succeeding formation (Neosho).

No. 3. Yellowish, calcareous shales which contain plenty of calcite (?) nodules but no fossils. Between 6′ and 7′.

No. 2. Similar shales containing plenty of fossils which in the lower part are extremely abundant. 7′ 2″.

No. 1. Massive limestone. Stratum not fully exposed. 4′ 8″ +.

*Distribution and character of the Cottonwood limestone.*—Along the bluffs of the Cottonwood River this limestone first appears as a prominent ledge near Ellinor and on account of folding may be followed up the Cottonwood River to Crawfordsville or Clements. It may be traced along the principal branches of the Cottonwood River as follows: Up the South Fork to three miles south of Bazaar; along Middle Creek for eight miles; and up Diamond Creek to Hymer. It is the most valuable dimension stone in the state and at various places are extensive quarries which afford an excellent opportunity to study the limestone and its overlying shales. Some of the more important quarries are those on the north side of the river between two and three miles east of Strong City; the Lantry & Sons' quarry in the city limits, and the Fox Creek quarry one mile west of Strong City. On the south side are those of the Rettiger Bros., Du Chanois and Jones two and one-half miles east of Cottonwood Falls, and the Perrin quarry in Cottonwood Falls, while farther up the river near Clements are the quarries of D. Y. Hamill. The limestone on a fresh fracture is yellowish-gray in color weathering to a light gray and generally appears along the side of the moderately steep bluffs as a series of rectangular blocks that have been separated from the main ledge. The stone is very strongly calcareous containing about 85 per cent. of calcium carbonate and less than 2 per cent. of magnesian carbonate.[1]

[1] Dr. S. W. Williston reports the following analysis:

| | |
|---|---|
| Insoluble matter - - - | 8.57 per cent. |
| Oxides of iron and alumina - - | 3.62 " |
| Calcium carbonate - - - | 84.72 " |

No. 1. View of the Cottonwood limestone and shales capped by the blocky limestones at the base of the Neosho formation. Fox Creek quarry west of Strong City.

The amount of flint contained in the rock varies. In some localities it is scarcely perceptible while in others the quantity is sufficient to make the rock comparatively valueless for economic purposes. There are very few fossils, with the exception of *Fusulina cylindrica*, Fischer, which is extremely abundant in the upper part of the stratum. The quarrymen call these fossils grains of wild rice, and on account of their great abundance Professor Swallow called the stratum the "*Fusulina* limestone."[1] This limestone forms one of the most important features in the stratigraphy of the Upper Palæozoic rocks of Kansas and in many respects is as valuable for stratigraphic purposes as the Tully or Corniferous limestones in the Devonian of New York.

*Fauna of the Cottonwood shales.*—The yellowish overlying shales, which may be called the Cottonwood shales, constitute one of the most fossiliferous horizons of the Carboniferous, although there are but a few species that are extremely abundant. The immense number of fossils in this shale was noted by Professor Haworth and Mr. Kirk, who stated that in the shale of the Rettiger quarries "marine invertebrate fossils are unusually abundant,"[2] but in general this, its most striking characteristic wherever exposed, seems to have been overlooked.[3]

Wherever the shale has been exposed for some time to the action of the atmosphere large numbers of loose fossils perfectly

| | | |
|---|---|---|
| Magnesian carbonate - - - | 1.75 | " |
| Sulphates - - - - | .90 | " |
| | 99.56 | " |

Mineral Res., U. S. for 1893, p. 563. The samples came from the Rettiger Bros.' quarry, the crushing strength being 6800 lbs.; weight per cubic foot 161.6 lbs.; and the specific gravity 2.59.

[1] Prel. Rep. Geol. Surv. Kans., p. 16.

[2] Kans. Univ. Quart., Vol. II., p. 113.

[3] Professor Broadhead probably noticed the fossils of this shale, but his reference is quite indefinite. The Professor mentions quarries in the Cottonwood Valley containing "about six feet of very good building stone," probably the Cottonwood limestone, and says, "the associated shale beds abound in fine fossils, including *Prod. semireticulatus; Hemp. crenistria;* a large variety of *Chonetes granulifera* and *Athyris subtilita*, *Archæocidaris*, and a Crinoid" (Trans. St. Louis Acad. Sci., Vol. IV., Pt. III., p. 492).

preserved may be found. This is especially true of *Chonetes granulifera*, Owen, which in places may be collected by the hundreds from the top of the underlying limestone, or in the soil formed by the decomposed shale.

In the Cottonwood shales at the Rettiger Bros.' quarry the following species were collected:

1. *Chonetes granulifera*, Owen. (aa)[1]
2. *Derbya crassa*, (M. and H.) Hall and Clarke. (a)
3. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea*, (Shep.) Keyes. (a)
4. *Productus semireticulatus*, (Martin) de Koninck. (a)
5. *Meekella striato-costata*, (Cox) White and St. John. (c)
6. *Productus nebrascensis*, Owen. (r)
7. *Aviculopecten McCoyi*, M. and H. (r)

   Imperfectly preserved specimens which seem to agree closely with this species. There are heavy costæ which show the base of spines and these ribs are separated by two or three smaller plications.
8. *Straparollus* (*Euomphalus*) *subrugosus*, Meek and Worth. = *catilloides*, (Con.) Keyes. (rr)
9. *Septopora biserialis*, (Swallow) Waagen. (rr)
10. *Rhombopora lepidodendroides*, Meek. (rr)
11. *Lophophyllum proliferum*, McChesney. (rr)
12. *Fusulina cylindrica*, Fischer. (rr)
13. *Aviculopecten occidentalis*, (Shum.) M. and W. (rr)
14. *Dielasma bovidens*, (Morton) H. and C. (rr.)
15. *Chætetes* cf. *carbonarius*, Worth. (rr)

    In addition to the above list the following species were obtained from exposures of the Cottonwood shales near Cottonwood Falls or Strong City:
16. *Phillipsia scitula*, M. and W. (?) (rr)
17. *Crinoid* plates and stem.
18. Fish plate.

[1] The relative abundance of the species is indicated in the following manner: a=abundant; aa=very abundant; c=common; r=rare; rr=very rare, when but one or two specimens are found.

19. *Archæocidaris* plates and spine.
20. *Bryozoa* sp.
21. *Glauconome* sp.

From the Hamill quarry near Clements the two following species were obtained:

22. *Productus cora*, d'Orbigny. (rr)
23. *Fistulipora nodulifera*, Meek. (rr)

A study of the above fauna will clearly show it to be one of the Upper Carboniferous of the Mississippi Valley and Great Plains, although many of the species occur in the deposits called Permo-Carboniferous and an occasional one has been reported from the so-called Permian rocks of the United States. A comparison of the fauna of the Wabaunsee formation with that of the Cottonwood will reveal the fact that while the former contains more than twice as many species as the latter, which proportion will probably not be materially changed by further search, still every species of the Cottonwood formation with the exception of *Aviculopecten McCoyi*, M. and H., and *Chætetes* cf. *carbonarius*, Worth, which are doubtfully identified, occurs in the Wabaunsee formation, consequently, as far as the biologic evidence is concerned, there is no support for placing the Cottonwood formation in a system or even series, distinct from that of the Wabaunsee.

*Former descriptions of the Cottonwood limestone.*—The Cottonwood limestone was among the first stones of the state to be used for construction where strength and durability were desired, but it is not known to the writer at what date it was first called the "Cottonwood stone." It forms bed No. 80 of Swallow, which he called the "*Fusulina* limestone" and described as "buff, porous and magnesian," six feet thick, exposed at "Manhattan, Cottonwood Falls and Mill Creek." [1]

It forms the summit of Blue Mount and Mount Prospect at Manhattan and the bluffs along Mill Creek above Alma, consequently it appears that Professor Swallow correlated the several exposures of this limestone correctly although he made no reference to its extent, in the descriptive part of the work. Later

[1] Prel. Rept. Geol. Surv. Kansas, 1866, p. 16.

No. 2. Line of the Cottonwood limestone on the north side of the Kansas River west of Manhattan. Characteristic appearance of the limestone along the bluffs of streams.

writers seem to have overlooked his conclusions and there has been much confusion concerning the correlation of the prominent limestones of the Kansas and Cottonwood valleys. Professor St. John referred to the extensive quarries near Strong City, where he stated "the ledge is extensively wrought."[1]

Professor Haworth and Mr. Kirk described briefly the Cottonwood limestone as it occurs on the Neosho River from Dunlap toward Council Grove and on the Cottonwood River near Cottonwood Falls, and called it Limestone System No. 13 "of their section."[2]

*Geographic extent of the Cottonwood limestone.*—In general it seems that the stratigraphic importance of the Cottonwood formation has been overlooked. The constant character of the limestone, its line of outcrop frequently marked by a row of massive, light gray rectangular blocks filled with *Fusulina cylindrica* and capped by a yellowish shale in which occur immense numbers of *Chonetes granulifera*, *Athyris subtilita*, *Productus semireticulatus* and a few other fossils constitutes one of the most distinctive formations yet seen in the upper Palæozoic rocks of Kansas, and is very valuable for the purposes of stratigraphic and areal geology. Recently there have been general statements in reference to its extent across the state,[3] and such distribution is very probable; although I believe it has actually been traced but part of the distance. In the summer of 1894

[1] Third Bien. Rep. [Kansas] State Board Agri., Vol. VIII., 1883, p. 584.

[2] Kans. Univ. Quart., Vol. II., pp. 112, 113, Pl. IV., Figs. 2 and 3. Also, see *ibid.*, Vol. III., p. 279.

[3] A pamphlet on the "Mineral Resources of Kansas," prepared for the Columbian Exposition, speaks of the Cottonwood Falls limestone as "the most extensive limestone bed in the state, and can be traced as one continuous formation across the state from north to south" (p. 18). The author, however, did not know the stratigraphic relations of the Cottonwood limestone, for he considered as one and the same the limestone at Manhattan in the Kansas valley and that at Florence in the Cottonwood valley, while as a matter of fact that at Florence is entirely different in character and is stratigraphically 250′ above the Cottonwood limestone. The "Report of the Kansas Board of World's Fair Managers, 1893," describes a limestone, which, from the localities mentioned (Manhattan, Alma, Strong City, etc.) is evidently the Cottonwood stone, that forms a "horizon which is traceable across the state from east of Marysville [Beattie, Marshall Co.], on the north, to Cambridge, Cowley county, on the south."

the writer traced this formation from the northern part of Greenwood county into Riley county north of the Kansas River. There are good exposures of the limestone in the eastern part of Chase county on the South Fork of the Cottonwood River and its eastern branches. It may be traced up the Cottonwood River to Clements; from Strong City to the vicinity of Ellinor, then across the divide into the Neosho valley near Dunlap, when it follows the bluffs of the river about half the distance to Council Grove, then turns northeasterly across the high land of Wabaunsee county, passing near Bushong and the heads of the various streams in eastern Wabaunsee to Eskridge at the head of Dragoon Creek. From Eskridge it continues north on the high land near the head of Mission Creek, reaching Mill Creek near Alma. It continues northerly across the divide toward Wabaunsee, then follows the high bluffs along the south side of the Kansas River to Manhattan and extends up the river valley to the vicinity of Ogden, about five miles below Fort Riley. Along the entire extent of this line which is about one half the distance across the state, the formation is clearly marked wherever there are exposures, and its distinctive characters are very constant.[1]

CHARLES S. PROSSER.

[1] The author first called attention to the important stratigraphic character of this formation and briefly outlined its course across eastern central Kansas in 1894 (see Bull. Geol. Soc. Amer., Vol. VI., p. 40, and particularly footnote ‡). Later Professor Haworth has indicated in a general way the outcrop of the Cottonwood Falls limestone across the state (Kans. Univ. Quart., Vol. III., April, 1895, Pl. XXI. and p. 279).

[To be continued.]

# *EDITORIAL.*

THE seventh summer meeting of the Geological Society of America, held at Springfield, Mass., will be remembered as one in which matters were transacted with promptness and commendable dispatch, amidst very agreeable surroundings. The principle of considering first only those papers whose authors were in attendance, and of reading the papers of absent members only when called for, proved highly satisfactory. Those who had come long distances to the meeting were able to present their papers properly, and at the same time were held closely to the time allowance they had themselves chosen. And it is to be hoped that similar methods will obtain at all future meetings. The session was short, lively and interesting. The president of the society, Professor N. S. Shaler, and the secretary, Professor H. L. Fairchild, are to be congratulated upon the success of the meeting. Of the nineteen papers upon the programme thirteen were presented by their authors, the others being read by title. Professor B. K. Emerson explained the geology of the central portion of Massachusetts, upon which he has been engaged for twenty-five years, and by means of elaborately detailed maps, which he has prepared for publication, and with the aid of others he has devised for his class room, he made clear the geological structure of the region.

Previous to the meeting he had conducted an excursion over the same ground, and had shown some of the chief exposures of metamorphosed palæozoic strata, whose character he has already demonstrated. Upon this trip he was assisted by Professor T. N. Dale and Professor Wm. H. Hobbs, who have been at work upon adjacent districts. The success of this excursion and of the short, impromptu one, which Professor Emerson kindly conducted on the afternoon of the last day of the meeting, has suggested the desirability of making the chief function of the summer meetings the geological excursion, or excursions, and the presentation of such papers as may be germane to the geological problems there encountered. The greater number of papers consequently crowded into the winter meetings could be satisfactorily considered and discussed if they were judiciously classified and were presented in such sections of the society as could be held at the same time without interference; papers of general interest being read before the society in general session. A partial subdivision of papers was attempted at the last winter meeting, in Baltimore, and promised well.

A list of the papers presented at the Springfield meeting follows. J. P. I.

* * *

1. George M. Dawson and R. G. McConnell:
   On the Glacial Deposits of Southwestern Alberta, in the Vicinity of the Rocky Mountains.
2. C. H. Hitchcock:
   The Champlain Glacial Epoch.
3. Warren Upham:
   Drumlins and Marginal Moraines of Ice-sheets.
4. H. L. Fairchild:
   The Glacial Genesee Lakes.
5. B. K. Emerson:
   The Geology of Old Hampshire County in Massachusetts.
6. N. H. Darton:
   Notes on Relations of Lower Members of Coastal Plain Series in South Carolina.
7. N. H. Darton:
   Resumé of General Stratigraphic Relations in the Atlantic Coastal Plain from New Jersey to South Carolina.
8. Arthur Hollick:
   Cretaceous Plants from Martha's Vineyard. Results Obtained from an Examination of the Material Collected by David White in 1889.
9. William B. Clark:
   On the Eocene Fauna of the Middle Atlantic slope.
10. R. T. Jackson and T. A. Jaggar:
   Arrangement and Development of Plates in the *Melonitidæ*.

11. GEORGE P. MERRILL:
On Asbestos and Asbestiform Minerals.

12. WM. H. HOBBS:
Pre-Cambrian Volcanoes in Southern Wisconsin.

13. A. CAPEN GILL:
A Geological Sketch of the Sierra Tlayacac, in the State of Morelos, Mexico.

14. C. H. GORDON:
Syenite-Gneiss (Leopard Rock) from the Apatite Region of Ottawa County, Canada.

15. J. F. KEMP:
The Titaniferous Iron Ores of the Adirondacks.

16. J. C. BRANNER:
The Decomposition of Rocks in Brazil.

17. W. M. DAVIS:
The Bearing of Physiography on Uniformitarianism.

18. C. R. VAN HISE:
Analysis of Folds.

19. N. S. SHALER:
On the Effects of the Expulsion of Gases from the Interior of the Earth.

# *PUBLICATIONS.*

*Summary of Current pre-Cambrian North American Literature.*[1]

Smith,[2] in 1892, reports on the Archean Rocks of Hunters Island and adjacent country. The rocks are divided into Laurentian and Huronian, and the latter subdivided into Coutchiching and Keewatin. The main occurrences of the Laurentian rocks are the Kawagansikok, Poo-Bah, Hunters Island and Saganaga areas. The Kawagansikok granite is in places fine grained and nearly devoid of mica and hornblende; in other places is a muscovite-granite; in others is garnetiferous granite-gneiss. The rock is frequently cut by coarse pegmatite veins. The Poo-Bah area is usually a coarse hornblende syenite, but in places it merges into a finer grained hornblende-granite. The Hunters Island rocks are usually biotite-granites, but the biotite is often replaced by, or associated with muscovite, hornblende or chlorite. At Agnes Lake angular fragments of Mica-schist or gneiss are found in the granite. At various places occur hornblende-granites. There are other isolated areas of granite which break through the Coutchiching rocks which cannot certainly be said to be of Laurentian age. The granites as a whole usually have a foliated character.

The Coutchiching series covers a large area in the northwestern part of the district, and several small areas are found to the eastward. The Couchiching rocks are usually mica-schists. In general their schistosity is parallel to that of the granites, but at Conmee Lake there is a discrepancy between the two which may indicate a structural unconformity or a fault. The mica-schist is cut by granite apophyses at various places. If foliation is taken as thickness the series would vary from 1.386 miles to 5.548 miles. However the mica-schists are regarded as repeated by folding. Although having isoclinal dips, there is a considerable variation which may indicate such folding.

Keewatin rocks are confined to the southeastern part of Hunters Island. They consist of quartzites, soft gray schists, quartz-porphyries,

[1] Continued from p. 236, Vol. III. JOURNAL OF GEOLOGY.

[2] Report on the Geology of Hunters Island and Adjacent Country, by W. H. C. SMITH. Ann. Rep. Geol. Sur. of Canada, for 1890–1, Vol. V., Part 1, G., pp. 5–76, 1892.

felsite, sericite-schists, conglomerates, altered traps, hornblende-schists and other green schists. Occasionally contained in them are areas of banded jasper and hematite. On the north side of Cache Bay is a felsitic conglomerate in contact with a coarse-grained hornblende-granite. Beds of dolomite are associated with this conglomerate. The breadth of the Keewatin series gives no certain criterion by which to estimate its thickness. The dip shows an apparently simple synclinal structure.

As to the relations of the Laurentian to the Huronian series, they have a general parallel schistosity, and there are many phenomena suggestive that the granitic and syenitic type is of igneous eruptive origin, later than the Huronian, but the hornblendic and micaceous phases of these granites may be rocks of different determinable ages, the discovery of which may throw light not only on the genesis of the Laurentian, but on its relations to the overlying Couchiching and Keewatin. Cutting both Laurentian and Couchiching rocks are diabase dikes in such attitudes as to leave little doubt that they were intruded since the last folding, on which assumption their geological age is post-Keewatin.

Grant,[1] in 1894, gives a general account of the geology of the Gunflint lake district. In Ts. 65 and 66 N., Rs. 4, 5 and 6 W., are Keewatin rocks, including the usual types—volcanic tuff, greenstone-schists, greenstone, and the Ogishke conglomerate. The Saganaga granite is intrusive in the Keewatin. The more crystalline schists of the district have been called Couchiching and Vermilion. It, however, appears that these rocks in this area are a more crystalline phase of the Keewatin, and that they owe their crystalline nature to the proximity of intrusive granite.

The iron-bearing rocks of Akeley Lake lie upon the Keewatin greenstone to the north, and on the south are overlaid by the great gabbro mass. The belt has a width of from 300 to 1300 feet, and a dip varying from 20° to almost vertical, but averaging 45° to 50°. Where widest, it has an average dip of 30°, which would make a maximum thickness of 650 feet. The iron ore is a titaniferous magnetite.

The Animikie rocks are little disturbed, except locally, having an

[1] Preliminary Report of Field Work during 1893 in Northeastern Minnesota, by U. S. Grant, 22d Ann. Rep. Geol. and Nat. Hist. Sur. of Minn, Part IV., pp. 67–78, 1894.

average dip of 8° or 10° a little east of south. The Animikie beds are interleaved with diabase sills. These give parallel east and west ridges, the south sides of which are gentle slopes, and the north steep mural descents. This topography has led Lawson to the conclusion that the apparent large number of sills are due to monoclinal faulting of fewer layers, but of this there is no evidence. The Animikie strata are divided as follows: an upper or graywacke-slate member, 1900 feet thick, composed of slates and graywackes, with fine-grained quartzites and quartz-slates; a middle or black slate member, 1050 feet thick, composed mainly of black slates, apparently carbonaceous, with a fine grained siliceous and flinty layer at the base 60 feet thick; and a lower or iron-bearing member, composed largely of jaspery, actinolitic, siliceous and magnetitic slates, usually thinly laminated, and some beds of cherty iron carbonate. The Akeley Lake rocks, first called Pewabic quartzite, are similar to the Gunflint iron-bearing rocks and different from the Pewabic quartzite of the western Mesabi range, and if these iron-bearing rocks are put at the base of the Animikie, there seems to be serious objection to regarding them as the basal quartzite, and the equivalent of the quartzite of the western Mesabi range. No true quartzite is found at the base of the Animikie in the Akeley Lake area, but the iron-bearing rocks at Gunflint Lake rest directly upon the Keewatin.

The quartzites of Pigeon Point are lithologically similar to the quartzite at the top of the graywacke-slate member, and are supposed to be equivalent to it. The igneous rocks are all intrusive. The diabase sills sometimes have a thickness of 100 feet. They have not been found in contact with nor to extend into the gabbro below. The great Keweenawan gabbro of the district has a varying mineralogical composition, sometimes being composed almost entirely of feldspar, thus forming anorthosite, and again being exceedingly rich in olivine. This gabbro includes fragments of the Animikie slates, and was found directly overlying and in contact with the uppermost member of the Animikie, thus showing it to be of post-Animikie age. Associated with the coarse-grained gabbros are finer grained rocks including gabbros, olivine-gabbros, norites and olivine-norites, which have been called muscovado. These are slightly older than the main mass of gabbro, which is seen cutting and including fragments of them.

The acid eruptive rocks, called augite-syenite by Irving, including reddish, hornblendic, granitic rocks, are found cutting the gabbro. In passing toward the granitic rocks, at first a few small acid dykes are seen. These increase in frequency in approaching the central mass of the granite, and at the edge of the mass apophyses can be traced directly from the granite into the gabbro. The dykes are not finer grained as a whole or at their edges, than the main mass, thus indicating the heated condition of the gabbro when the dykes were intruded. It is concluded that while the granite is of later date than the gabbro, it is not much later, and was perhaps intruded before the complete solidification of the basic rock.

Culver,[1] in 1894, describes the rocks of Itasca county, Minn. The Pokegama quartzite was found to extend from the north end of Pokegama Lake northeasterly to the rapids of Prairie River. This rock is flat lying, with low southerly or southeasterly dip, and seems to have been bowed into a series of low flat arches. The lower beds are fine grained, hard and massive, although broken into cubical blocks. In the upper portions of the quartzite in many places is found a considerable quantity of iron ore. In cross section there are alternately sheets of ore and sheets of quartz. In the hand specimen these quartz layers show no grains. The structure is porous, and the quartz is usually stained red. Both the ore and quartz layers are exceedingly irregular, and are often interrupted or cut by each other.

The Prairie River granite lies in a belt parallel to the Pokegama quartzite. It contains some bodies of schist, which are taken to indicate that the granite is eruptive. Thrust planes are numerous, and generally have either vertical or very steep dips.

On Big Fork River, a few miles above the mouth of Rice River, diorite was found, and also at Koochiching Falls in the Rainy River. Greenstones constitute the chief exposures between Rice River and Big Falls. They comprise beds which are purely eruptive, other beds which are consolidated tuffs, and other phases which it is not possible to place certainly in either class. The mica-schists constitute an immense series, extending on the Big Fork River from a point twelve miles below Little Falls to within fifteen miles of Rainy River. At various places the mica-schist is cut by granite. In passing from the mica-schist to the granite, the mica-schist becomes veined with a granite, which gradually increases in

[1] Notes on the Geology of Itasca county, Minn., by G. E. CULVER. Geol. and Nat. Hist. Sur. of Minn., 22d Ann. Rep., Part VIII., pp. 97–114; 1894.

abundance, until granite becomes the predominating rock. The schists are also cut by dikes of greenstone.

Elftman,[1] in 1894, publishes his field notes on Northeastern Minnesota. In the region north of Snowbank Lake are found conglomerate, mica-schist, sericite-schist, argillite, diabase, conglomeratic greenstone, porphyry, augite-granite and hornblende-granite. The former of these granites has heretofore been called gray syenite, and the latter red syenite.

On the west shore of Boot Lake, in the S.W. ¼, N.W. ¼, Sec. 21, T. 64 N., R. 8 W., are several large dykes of porphyry cutting the graywacke and schist. In the S.W. ¼, N.E. ¼, of the same section, on the east side of a long point, dikes of granite are found cutting the conglomerate in all directions, and distorting the strata in a very complicated manner. In the conglomerate are bowlders up to four feet in diameter of gneiss, slate, diabase and granite, the last being scarcely distinguishable from the granite which cuts the conglomerate. In some instances a granite dike was found to cut some of the large bowlders of the conglomerate, when the contact between the dike and the granite bowlders could not easily be determined. The exact relations of the hornblende-granite and the augite-granite to each other, and the relations of the latter to the sedimentaries, are still doubtful. The gray granite has not been found in contact with the schists, argillites and conglomerates, and it is cut by the red granite, which also cuts the schist. The hornblende-schists and mica-schists of Snowbank and White Iron Lakes grade into argillaceous slates and conglomerates, the schistose character being most fully developed at the contact with the granite.

The Animikie actinolite-magnetite-schists are derived from rock containing an original iron carbonate. As the formation thins out toward the east, and passes under the gabbro, it becomes more crystalline. Near the contact of the gabbro augite and olivine occur intimately associated with the actinolite and magnetite of the Animikie schists. The black slates have been changed into biotite-schist in the proximity of the gabbro. These slates disappear before the Dunke River is reached, having been removed at the time of the gabbro intru-

[1] Preliminary Report of Field Work during 1893 in Northeastern Minnesota, by A. H. ELFTMAN. Geol. and Nat. Hist. Sur. of Minn., 22d Ann. Rep., Part XII, pp. 141–180, 1894.

sion. The Pewabic quartzite at the bottom of the Animikie decreases in thickness as Birch Lake is approached from the west, and in the vicinity of Iron Lake disappears entirely. From this locality eastward the iron-bearing rock rests upon the granite. It is concluded that the Pewabic quartzite between Birch Lake and Gunflint Lake belongs to the middle iron-bearing member of the Animikie.

In Ts. 62 N. and 61 N., Rs. 10 W. and 11 W., occurs a heavily bedded olivine gabbro. In going from the northern and southern limits of the gabbro toward the center of the area it is noticeable that the ferro-magnesian minerals decrease and the feldspar increases in proportion, until in the center of the mass occur numerous knobs and areas, a mile or more in extent, composed of plagioclase rock or anorthosite, which are regarded as segregations. In the center of the mass the rock has greater coarseness of texture, and also more of a stratified appearance, arising from the arrangement of the constituent minerals in bands. The mineral and chemical composition of the various parts of the formation correspond to the known rules which govern the cooling of liquid magmas, and the whole is regarded as a batholitic intrusion rather than a surface flow.

Red rocks, comprising augite-syenite, quartz-porphyry, felsite, etc., occur in the vicinity of Greenwood Lake, and were followed to the shores of Lake Superior, making together one prominent group of rocks.

The dark gabbros of Irving, the diabases and the amygdaloids are placed in another group, called the diabase group. The anorthosites of the coast of Lake Superior, described by Lawson as pre-Keweenawan, and newly discovered masses back from the coast, are found to be detached blocks from the great gabbro mass enclosed in and underlain by the black gabbro, as previously held by Irving and Winchell. The latter rock is considered as the effusive equivalent of the great basal gabbro. After the aggregations of feldspar had separated from the gabbro magma, and were floating around in it, they were ejected in portions of the unsolidified magma, and being lighter than it, floated near the surface, and are found only near the top of the first outburst of lava or black gabbro. Later, when the rock was somewhat eroded, the feldspar knobs projected above the surrounding rocks, and later were covered by the flows of the red rock group. Therefore, the conclusion of Lawson that the anorthosite forms a pre-Keweenawan terrane, is rendered valueless.

In chronological order the Keweenawan of the north shore of Lake Superior can be divided into gabbro, diabase, red rocks and later dikes.

Grant,[1] in 1894, describes the lowest beds of Grand Portage Island, north coast of Lake Superior, as consisting of arenaceous slates, sandstones and conglomerates, the fragments of the latter being quartz, quartzite, siliceous slate, a dark flinty rock, red quartz-porphyry and red granite. These are in part clearly waterworn. All of the pebbles of the conglomerate can be matched in the Animikie strata near by. These beds are regarded as the lowest of the Keweenawan in this locality, and the material in the conglomerate shows that the Animikie clastics had been subjected to metamorphosing forces before Keweenawan time, and, as agreed by all Lake Superior geologists, that there was an erosion interval between the two. As the red quartz porphyry and the granite have been shown to be intrusive in the Animikie, and also in the gabbro and diabase of Pigeon Point and Grand Portage, it is concluded that these intrusions occurred at a date later than the Keweenawan.

COMMENTS.

It is to be presumed that this last statement applies only to the Keweenawan of the locality discussed.

Lawson,[2] in 1893, describes a multiple diabase dike near the mouth of White Gravel River on the northeast coast of Lake Superior, where occur in a breadth of fourteen feet no less than twenty-eight vertically intrusive sheets of diabase, ranging in thickness from one inch to six and one-half inches, separated by twenty-seven sheets of granite, ranging in thickness from a quarter of an inch to eight inches. The dikes anastomose and are connected at various places, showing that they are due to a single intrusion. The granite is seemingly homogeneous, there being no differentiation of structure or of mineral composition. It is believed that the splitting of the granite was due directly to the invasion of the diabase magma. This occurrence is comparable to the complex parallel invasion of the schistose rocks of the Ontarian system by granite.

[1] Note on the Keweenawan Rocks of Grand Portage Island, North Coast of Lake Superior, by U. S. GRANT. Am. Geol., Vol. XIII., No. 6, pp. 437–438, 1894.

[2] Multiple Diabase Dike, by A. C. LAWSON. Am. Geol., Vol. XIII., No. 5, pp. 293–296, May, 1894.

Spurr,[1] in 1894, gives an account of the rocks of the Mesabi district, and particularly of the iron-bearing rocks.

The oldest formation of the district is the Keewatin, the most common rock of which is green schist, but associated with this, especially near the granites, are hornblende-schists and mica-schists. The schists have a regional cleavage, which is nearly uniform in trend, about N. 70° E. and nearly vertical. Next in age to the Keewatin schists is the hornblende-granite of the Giants Range. This range has an average width of about ten miles, and its direction is the same as that of the schistosity of the Keewatin rocks. The granite is intrusive in the schists, as shown by numerous fragments imbedded in it, by stringers of the granite in the schists, and the metamorphism of the schists adjacent to the granite.

Unconformably upon the former is the Animikie series. The Animikie series has no marked folding, slaty cleavage or schistose structure. The rocks of the series are in a gentle southern monocline, in a direction perhaps 10° or 15° East of South. This monocline has gentle undulations, with axes parallel to its dip, and in the Virginia area has been faulted. The amount of disturbance is greater adjacent to the central part of the district, where are found the Keweenawan rocks. It is probable that the weight of the Keweenawan rocks has produced a sinking in the area south of the Animikie, and that this has produced the tilting. The Animikie series may be divided into three chief members: the Pewabic quartzite, the iron-bearing member and the upper slates. The Pewabic quartzite is a fragmental rock, indurated by the enlargement of quartz grains. It occasionally passes into a fine-grained conglomerate. The iron-bearing member is composed of peculiar rocks, presenting no resemblance to the Pewabic quartzite or to the upper slate. The upper slates are of great thickness, and have at their base an impure limestone, often dolomitized or sideritized.

The part of the iron-bearing member from Pokegama Falls to Embarass Lake is called the Western Mesabi range, that from Embarass Lake to Gunflint Lake, the Eastern Mesabi range, and from Gunflint Lake east, the International Boundary area. The description of the iron-bearing member below applies to the western part of the district. It has a thickness varying from 500 to 1000 feet, with an average of about 800 feet. The dip varies from less than 10° to as much as 30°,

[1] The Iron-bearing Rocks of the Mesabi Range in Minnesota, by J. EDWARD SPURR. Geol. and Nat. Hist. Sur. of Minn., Bull. X., p. 268, with geol. maps, 1894.

the width of the formation varying correspondingly from two or three miles to less than half a mile, the average width being one mile, and the average dip 10°. Resting upon the iron-bearing member is a great thickness of fine-grained slates, at the base of which is locally an impure dolomitic limestone. When this limestone is present, the contact between the iron-bearing member and upper slate cannot be distinctly located.

The least altered phase of the iron-bearing member is a rock called taconyte, which consists of a background of cryptocrystalline, phenocrystalline and chalcedonic silica, in which are numerous granules. These are composed of glauconite, siderite, hematite, magnetite, limonite and cryptocrystalline silica, in the very freshest phase the two former being predominant. The granules in one of these fresher phases by analyses showed about 35 per cent. of siderite and 65 per cent. of glauconite, or about 22 per cent. of ferrous oxide in the form of siderite; and about 10 per cent. of ferrous and ferric oxide, two-thirds being the former in the glauconite. Other analyses gave similar results. Analyses showed a very little calcium and magnesium. In the freshest phase found were seen, in thin section, probably detrital original grains of carbonate, recognized by their cleavage as calcite or dolomite. From the taconyte, by a complicated series of metasomatic changes, there have developed cherts and jaspers, which are sideritic, hematitic, magnetitic or actinolitic, or two or more of these combined. During the process the chert and iron oxides were largely concentrated in alternating bands. The cherts and jaspers are frequently concretionary and brecciated. They have often a prismatic jointing and horizontal parting.

These transformations were caused by downward percolating waters, carrying as the chief agents oxygen and carbonic acid, and as subordinate agents sulphuric acid and alkalies. In the changes from glauconite and siderite to the oxides, there was an important shrinkage of the mass, and this has resulted in the brecciation, prismatic jointing horizontal parting and banding. The prismatic jointing is analogous in its formation to the shrinkage of basaltic columns of lava. The horizontal parting is caused by a later shrinkage along the least diameters of the columns formed by the prismatic jointing. The banding is due to the removal of silica and the entrance of iron along the parting.

The ore deposits rests upon the Pewabic quartzite, or upon the hard and little altered iron-bearing rock, in areas of especial weakness or disturbance, as (1) actual fault lines, (2) incipient fault lines, (3) apices of anticlinal folds, and the troughs of synclines. These are places of fracture and where abundant waters were converged, often form wide areas, and therefore where large quantities of iron were supplied. The downward percolating water, taking iron carbonate in solution, precipitated the iron as oxide in those places where there was an abundance of oxygen, and at the same time took the silica in solution, thus forming the ore bodies. Between those of the largest size and the small local concentrations there are all gradations. The larger deposits of ore occur where they are protected from glacial erosion on the north by a hard ridge of the Keewatin rocks, and especially when the hard rocks give slight elevations on either side, so as to present a basin-like depression.

The glauconite in origin is believed to be the same as modern glauconites, that is, it has developed within foraminifera and other minute shells, as a result of a reaction between the organic matter within the shells and fine ferriferous clay. As the formation contains only a small quantity of ordinary fragmental quartz grains, it formed in water at a depth beyond which much of these material was deposited. As its upper horizon grades into limestone, this indicates a further subsidence of the area, so that the distance from the shore line became so great that very little mechanical detritus was furnished, and the deposit was made up of calcareous matter.

In the eastern Mesabi district the Animikie strata are pierced and intermingled with the northern border of the Keweenawan rocks, so that their normal attitude is often much disturbed. With this change the iron of the iron-bearing member becomes largely magnetic and the silica hard and crystalline. It is concluded that the iron before Keweenawan time was here in the state of sesquioxide, and that the heat of the igneous Keweenawan rocks and the disturbances of the Animikie series produced by them are the causes of the change of the sesquioxide of iron to its magnetic form. Thus the normal process of decomposition and concentration was brought to a close, and this probably explains the poverty of this part of the district in large ore deposits.

At the base of the Cretaceous are ferriferous detrital deposits derived from the Animikie. A study of these indicates that the metasomatic processes had gone far before Cretaceous time, although they have since continued to the present time.

COMMENTS.

This account of the Mesabi district is fairly satisfactory. The discovery of a large amount of glauconite in the least altered phase of the iron-bearing rock is an important additional point in the genesis of the rocks of the iron-bearing formations of the Lake Superior region. However, the conclusion that all of the iron of the iron-bearing formation, even in the Mesabi district, is derived from glauconite hardly seems established. In the least altered phase of the rocks, one which shows comparatively little or no evidence of change, according to the analyses given, a larger proportion of the iron is in the form of siderite than in the form of glauconite. Also in the least altered phase of rock, what were regarded as original detrital grains of calcite or dolomite were seen. These were taken to be one of these minerals from their cleavage, but as the cleavage of siderite is of an identical character, and as the analyses of the least altered phases of the rock show abundant siderite, and but a minute quantity of magnesium and calcium, it seems far more probable that this original material is siderite. There is no reason, so far as the writer can see, why a part of the iron should not have formed as siderite, and another part as glauconite, even in the Mesabi district itself, and it is wholly possible that in the Lake Superior region, in the Upper Huronian of which the Animikie is a part, in one district glauconite may have been the predominant form, while in another siderite was the more abundant.

It is of interest to note that the succession of rocks in the Mesabi district is the same as previously determined in the Penokee district and that the processes of development of the various phases of the altered ferruginous rocks, the agents which did the work, the resultant types and the concentration of the ore bodies, as given for the Mesabi district, are remarkably similar to those which have been ascertained to apply to other districts of the Lake Superior region.[1] The frequent presence of the ores in basins is regarded as due to the more resistant character of the surrounding Keewatin rocks, rather than to

[1] The Penokee Iron-bearing Series of Michigan and Wisconsin, by ROLAND DUER IRVING and CHARLES RICHARD VAN HISE. Tenth An. Rep., U. S. G. S., Chap. V., pp. 347–458, 1890, and Mon. XIX., U. S. G. S., Chap. V., pp. 182–295, 1892.

The Iron Ores of the Lake Superior Region, by C. R. VAN HISE. Trans. Wis. Acad. Sci., Arts and Letters, Vol. VIII., pp. 219–223, December 1891.

The Iron Ores of the Marquette District of Michigan, by C. R. VAN HISE. Am. Jour. Sci., Vol. XLIII., pp. 116–132, February 1892.

their original concentration in such places. The fact that the southern dipping monclinals are folded into a series of slight anticlines and synclines, combined with the presence of iron ore in basins, seems to me to be strong evidence that many if not all the larger ore bodies in the Mesabi district as elsewhere were concentrated in pitching synclinal troughs. The recent development of the mines confirm this conclusion and give no evidence that the large ore deposits have formed at anticlines or faults. The following laws, worked out in reference to the other districts of the Lake Superior region, appear also to apply to the Mesabi district, and if so, they may be said to be universal for this region.

(1) The iron ores always rest upon a relatively impervious basement. This basement may be a shale, a slate, a quartzite, an amygdaloid, a volcanic tuff, an intrusive mass or a dike, a less porous layer of the iron-bearing formation, or any combination of these. (2) Large ore bodies are chiefly found where the impervious basements, simple or complex, form pitching troughs. (3) These pitching troughs are particularly likely to bear unusually large ore bodies when the iron-bearing formation has been brecciated or shattered by folding or some other process, so as to allow ready entrance to percolating waters. Within the troughs the iron-bearing and oxygen-bearing solutions have been converged and mingled, thus precipitating the iron oxide.

Spurr,[1] in 1894, discusses the stratigraphic position of the Thompson slates of northeastern Minnesota. These have heretofore been correlated with the Animikie slates. However, almost every phase of slate of the Thompson series can be duplicated by the less altered phases of the Keewatin schists of the Mesabi range. In the vicinity of the Mississippi River the Thompson series becomes partly crystalline, being changed into sericitic, micaceous, hornblendic, staurolitic or garnetiferous schists which correspond exactly with the green schists of the Keewatin. The cleavage of the Thompson series marks a distinctively pre-Animikie disturbance. The trend of the cleavage corresponds with that of the schistosity of the Keewatin of the Mesabi range, and it is thought that the two were developed at the same time. The Thompson series has undergone a considerable folding, and in this respect also more resembles the Keewatin than the Animikie slates,

[1] The Stratigraphic Position of the Thompson Slates, by J. E. SPURR. Am. Jour. Sci., Vol. XLVIII., No. 294, pp. 159–165, August 1894.

which are in an undisturbed condition. The Thompson series is therefore regarded as unconformably below the Animikie, and is provisionally correlated with the Keewatin.

COMMENTS.

No petrographical descriptions are given of the Thompson slate and of the Keweenawan green schists which are said to be similar. The essential likeness or unlikeness of such fine-grained rocks as the Thompson slates and the Keewatin green schists can only be ascertained by microscopical studies. The Thompson slates with the microscope are seen to be little altered fragmental rocks, while the green schists of the Mesabi range are thoroughly crystalline, and in many places altered volcanic rocks. Further, the crystalline schists of the Mississippi River are not connected by continuous exposure with the Thompson slates, and may belong to a different series from them. Certainly a much more thorough study of the problem is required before it can be considered as probable that Irving was wrong in placing the Thompson slates as a part of the Animikie series.

C. R. VAN HISE.

THE

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## ON THE CLIFFS AND EXOTIC BLOCKS OF NORTH SWITZERLAND.

THE cliffs and exotic blocks that occur along the north border of the Alps and Carpathians have long remained as exceptional in occurrence and as difficult of explanation as were for years the so-called newer gneisses lying upon the early palæozoic sediments of northwest Scotland. The following paper is a brief summary of the work of two summers along the cliff-belt in Switzerland, chiefly in the region of the Lake of Lucerne where these phenomena are most typically developed. It will be my endeavor to present and discuss some of the problems which this work has suggested rather than to give a description of the region.

*Introduction and definition of terms.*—A glance at a good geological map of Switzerland[1] shows that the northernmost chains of the Alps, striking about E. N. E.–W. S. W. between Interlaken and the Upper Rhine valley (near the Sentis) are composed of Cretaceous strata with only rarely a patch of Jurassic rock exposed in the more deeply eroded anticlines and with Tertiary deposits filling in the synclines and in places reaching up over the backs of the more depressed Cretaceous folds.

These Tertiary beds require our first attention. They consist of a thick series of gray or bluish slaty clays, shales and marls with subordinately included banks of limestone, sandstone, brec-

[1] V. Geologische Uebersichts Karte der Alpen, by DR. FRANZ NÖE 1 : 1,000,000, Vienna, 1890, $2.50.

cias and conglomerates of early Tertiary (Eocene) and everywhere known under the name of *Flysch*. The thickness of the whole is, because of complicated movements which have taken place and the monotony of its petrographical characters, very difficult to determine. It has at some points been pinched out to a few feet; at others it is apparently several hundred feet in thickness.

This formation known as the Flysch is of especial interest to us because it is in it that the "cliffs" occur. The geological term "Klippe" or cliff, if we translate the term, was originally applied on account of the striking and abrupt manner in which these masses rise above their level or gently rolling Tertiary (Flysch) surroundings like cliffs above a beach. As geologists have learned more of the true nature of these masses, the term has come to take on a more definite geological significance, and is now somewhat loosely applied to island-like masses of rock which are stratigraphically, palæontologically, petrographically, and usually orographically foreign to the region in which they occur. Thus the Mythen overlooking the Lake Lucerne a short distance east of Brunnen and the Rigi are good types of the class —isolated masses, striking in appearance and composed of strata which have been found *in situ* nowhere else in all Switzerland.

To the rocks found in the cliffs the term "exotic" has been applied to express their foreign nature and to distinguish them from the "erratic" material brought down by the glaciers.

The exotic material of the cliffs consists of masses of dolomites, marls, shales and sandstones in certain of which characteristic Triassic and Jurassic fossils have been found. It lies upon or more or less imbedded in the soft Tertiary Flysch shales and the masses of it range in size from the smallest angular fragment up to cliffs a half mile and more in length and several hundred feet in height.[1] Of these the smaller blocks which were obviously loose, disconnected masses have been long known as "the exotic blocks" of the Flysch, while the more pretentious masses which on account of their size were *apparently in situ*, were termed

[1] For comparison v. Neumayr's description of the Carpathian cliffs which are often much larger than this. Erdgeschichte, Leipzic, 1887, Vol. II., p. 672.

"cliffs." A careful comparison of the cliff masses however with the exotic blocks showed that the two are the same. In point of size as well as facial development no distinction could be established between them, for the same strata containing the same fauna occur in both and in point of bulk the exotic block masses were found to occur in all sizes up to those of the smaller cliff masses. In the accompanying map the distinction between the two is a purely arbitrary one, the attempt being made simply to indicate the masses previously recognized as "cliffs" in the literature of the subject for convenience in discussion.

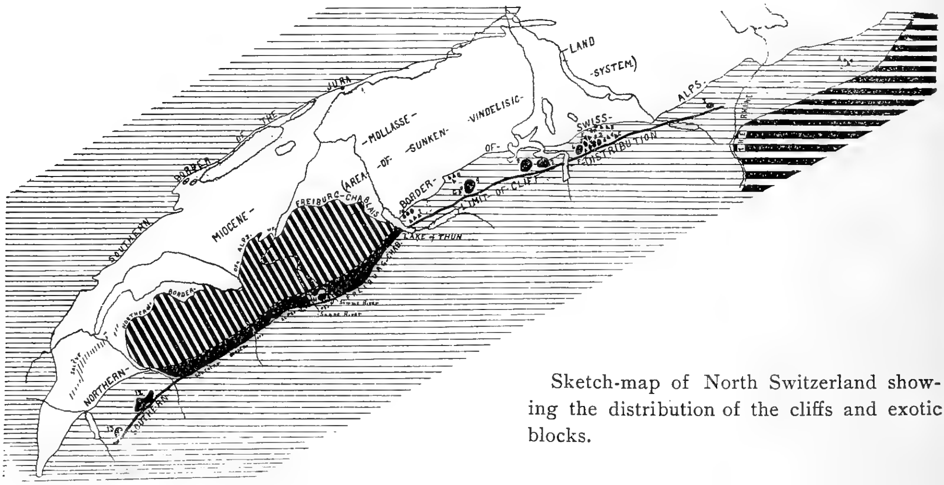
*Historical.*—Before proceeding to the results of my own studies I may introduce a brief sketch of previous work. On account of the scarcity of fossil remains in them the Swiss cliffs were long thought to be in some unexplained way mere abnormal developments of the strata of the adjacent chains and to be therefore of Cretaceous age. The petrographic similarity of one of the cliff strata now known to be Jurassic, to the Swiss Cretaceous Seewenkalk gave color to this idea. In 1875 Professor F. J. Kaufmann succeeded after long and patient search in discovering a set of fossils which proved beyond all doubt that the cliff masses on the Lake of Lucerne (Mythen, Buochserhorn, Stanzerhorn, and also the group to the southwest by Giswyl) contained a strata of Jurassic age.[1] Subsequent studies especially those of Stutz[2] have confirmed this and added to our knowledge of the fauna. The group of cliff-like masses to the east of the Mythen Iberg (see map) were at this time not recognized as belonging to the cliffs, as Kaufmann had in 1871 after a brief reconnoissance declared them on stratigraphical grounds to be a transition deposit between the uppermost Cretaceous and the base of the Jurassic. In 1889 Professor Steinmann upon further examination compared the strata here found in part with the Trias and Jura of Algau in the East Alps and held them to be of corresponding age. My own studies in 1891 and 1892 con-

[1] F. J. KAUFMANN, Fünf neue Jurassier, Jahrbuch des Schweits. Alpen Clubs, XI. Jahrgang, separate.

[2] STUTZ: Das Keuperbecken am Vierwaldstättersee, Neues Jahrbuch, 1890, II., p. 99.

firmed this view, as I succeeded in finding fossils which showed that these masses possessed in the main the same faunal peculiarities as the cliffs which Kaufmann had described farther west.

*Exotic and Helvetian series compared.*—The finding of fossils added rather than otherwise to the difficulty of understanding the cliffs because it marked more sharply than before the contrast between the exotic or cliff series on the one hand, and the normal or Helvetian series on the other. A brief tabular summary




Sketch-map of North Switzerland showing the distribution of the cliffs and exotic blocks.

of the cliff strata (including those in the exotic blocks and the Freiburg-Chablais Alps) will bring out more clearly this distinction:

SUMMARY OF THE CLIFF STRATA.

*Trias.*

1. *Lower Muschelkalk*, black limestone w. *Spirigera trigonella*, Schl.; *Aulacothyris angusta*, Schl.; *Coenothyris vulgaris*, etc. Not known in Switzerland outside of exotic series.

2. *Diplopora limestone*, gray to yellow, streaked with yellow dolomitic portions w. *Diplopora annulata*, Schfl; D. *macrostoma Gümb*, etc. Not known in Switzerland outside of exotic series.

3. *Rauhwacke and Gypsum.*—Found in Helvetian series also.

4. *Raible Marls*, dark gray to black, sometimes sandy, with *Equisetum columnare.* Unknown in Switzerland outside of exotic series.

5. *Rötidolomite*, yellow to rust colored, compact, crystalline. Found in Helvetian series.

6. *Haupt Dolomite*, hard, gray, sugar-grained dolomite, with angular fracture, very characteristic in the landscape. Found in Switzerland only in the exotic series.

7. *Rhätic*, gray to black crystalline limestone with *Avicula contorta*, very characteristic. Not found in Switzerland outside of the exotic series.

*Jurassic.*

1. *Liasic Fleckenkalk*, gray, brittle limestone w. black spots as if colored by bitumen. In Switzerland restricted to exotic series.

2. *Crinoidal Limestone of Lias*, brown to red, colored by iron; *Terebratula erbaensis*, Suess; *Rynchonella mutans*, Rothpl. In Switzerland only in exotic series.

3. *Crinoidal Limestone of Dogger*, like last, with *Pecten verticillatus* Stol., *Ammonites Sowerbyi*, etc. In Switzerland known only in exotic series.

4. *Birmensdorf beds.*—"Calcaire concrétionné" (?), hard, gray limestone in small rounded or lens-shaped masses imbedded in gray clay shale with (?) *Phylloceras.* Found only in exotic series in Switzerland.

5. *Malm.*—"Châtel limestone" of Studor with *Aspidoceras acanthicun* Opp., *Aptychus punctatus* Park, etc. Found only in exotic series.

6. *Radiolarian Chert.*—Red with iron, filled Radiolaria and associated with red clay. In Switzerland only in exotic series.

7. *Aptychus Limestone*, red and white fibrous limestone poor in macro-fossils (*Aptychus and Inoceramus*) but rich in *Foraminifera.* In Switzerland found only in exotic series.

*Cretaceous.*

*Berrias beds*, gray shales with *Aptychus angulicostatus.* Found also in northern chains of Swiss strata.

It will be seen that of the fifteen formations found in the exotic series three only—the Rauhwacke with the associated gypsum; the Rötidolomite and the Berrias beds, *i. e.*, two near the bottom and one at the top of the strata—are also found in the normal Helvetian series. In the strata between these we find in Switzerland in the Trias, which is in general but weakly developed, nothing at all to correspond to the characteristic Muschelkalk, Haupt dolomite, Contorta beds (Rhätic) etc. In the Jurassic of Switzerland we find a series of clay shales, sandstones, iron oolites and gray crinoidal limestones with fossils of middle European type and differing throughout from those found in the cliffs. These are followed by thick series of dark colored limestone with Jura facies in general.

*Geologic relations of cliffs to their surroundings.*—The differences which we thus see in the facial development of the Swiss strata and of the cliff or "exotic" strata of *the same age* lying side by side with them in north Switzerland, and beside which the correspondences seem quite insignificant, are so striking as to stimulate inquiry as to their cause and possible explanation.

The attempt was therefore first made to determine the relations which the cliff masses sustained to the surrounding Helvetian chains, to determine if possible whether these masses extended *down through* the Flysch above which they rose or simply lay as rootless block masses *upon* the Helvetian chains. It will naturally be impossible for us to enter here with any detail into a line of evidence based to a great extent upon local structural relations of the region studied and involving a considerable mass of local description and local facts.[1] There are, however, certain general features common to and characteristic of the cliffs to which I may refer. One line of such evidence is furnished by the conditions of the strata in the cliffs as contrasted with those near them. A second by the more general relations of the cliffs to the surrounding chains.

If the cliff masses be superficial in their nature, they must have been thrust from the side, and we should in that case find evidence of such overthrust in the cliff masses them-

[1] For these details cf. Beiträge z. geol. Karte d. Schweiz, Vol. XXXIII, Bern, 1893.

selves. Such we do find. All of the cliff strata show evidence of great pressure; they are fractured and often traversed thickly with calcite veins (especially the harder Haupt-Dolomite and the Tithon); the less brittle rocks are strongly contorted and full of cleavage structure and of slickensides (especially the softer Tithon beds of the cliffs); certain of the less resistant beds (as the Aptychus limestone and Raible marls on the Roggenstock and Laucheren) are greatly thinned by pressure or in places entirely pinched out. All these features are evidence of strong pressure, but more striking is the further fact in this connection, viz., that all evidence of disturbance, such as is found in the cliff masses and I may also add in the larger exotic block masses near the cliffs, is entirely wanting in the Helvetian strata all about. It might of course be said that the evidences of pressure mentioned would be as well accounted for if the cliffs were thrust powerfully upward from below through the younger Swiss strata upon which they lie, as has been thought by Professor Neumayr to be the case with the Carpathian cliffs. But at Iberg and in the other larger cliffs in the region of the Lake of Lucerne it is hard to see how such an upward thrust could have taken place powerful enough to force masses half a mile long through beds of limestone (Urgonkalk, Gault and Cenoman) several hundred feet thick without showing some evidence of the disturbance in the rock thus thrust through at least in the immediate vicinity of the cliffs. Such evidence, however, we fail to find either in the alteration of the general strike or dip of the Swiss beds or in indications of pressure in the minute structure of the rock itself. This contrast indicates that the one set of rocks has undergone disturbance which the other has not, and that the two have been affected by a different set of dislocations. In the Roggenstock near Iberg the cliff strata lie nearly horizontal. The Swiss strata below them are also nearly horizontal at this place. This position is what we would expect were the cliff thrust from the side, but very difficult to understand if they were thrust from below. The long, low mass of the Laucheren-Mördergrube cliff presents also the same difficulty on the latter hypothesis. Again the strata on the Roggenstock and the Kleine Mythe are not only nearly horizontal but actually in *inverted order* with younger strata below and older above. This complete inversion seems impossible to explain on the theory of an upthrust yet it is a common phenomenon accompanying powerful lateral thrust.

Without entering here into further details I may mention one or two facts of more general significance bearing on the relations of the cliffs to the surrounding strata. One very singular feature is the fact that the Swiss cliffs and the exotic blocks as far as I know them, invariably occur in the Tertiary Flysch shales. In spite of the extensive erosion which has attacked the whole region in which the cliff phenomena occur *the cliffs are found nowhere where the Flysch has disappeared.* If they came up from beneath, through the Cretaceous and Tertiary, we should surely expect to find hard and resistant limestones and dolomites of the cliffs at some points remaining after the softer Flysch shales had been eroded away, or at least some point where the cliff had not been thrust entirely through the Flysch and exposed between the jaws of a Cretaceous anticline on its way through. We find it difficult to see on the upward thrust hypothesis why the whole exotic phenomena should be dependent upon the presence of the Flysch. At Iberg we have a striking example of this dependence. It will be seen on a good general map that owing to a local sinking of the Swiss chains at this place, Flysch shales extend farther southward than they do to the east or west of here, continuing up over the top of the Roggenstock-Fallenfluh anticline, though usually confined to the troughs, and here also peculiarly enough the cliffs occur, *i. e.*, on the top of this anticline though more commonly the exotic phenomena appear in the Flysch-filled synclines only. If the Iberg cliffs could have come from beneath and be therefore associated in origin with the Swiss chains, it is difficult to understand why in the the strike of the anticline to the east and west of their present position they should disappear as soon as the Flysch disappears. This relationship between the cliffs and the Flysch becomes intelligible, however, as soon as we conceive of the exotic masses as thrust from the side and *thrust over Flysch* upon which and in which they lie, so that the erosion of the latter would necessarily bring about the erosion and disappearance of the former. Another striking feature of the cliff masses is to be found in the fact that in spite of the confusion into which they have been thrust they give evidence of a generic if not of an earlier actual physical connection with one another from the fact that they show in certain cases a notable *correspondence of irregularities* in two adjacent cliffs. Thus the Roggenstock and the adjacent Laucheren cliffs both present to us Triassic "Haupt Dolomite" lying upon Jurassic Aptychus limestone, and the striking correspondence of strata in the two neighboring masses of the Stanzerhorn and the Buochserhorn has been already remarked by Stutz in his description of them. This would be what we should expect were the cliff masses part of a general overthrust, much confused as a whole, but still showing in places evidence of the original unity of the entire mass.

The last two points suggest a third. If the cliffs are part of a general overthrust, as the whole region has been strongly eroded we might expect to find traces of the original overthrust in the material brought down by the agencies of erosion and deposited along the foot of the Alps. Singularly enough we do find in the Miocene lowlands stretching along the north border of the Alps a vast amount of material in fragments from a fraction of an inch to five or six feet in diameter and much waterworn as a rule, but often fossiliferous, and showing in striking degree the same facial development as the cliff series. This material occurs in thick banks of a more or less consolidated conglomerate known under the name of *Nagelfluh*. Dr. Früh, of the University in Zurich, who has given us the most complete account of this conglomerate, described from it "Muschelkalk," Diplopora Limestone, Rauhwacke, Haupt Dolomite, Rhaetic, "Fleckenkalk," Hierletz beds, Aspidoceras beds, Radiolarian chert and Aptychus limetone. A comparison with the table of cliff strata given above will show the striking similarity between the two. The evidence of very extensive erosion of cliff material thus afforded by the study of the Nagelfluh furnishes additional proof that the cliffs are but the last remnants of a once much more extensive cap covering the outer Alpine chains. Were the cliff masses thrust upward from below through the Helvetian Cretaceous and Tertiary anticlines we could hardly expect to find so much eroded material derived from them as we do indeed find in the Nagelfluh. For in that case we should expect the cliff masses to be in some places less completely thrust through the encasing younger strata, and therefore more or less completely hidden by them, so that the cliffs would become exposed to its action only after erosion had removed the younger covering. We should therefore expect to find the cliff masses increasing in number and extent as deepening erosion exposed them more and more to view. We find, however, abundant evidence that the cliffs cover a much less extensive area today than formerly. Again in case of an upthrust from below we should further expect that the percentage of cliff strata in the material carried from the surface by erosion would have been less in former times than it is today—it could surely not have been greater. An examination of the stream beds coming from the cliff belt shows today a decided preponderance of Helvetian over cliff strata in general. Instead now of finding in the Nagelfluh, as we would expect an even greater preponderance of Helvetian over cliff strata we find the amount of Helvetian rocks insignificantly small. This striking fact can, as it seems to me, only be explained on the ground that the Helvetian strata were at the time of the deposit of the Nagelfluh to a considerable degree protected from the erosion which attacked and carried down to the Miocene seashore vast quantities of cliff material. To assume that the protection consisted in a cap of cliff strata which covered large portions of the outer chains would be in harmony with the theory of overthrust but seems to be quite inexplicable on the hypothesis that the cliff masses were pushed up through the strata where they occur.

With this imperfect summary we have endeavored to give some of the more important reasons for believing that the Swiss cliffs are superficial phenomena lying upon the surface of the normal Swiss series and immediately upon the Flysch and have been therefore thrust from the side into their present position.

*Origin of the cliffs.*—We now approach another, perhaps the most difficult question relating to the cliffs—the question of their origin. As the cliff masses themselves do not furnish us direct evidence of the direction from which they may have been thrust, we are led to look for other and indirect evidence. The solution of this problem must depend therefore in great part upon the study of the faunal characters and relationships of the exotic strata, in connection with the stratigraphy, their petrographic characters and their distribution. An important circumstance and one which has probably retarded more than anything else the acceptance of the idea of overthrust, is the fact that, in distinction from the analogous phenomena in France, Scotland and America, in Switzerland no rock masses are known which contain *in situ* the strata and fossils found in the cliffs and whence therefore the cliff masses could be supposed to have proceeded. It has seemed therefore quite impossible to trace them to their original home or basin of deposit. In looking for the basin of deposit of the cliff series the region to the south of the cliff zone is soon seen to be excluded for reasons already indicated, viz., that the faunal and other characters of the exotic series are so entirely distinct from those of the Helvetian series which occupy all the district of the Glarnese Alps to the south, and although to the south still further strata bearing the same facial characters are known in the vicinity of the Italian Lakes the extreme distance of these outcrops, sixty-five miles or more, as well as the physical character of the intervening Alps, effectually precludes the possibility of deriving the cliffs from that quarter. As the cliff masses were evidently not introduced from the east or west we are led to look to the plains to the north (schweizer'sche Hochebene). Many years ago the famous Swiss geologist Studer for reasons quite different from those here considered was led to believe in the existence of a sunken mountain system[1] buried beneath the young (Miocene) strata of the Swiss plains which has since been assumed to exist by numerous other geologists and has received the name of "das Vindelisische Gebirge" from Professor Gümbel.

[1] Cf. Profiles in STUDER's Geologie der Alpen, Vol. II., p. 434–436.

The study of the cliffs has brought us back to this old hypothesis with renewed assurance of its innate probability.

In considering this question it is important to have clearly in mind the relations sustained by the "East Alps" (that portion of the Alps lying to the east of the Rhine) on the one hand, and by the Freiburg Alps to the west of Lake Thun on the other to our cliff masses. (Compare accompanying map.) The East Alps bound the cliff zone on the east as do the Alps of Freiburg on the west. Both the East Alps and the Alps of Freiburg have long been known to contain a Mesozoic rock series facially quite distinct from those of the normal Swiss mesozoic, so that the term "Helvetian (Swiss) series," "East Alpine series" and "Freiburg series" have been used to distinguish the three. Since the time of Brunner's discovery of *Avicula contorta*, a characteristic East Alpine upper Trias form, in the Alps of Freiburg (Stockholm) it has been repeatedly pointed out that there are numerous features of resemblance between the strata of these two territories lying at either extremity of our cliff zone. Realizing the importance of establishing this point and the relations of the cliffs to the whole, I undertook to make a tabulation of the strata and fossils of the Trias, Jura and lower Cretaceous (all occurring in the cliffs and exotic blocks) of (1) the "East Alps," (2) the cliffs and exotic blocks, and (3) the Alps of Freiburg. The result of this comparison has shown that the strata of all three have essentially the same facial development, and might belong therefore to the same basin of deposit. (For the geographic relations of these regions see map.) The importance of this point for the understanding of the cliffs can hardly be overestimated. It shows us that the basin of deposit of the East Alpine series was not confined to the east of the Rhine, but extended, or at least repeated itself, far to the west of it along the north border of the Alps; it shows us further that the cliff zone stretches between the East Alps and Freiburg Alps as the remnant of a once more or less continuous deposit connecting the two; and it leads us to suspect that on the same basis of unity whatever greater movements have taken place in the cliff masses would be very likely to have similarly affected the strata of the Alps of Freiburg. In order to test this point I visited the Alps of Freiburg in the summer of 1893. We ought here to be able it was thought (1) to distinguish clearly between the "Freiburg" (exotic) and the normal "Helvetian" series and therefore determine by direct examination at the place of contact between the two kinds of rocks whether the Freiburg strata show evidence of an overthrust southward upon the Swiss chains as we had been led to assume was the case with the cliffs. The results of these investigations, published elsewhere,[1] showed evidence of an overlapping of Freiburg strata southward 4.5 kilometers upon normal and characteristic Helvetian beds, which were disclosed in the deeply cut valleys of the upper Simme and Saane rivers. Here, too, we find the same sharp contrast between the excessively disturbed and often inverted Freiburg strata and the horizontal Helvetian series that we noted in the cliff zone to the east; also similar breccias occur on the plane of overthrust. Here, too, as in the vicinity of Iberg, the overthrust is everywhere over the Flysch, so that the time of the movement corresponds to the time of movement farther east.

Another feature which favors the view of overthrust from the north is to be found in the peculiar distribution of the exotic material over the belt occupied by the cliffs. Here I cannot perhaps do better than to refer to the accompanying sketch map where this feature is indicated, and point out what the map is intended to show.

## EXPLANATION OF THE SKETCH MAP.

The map of North Switzerland shows the distribution of the cliff masses and "exotic blocks" of North Switzerland in the cliff zone extending from Lake Thun to the Rhine and the relation of this cliff zone to the surrounding country. All portions colored black, either solid or diagonally striped, represent exotic material. The size of these masses has been necessarily exaggerated in the map, though the relative size of the different

[1] Berichte der naturforschenden Gesellschaft zu Freiburg in Baden, Vol. IV., No. 2.

exotic masses among themselves and their relative abundance has been expressed as well as possible.

In this cliff zone the rounded black patches represent the larger cliff masses as follows:

No. 1 (eastermost cliff known) = Berglittenstein cliff, in the Toggenberg syncline near Grabs.
No. 2 = Roggenstock cliff, near Iberg in Upper Sihl valley.
No. 3 = Laucheren-Mördergrube cliff, near Iberg.
No. 4 = Schien-Gründelhüttle cliff, two masses near Iberg.
No. 5 = Zweckenalp cliff, near Schwyz, Lake of Lucerne.
No. 6 = Die Mythen cliffs—three masses near Schwyz.
No. 7 = Buochserhorn cliffs—three distinct masses according to Heim[1]; five according to Stutz[2]; on Lake of Lucerne.
No. 8 = Stanzerhorn cliff—near Lake of Lucerne.
No. 9 = Giswyl cliffs—several more or less disconnected masses.
No. 10 = Niederhorn cliffs—three small exotic masses described by Kaufmann,[3] near the northwest foot of the Niederhorn.
(I may also mention here for completeness, farther to the west.)
No. 11 = Lenk-Lauenen cliffs[4]—exotic masses in the Upper Saane valley between Lenk and Lauenen.
Nos. 12 and 13—Westernmost cliff-like masses = Thônes masses—thought to be "cliffs," to the southwest of the Chablais region.[5]

In this same Thun-Rhine cliff zone are also represented, as well as could be in a map of this size, the distribution of the smaller exotic masses or "exotic blocks" (in general those masses that are less than 25 meters in diameter) as far as I have been able to determine their presence either by personal visit or, as in one instance (H), from the literature alone. There is undoubtedly much more such material in the Flysch which further search will reveal. The principal groups of exotic blocks are indicated on the map by the following letters:

[1] HEIM: Unser Wissen von der Erde, Geogr. Anstalt. Leipsic, 1889—see map of Lake Lucerne.

[2] Das Keupenbecken am. 4- Waldstätter See, Neues Jahrbuch, etc., 1890, II. p. 99 ff.

[3] Beiträge z. geol. Karte der Schweiz, Vol. XXIV., pp. 282–285, 524.

[4] See Berichte der Naturforsch. Geo. zur Freiburg i B., Vol. IX., No. 2, p. 122 ff.

[5] See FAVRE: Carte geol. d. voisines du Mont Blanc, Winterthur, 1862.

| | | |
|---|---|---|
| A | Easternmost group | = Bolgen group—west of the Iller valley. |
| B | | = Barlaui Alp group—northeast of Iberg. |
| C | | = Tannstaffelalp group--in Wäggi valley east of Iberg. |
| D | | = Steinibach group, four to six kilometers north of Iberg. |
| E | | = Geschwend-Surbrunnen group—one to two kilometers north of Iberg. |
| F | | = Gründelhüttli group, west of Iberg. |
| G | | = Giswyl group, near Giswyl. |
| H | | = Flühli group, northwest of Giswyl. |
| I | | = Habkern group, in Habkern valley. |

At the south edge of Freiburg Alps southwest of Lake Thun may be mentioned:

| | |
|---|---|
| J | = Lenk-Lauenen group, between Bad Lenk and Lauenen. |

At the west end of the Rhine-Thun cliff zone are seen the Alps of Freiburg and Chablais. It should be noted that the southern edge of these Alps are in line with the southern limit of cliff distribution; the northern border, on the other hand, is not in line with the northern border of the Swiss Alps, but extends in the form of a bow far out into the Miocene plains (Molasse land). In the upper valleys of the Saane and Simmen rivers (see map) where these valleys are cut deeply into the Freiburg strata typical Helvetian strata, Flysch and Nummulitic limestone have been found lying below Triassic and Jurassic strata in Freiburg facies,[1] indicating that the Freiburg Alps at this point were thrust southward two and one-half to four and one-half kilometers over the Helvetian strata. We have, therefore, drawn a dotted line across the southern portion of the Freiburg-Chablais zone to indicate the probable zone of overthrust and colored all south of this zone black. It may, however, be that this overthrust is of a more local nature. The remainder of the region is striped diagonally black and white.

To the east of the Rhine-Thun cliff zone the area of the strata in East Alpine facies is roughly indicated by alternating

[1] Cf, Berichte d. Naturforschende Gesell. v. Freiburg i. B. Vol. IX., Part 2, p. 122, 1894.

bands of black and white running horizontally. It will be seen that the East Alps do not begin at once at the Rhine, but there is a promontory-like wedge of Helvetian strata (fine black horizontal lines) projecting along in front of their north border a considerable distance. In this wedge occur the enigmatical exotic bowlders by Bolgen (A of the map).

It will be noticed that the cliffs and exotic blocks are scattered with considerable irregularity along the north border of the Alps over a belt of Helvetian strata (indicated by the light horizontal lines) from about two to nearly nine kilometers broad. The exotic masses do not extend anywhere south of this strip. In the vicinity of Iberg, which has been studied with especial thoroughness, may be seen how the whole region between the southern border of the cliff belt and the northern border of the Helvetian chains is covered with exotic material. Abundant as is this exotic material here, every trace of it disappears a short distance south of the cliffs. This most striking limitation of the distribution of the exotic strata southward all along the Thun-Rhine cliff belt is precisely what we would expect if there had been an overthrust like that hypothecated.

*Summary and conclusion.*—To recapitulate, we have found Alpine facies in the Freiburg Alps at the west end of the cliff zone, Alpine facies again at the east end in the "East Alps," Alpine facies also in the superficial cliffs and exotic blocks between these two points. In the Nagelfluh we have evidence of a former much greater extent of the cliff masses. In the cliffs themselves and in the fact that cliffs and exotic blocks lie invariably in Flysch we find evidence that they were thrust over Flysch; lastly, in the supposed Vindelicic system beneath the Miocene plains north of the cliffs we have a place—and apparently the only place—from which it seems possible that the cliffs could have been derived. These conclusions afford us the most satisfactory explanation of the cliff belt and the Freiburg-Chablais region as a whole and their relations to the East Alps, and render intelligible the presence of the Swiss plains—sunken between the "horsts" of the Alps and the Jura—and the isolated position of the Jural mountains on the far side of them.

Bearing in mind the geographic relations of Cliff-Freiburg-Chablais exotic belt we can, in accordance with the above view, reconstruct in some measure the geographic conditions of this part of the world in early and middle Mesozoic times. According to this view there extended in Jura-Trias times between the present site of the Alps and the Jural mountains opposite a Vindelicic sea in which East Alpine life and conditions prevailed. A comparison of the exotic (Vindelicic) series with the Helvetian and Jurassic faunas shows beyond doubt that the cliff series represent deposits in comparatively deep water.[1] We may, therefore, assume that the sea of this region was at that time characterized along the Vindelicic area by a deeper sea. If the passage from the more shallow Helvetian to the deeper Vindelicic sea was not too abrupt we might therefore expect to find indications of transition in the outermost (northernmost) chains of the Alps. Hence the fact pointed out by Stutz that along the Axenstrasse on the Lake of Lucerne the outer chains contain certain subordinate beds of more Alpine facies (Diphya-beds, "Stramberg beds"—strata with Terebratula janitor) has a peculiar interest. And the fact that certain of the cliff strata have been shown to present facial similarity to others occurring on the north side of the Vindelicic region would further bear out this conception by showing a relationship between the cliff series and strata to the north.

E. C. QUEREAU.

[1] As evidenced, for example, by the presence of Aptychus limestone, Globigerina shales, Radiolarian chert and associated red clay in the cliffs.

# THE PREGLACIAL VALLEYS OF THE MISSISSIPPI AND ITS TRIBUTARIES.

It is the purpose of this paper to bring together such data as are available on the subject of preglacial drainage lines, in the northern part of the Mississippi basin. It is thought that such a presentation will aid in drawing inferences concerning several important questions connected with glaciation; among which are the preglacial altitude of the region, the differential crust movements, and the effect of glaciation in enlarging and deepening valleys. It will be mainly a contribution of facts. The questions upon which these facts have a bearing need the full light of these and other data before inferences of much value can be drawn.

This district has, in some respects, advantages not possessed by other districts. (1) It has a driftless area in which the breadth and depth of large preglacial valleys can be accurately determined. The location of this driftless area is particularly fortunate, being over the line of so prominent a valley as the Mississippi, a valley which crosses drift-covered areas both above and below the driftless area. (2) In some parts of the glaciated region the oldest drift sheets are not well represented, and it often becomes difficult to decide whether a given valley was cut to its present depth in preglacial time or has been deepened in inter-glacial or post-glacial times. In the region here discussed some of the valleys are filled with the oldest drift sheet of which we have knowledge, and their floors have not since been subject to the scour of streams. We can, therefore, confidently place their excavation before the first ice invasion. (3) In this region the valleys of some of the main arteries of preglacial drainage are found running parallel with the longer axis of one of the deepest lake basins, the basin of Lake Michigan. A study of the contours of these valleys, combined with a study of the lake basin should help to an understanding of the influence of the ice-sheet in giving this basin its low altitude. The slope of preglacial valley floors will throw light upon differential crust movements which have affected the basin. Unfortunately we have as yet very few data from Wisconsin, a district which should furnish many important data when the reports of its borings are collected and its preglacial drainage lines worked out.

### COURSES OF THE MAIN PREGLACIAL DRAINAGE LINES.

Concerning the course of the Mississippi above the mouth of the Minnesota River very little is known. It is probable, however, that its drainage area was about as great as that of the present stream. From the mouth of the Minnesota southward to the mouth of the Wapsipinnicon River below Clinton, Iowa, a distance of about 300 miles, the present stream follows the line of the preglacial, the only deviations from that line being slight encroachments on the bluffs of the old valley, as at Fulton, Illinois, where a rocky point belonging to the old west bluff has been cut off by the present stream. Below the mouth of the Wapsipinnicon, the present stream for a distance of forty miles (to Muscatine, Iowa) is in a new course. The bordering districts are heavily covered with drift and it is not an easy matter to determine the course of the old valley. I expressed the opinion, some three years ago, that the course was southeastward through the Green River basin to a bend of the Illinois River near Hennepin.[1] This opinion was based upon the existence of a low tract of country connecting the Mississippi with the Illinois along the north border of the Coal Measure formations. It has since been discovered by Professor J. A. Udden that a similar tract of country more completely concealed by the drift follows the northern border of the Coal Measure area westward and southwestward from the mouth of the Wapsipinnicon through Scott and Muscatine counties, Iowa, to the old valley below Muscatine. Which of these courses was taken by the preglacial upper Mississippi is being made a matter of special investigation by Professor Udden, and we look for an early publication of the results of his investigations. He informs me that the lowest

[1] Proc. A. A. A. S., Rochester Meeting, Vol. XLI., 1892, p. 176.

altitudes yet brought to light by borings are along the line leading through eastern Iowa, but that the line leading southeastward to the Illinois has been less perfectly tested by borings and hence may contain a channel equally deep.

From Muscatine to the Mississippi embayment of the Gulf above Cairo, Illinois, the present line of the Mississippi is nearly coincident with that of the preglacial line. The most important diversion is at the lower rapids just above Keokuk, where for a distance of twelve miles the present stream is cutting a new valley parallel to and slightly east of the preglacial course. There are slight diversions of the present stream into the edge of the bordering bluffs at two points below St. Louis, similar to the one noted above, at Fulton. One of these is at Fountain Bluff and the other at Thebes, Illinois. The preglacial course is plainly traceable around the rocky points which the present stream cuts off, and is utilized at flood seasons in both cases.

In the district between St. Paul, Minnesota, and the mouth of the Illinois the eastern tributaries of the Mississippi, with the exception of the Wisconsin River, were very small, owing to the existence of a large parallel valley traversing southern Wisconsin and western Illinois, as shown below. Western tributaries of the Mississippi appear to have drained a wide area but their courses have not as yet been worked out, for the region is very heavily covered with drift, and a large number of borings will be necessary to establish, even approximately, the course of preglacial drainage. It is certain that the present and preglacial systems of drainage are coincident in but a few places.

The preglacial Rock River drainage basin apparently extended to the Mineral Ridge axis on the northwest and to the Niagara escarpment on the east. The course of the main line of drainage was probably along the axis of the trough west of the Niagara escarpment. Whether the drainage of this trough was then divided, as at present, between Green Bay and Rock River, the writer is not prepared to judge, for this is a district which has not been personally examined and the published data are scarcely adequate to warrant a decision.

Rock River follows nearly its preglacial course from the Kettle moraine in southern Wisconsin, southward to the mouth of the Kishwaukee, a few miles below Rockford, Illinois, where it turns to the southwest and follows a new valley to the Mississippi.[1] The preglacial course of the river is plainly traceable southward from the mouth of the Kishwaukee across eastern Ogle county to the vicinity of Rochelle, the drift being insufficient to fill the old valley to the level of the bluffs. From Ogle county southward across Lee and Bureau counties to the bend of the Illinois River at Hennepin, borings have shown the presence of a deep channel. Several have gone to depths below that of the rock surface a few miles to the west. Only one of these borings, the artesian well at Princeton, Illinois, has reached the rock floor. This shows a drift filling of 440 feet, and probably strikes the deepest part of the old valley, the rock floor being as low as at any point yet found in the course of the whole channel. There can scarcely be a doubt that the preglacial course of Rock River was southward along this line to the Illinois, and thence to the Mississippi, though we have as yet no borings, except the one at Princeton, which test its deepest portion at any point between the Wisconsin line and bend of the Illinois.

The courses of the preglacial tributaries of the Rock-Illinois are known only in a few instances, owing to the great amount of drift which conceals them. The Pecatonica Valley which enters from the west, just below the Wisconsin line, is mainly in a preglacial course and so are its main tributaries, Yellow Creek and Sugar River. The Kishwaukee is largely in a new valley and enters the Rock River Valley through a gorge at its mouth. The upper portion of the Illinois, including its headwater streams—the Fox, the Des Plaines and the Kankakee—are all in postglacial valleys. They cross a somewhat elevated limestone district which, like the Niagara escarpment to the north, seems to have formed the preglacial watershed between the Rock-Illinois drainage basin and the basin now occupied by Lake Michigan. They thus bring to the present Illinois the drainage of a large district which formerly discharged into the Lake Michigan basin.

[1] Changes of drainage in the Rock River basin in Illinois, by FRANK LEVERETT, Proc. A. A. A. S., Madison Meeting, Vol. XLII., 1893, p. 179.

Southward from Hennepin the drift deposits are so heavy that it has been found impossible to map out the courses of preglacial drainage. A basin or expansion of the valley just north of the mouth of the Sangamon River, and a very low altitude of rock surface for some distance to the east of this basin is thought to indicate the point where a large preglacial tributary enters from the east. The Sangamon drains a region which probably then, as now, discharged to the north, perhaps joining this large eastern tributary. South from the Sangamon River the preglacial tributaries were about the same size as the present, there being a well-defined rock divide between the headwaters of the south fork of the Sangamon and the lower portion of the Illinois. The western tributaries of the Illinois were probably small as were the present ones, owing to its nearness to the Mississippi.

The present Wabash River follows a preglacial drainage line from its bend near Covington, in western Indiana, southward to the Ohio River. The stream is in a new valley for a few miles above Covington but is again in a preglacial valley in the vicinity of La Fayette. It is probable that this preglacial valley leads westward past Oxford, Indiana, and thence south to the preglacial Wabash near Covington. From near Delphi, Indiana, to its source the Wabash is mainly in a new course. The headwater portion of the streams forming the preglacial Wabash may prove to have been in the Lake Michigan basin. But if so the connection with the Wabash is through a very much narrower trough than that occupied by Lake Michigan. Borings at North Judson, Winamac and Monticello, Indiana, situated near the line connecting the head of Lake Michigan with the preglacial valley at La Fayette, go to a level about 100 feet below the surface of Lake Michigan before entering rock. But within a few miles east of this line, rock ledges have an altitude as great as the surface of Lake Michigan, while immediately west of this line they rise 90–125 feet above that level. This trough cannot have, in the vicinity of Monticello, a breadth of more than ten miles. Monticello is situated near the middle of the trough. The probabilities are, therefore, against the existence of a much deeper channel in it.

Borings have been made at frequent intervals westward and northwestward from this trough across northwestern Indiana and northeastern Illinois and none of them show so low a rock surface as this line presents. They usually enter rock above the level of Lake Michigan. There seems, therefore, no ground for suggesting a southward or southwestward outlet of the Lake Michigan basin further west than the line which leads from the head of the lake to La Fayette, Indiana. Furthermore this seems the most probable line for a channel, since it follows nearly the western edge of the soft Devonian shales, where degradation would naturally proceed more rapidly than in the firm and resistant limestone ledges to the west.

The tributaries of the Wabash in its lower portion follow, to a large extent, their preglacial courses. The eastern tributaries drain a driftless region in Indiana, while the western drain a region thinly clad with drift in southern Illinois. From the latitude of Terre Haute and St. Louis southward, the Mississippi and Wabash seem to have divided the drainage of southern Illinois in preglacial times, about as they do at present.

The Ohio River seems to have been greatly enlarged by the ice invasion. But little study has been given the lower course of this stream. It is probable, however, that from southern Ohio to its mouth it follows nearly the preglacial line, since that portion was encroached upon but little by the ice-sheet. The upper course from eastern Ohio northward seems to have discharged to the Lake Erie basin.[1] The Muskingum Valley of eastern Ohio is thought by Professor W. G. Tight, to have discharged northwestward in preglacial times, instead of southward into the Ohio.[2] The data collected by Professor Tight make it appear quite probable that this valley was a tributary to the Scioto basin. The view that it continued across that basin into the Wabash seems less fully sustained.

[1] For a presentation of the evidence see Amer. Jour. Sci., Vol. XLVII., 1894, pp. 247–283. The paper referred to contains references to the literature of the subject, which is already quite extensive.

[2] A contribution to the knowledge of the Preglacial Drainage of the Ohio, W. G. Tight, Bull. Sci. Lab., Denison University, Vol. VIII., pp. 35–61. With two plates. Granville, Ohio, 1894.

ELEVATION AND SLOPE OF PREGLACIAL VALLEY FLOORS COMPARED WITH PRESENT STREAMS.

*The Mississippi Valley.*—In this discussion we assume for convenience that the upper Mississippi found its continuation from the mouth of the Wapsipinnicon through Scott and Muscatine counties, Iowa, to the preglacial valley below Muscatine. On a subsequent page we discuss the comparative elevations and slopes of the valley floors of the upper Mississippi and the Illinois.

In preparing the table which follows some difficulty was found in deciding upon distances. In the portion above Cairo there are few oxbows or other deflections from a direct course, hence the distances at high and low water stages are not greatly different, and the high water distance is usually taken. In the portion below Cairo the oxbows and deflections of the stream are numerous. The low water stage involves, therefore, a much greater distance than the high water stage. The distances given are the low water route. They are taken from *Dana's Manual.* The distance from Cairo to Memphis at high water stage is about 150 miles, or only two-thirds that of the low water stage. Between Memphis and the Gulf the distance at high water is estimated to be but 500 miles, or 350 less than the low water stage. Taking the direct course, the rate of fall between Cairo and Memphis at high water stage is 8.24 inches per mile, while between Memphis and the Gulf it is 5.23 inches per mile. Some interesting differences in the rate of fall between certain points at high water and low water stages appear in the upper Mississippi. Thus for a few miles above each of the rapids there is a greater fall at flood stage than at low water. The low water stage is below the usual rate of fall, owing probably to the barrier presented by the rock floor at the head of the rapids. This barrier has little effect upon high water stages, and the descent of the stream is, therefore, nearer the normal.

It is probable that the borings at Fort Snelling, St. Paul, Dubuque, Sabula, Fort Madison, Bellefontaine and East St. Louis, enter the deep part of the preglacial channel, though they may not mark the very lowest limit of erosion. The other borings probably strike shelves bordering the channel when not on

RATE OF FALL OF THE PREGLACIAL ROCK FLOOR AND THE PRESENT MISSISSIPPI FROM FORT SNELLING, MINNESOTA, TO THE GULF OF MEXICO.

| Location | Dist. Miles | Low Water A. T. | High Water A. T. | Fall per Mile L. W. | Fall per Mile H. W. | Rock Floor A. T. |
|---|---|---|---|---|---|---|
| | | Ft. | Ft. | In. | In. | Ft. |
| Ft. Snelling, Minn. | 0 | 686 | ........ | ........ | ........ | 486[1] |
| St. Paul, Minn. | 6 | 683 | 702 | 6.00 | ........ | 483[1] |
| Lake City, Minn. | 55 | 658 | ........ | 5.45 | ........ | 495[2] |
| La Crosse, Wis. | 68 | 628 | 643 | 5.30 | 5.75 | 504[3] |
| Prairie du Chien, Wis. | 60 | 604 | 623 | 4.80 | 4.00 | 492[3] |
| Dubuque, Iowa | 55 | 585 | 607 | 4.14 | 3.49 | 453[3] |
| Sabula, Iowa | 36 | 572 | 592 | 4.33 | 5.00 | 429[4] |
| Fulton, Ill. | 16 | 566 | 587 | 4.50 | 3.75 | 465 |
| Le Claire, Iowa (New Ch.). | 20 | 562 | 576 | 2.40 | 6.60 | 550 |
| Rock Island, Ill. (New Ch.). | 16 | 542 | 560 | 15.00 | 12.00 | 530 |
| Muscatine, Iowa (New Ch.). | 24 | 531 | 547 | 5.50 | 6.50 | 506 |
| Near Wilton, Iowa (Old Ch.) | ........ | ........ | ........ | ........ | ........ | 400–[5] |
| Mouth of Iowa River | 18 | 523 | 539 | 5.33 | 5.33 | 445– |
| Burlington, Iowa | 24 | 511 | 527 | 6.00 | 6.00 | 430– |
| Ft. Madison, Iowa | 18 | 502 | 518 | 6.00 | 6.00 | 365[6] |
| Near Montrose (Old Ch.) | ........ | ........ | ........ | ........ | ........ | 374[7] |
| Montrose, Iowa (New Ch.). | 9 | 500 | 514 | 2.66 | 5.35 | 490 |
| Keokuk, Iowa | 12 | 477 | 494 | 23.00 | 20.00 | 470 |
| Quincy, Ill. | 38 | 458 | 476 | 6.00 | 5.68 | 413[8] |
| Hannibal, Mo. | 17 | 450 | 467 | 5.64 | 6.35 | 362[9] |
| Louisiana, Mo. | 25 | 437 | 453 | 6.24 | 6.72 | 380–[10] |
| Mouth of Illinois River | 68 | 403 | 422 | 6.00 | 5.47 | ? |
| Bellefontaine, Mo. | 17 | 402 | 420± | 0.70 | 1.40± | 295[11] |
| East St. Louis, Ill. | 24.3 | 380 | 414 | 10.86 | 2.96± | 284[12] |
| E. Carondelet, Ill. | 6 | 377 | 412 | 6.00 | 4.00 | 330 |
| Fountain Bluff, Ill. | 100 | 313 | 357 | 7.68 | 6.60 | 300[13] |
| Thebes, Ill. | 40 | 291 | 339 | 6.60 | 5.40 | 280[13] |
| Cairo, Ill.[14] | 35 | 270 | 321 | 7.20 | 6.16 | ? |
| Memphis, Tenn.[15] | 233 | 183 | 218 | 4.48 | 8.24 | ........ |
| Mouth of river | 855 | 0 | ........ | 2.56 | 5.23 | ........ |

[1] N. H. WINCHELL: Amer. Geol., Aug., 1892.

[2] Geol. of Minnesota, Vol. II., p. 17.

[3] CHAMBERLIN and SALISBURY: Sixth An. Rept. U. S. G. S., p. 223.

[4] Data given by W. R. Oake, Ex-Mayor of Sabula.

[5] This point is about ten miles from Muscatine and fifty miles from Fulton making the old course about the same length as the new one. A well at this point, reported by Professor Udden, failed to reach rock at elevation 400 feet A. T.

[6] C. H. GORDON: Geol. of Iowa, Vol. III., 1893, p. 246. A well one-half mile north of Ft. Madison reaches a level about 365 feet A. T. without entering rock. The channel may, therefore, be deeper than that shown by the Ft. Madison wells.

[7] Beck's Artesian Well, Geol. of Iowa, Vol. III., p. 247.

[8] Bridge piers rest on a rock shelf 35–40 feet below low water (G. K. Warren).

[9] Data concerning channel piers furnished by W. S. Lincoln, Chief Engineer of Wabash Railroad, St. Louis, Mo.

slopes near the border of the valley. It certainly should not be assumed that they have entered the deepest part of the channel.

If the borings at the points named reach the lowest part of the channel, we may estimate the rate of descent of the rock floor between St. Paul and St. Louis. Between St. Paul and Sabula, a distance of 274 miles, the descent is only 57 feet or 2½ inches per mile. Between Sabula and Fort Madison, a distance of about 140 miles, the descent is 64 feet or about 5½ inches per mile. Between Fort Madison and East St. Louis, a distance of about 210 miles, the descent is about 80 feet or 4.57 inches per mile. These data indicate much less descent from St. Paul to Sabula than below Sabula. We can hardly suppose that a much deeper portion of the channel occurs opposite Sabula, for the well at this village was sunk in the middle of the valley. It seems probable, therefore, that the valley floor has been slightly warped, so that its altitude at Sabula is higher, or at St. Paul lower, than it was when the stream flowed upon the rock floor. To completely demonstrate such a warping, it will be necessary to make certain that the low altitude at Fort Snelling and St. Paul is not due to local deepening, such as may have been produced by glacial water falls, or by subglacial erosion by water or ice. At Sabula no such agencies could have been operative.

The descent in the rock floor, from Sabula to East St. Louis, is not markedly different from that of the present stream, being 145 feet, where the present stream falls 192 feet. If we reduce the descent of the present stream at the two rapids to the average rate for the river it lessens the difference thirty feet, leaving but seventeen feet difference in a distance of about 350 miles,

[10] Bed of present stream is 380 feet A. T. (G. K. Warren).

[11] Mo. Riv. Com. Rept. for 1890. The low water altitude here given is on the Missouri.

[12] Data concerning depth to rock at bridge piers, furnished by Robert Moore, C. E., St. Louis, Mo.

[13] In new channel (G. K. Warren).

[14] Low water varies from 267–279 feet A. T. (Gannett).

[15] Tertiary clays set in at bed of river and extend nearly to sea level (Reports on Memphis water supply, by J. M. STAFFORD and LAWRENCE JOHNSON, issued by Artesian Water Co. of Memphis).

or but six-tenths of an inch per mile. Under present conditions the river will soon remove the rapids and reduce its rate of fall to that of the rock floor, if not, to a lower rate.

*The Missouri Valley.*—For purposes of comparison with the Mississippi Valley, and valleys further east we introduce at this point a few statements concerning the Missouri Valley, followed by a table showing the elevation and slope of the valley floor and of the present stream, from Sioux City to the mouth of the stream. The table is compiled chiefly from data given in the annual reports of the Missouri River Commission for 1890 and 1892. We are indebted for additional data to Mr. George S. Morison of Chicago, chief engineer in the construction of several bridges across the Missouri. We are also indebted to Professor J. E. Todd, State Geologist of South Dakota, for suggestions, both published and unpublished, concerning the history of this youthful but somewhat overgrown tributary of the Mississippi.

The researches of Professor Todd and others have developed the fact that the present course of the Missouri, through the Dakotas is independent of preglacial valleys, and dependent upon the position of the ice margin. Its course along the boundary of Nebraska is considered by Professor Todd to antedate but little the late ice invasion which was marked by the Altamont moraine. He finds evidence that Lake Cheyenne persisted, in eastern Nebraska, southeastern Dakota and southwestern Iowa, to the beginning of the glacial period[1] and infers a very low altitude for the region up to that time, one not calculated for deep erosion of valleys. He writes that he has not yet found a clear case along the Missouri Valley, of excavation prior to the glacial deposition. In examinations of the rock surface exposed in sinking the piers of the bridges at Blair and Omaha, he failed to discover evidence of glacial action. Alleged glacial deposits in the valley lower down, as at St. Charles, Missouri, he thinks capable of another interpretation. The entire valley may prove to be more recent than the Kansan stage of glaciation.

[1] Evidence that Lake Cheyenne continued till the Ice Age, by J. E. Todd, Proc. A. A. A. S., Cleveland Meeting, Vol. XXXVII., 1888, pp. 202, 203.

The reports of the Missouri River Commission show, in profile, the results of a series of test borings across the entire breadth of the valley at Sibley, Missouri.[1] The rock floor nowhere stands more than sixty-five feet below low water, or little, if any, below the scour of the present stream. Borings at St. Charles, Missouri, on the very border of the Mississippi Valley, apparently test the rock floor of the Missouri in its lowest part, and find it but seventy feet below low water.[2] Only twenty miles below St. Charles at Bellefontaine, the bridge shows at its north pier a rock floor 107 feet below low water at this point. The rock floor is perhaps still lower between there and the Mississippi channel four miles to the north, there being a slight northward descent in the rock floor at the north pier. The available data seem to indicate that where the Missouri joins the Mississippi, the latter has a channel forty to fifty feet or more deeper than the former.

ALTITUDES OF THE ROCK FLOOR AND PRESENT MISSOURI AT BRIDGES BETWEEN SIOUX CITY, IOWA, AND THE MOUTH OF THE STREAM.[1]

| Location | Dist. Miles | Low water A. T. | Fall per mile | Rock Floor, A. T. |
|---|---|---|---|---|
| | | Ft. | In. | Ft. |
| Sioux City, Iowa | 0 | 1076 | | 950 ± |
| Blair, Nebraska | 102.8 | 986 | 10.50 | 934–944 |
| Omaha, Nebraska | 35.5 | 963 | 7.77 | 839–890 |
| Plattsmouth, Nebraska | 25.5 | 943 | 9.41 | 872 |
| Nebraska City, Nebraska | 25.9 | 910 | 15.29 | 750[2] }<br>815–855 } |
| Rulo, Nebraska, | 70.2 | 843 | 11.45 | 715[3] |
| White Cloud, Kansas | 12.1 | 833 | 9.90 | 772 |
| St. Joseph, Missouri | 46.4 | 794 ± | 10.08 | 743 |
| Leavenworth, Kansas | 57.2 | 745 | 10.28 | 688 — |
| Kansas City, Missouri | 31.1 | 721 | 9.26 | 660–680 |
| Randolph Bluffs, Missouri | 4.0 | 713 | 24.00 | 631 |
| Sibley, Missouri | 36.7 | 690 | 7.52 | 625–655 |
| Glasgow, Missouri | 102.5 | 594 | 10.23 | 550 |
| Booneville, Missouri | 31.7 | 570 | 9.08 | 513 |
| St. Charles, Missouri | 177.7 | 420 | 10.13 | 350 |
| Bellefontaine, Missouri | 21.7 | 406 }<br>402 } | 7.79 | 295 |

[1] Report of Missouri River Commission for 1889–90, Appendix XX. of the Annual Report of the Chief of Engineers for 1890, p. 3379, Plates V. and VI., Government Printing Office, Washington.

[2] Loc. cit., p. 3377 and Plates I. and II.

*The Illinois Valley.*—The data concerning the rock floor from the bend of the Illinois northward, along the preglacial valley are very meager. Professor Chamberlin reports a boring at Lake Koshkonong, Wisconsin, which failed to reach rock at 450 feet. A. T. A boring at Janesville, Wisconsin, enters rock at 530 feet A. T. and several at Rockford, Illinois, at 529–588 feet A. T. But these are all very near the west bluff and, in all probability, enter rock much above the level of the deepest part of the old channel. It is in the portion of the old valley occupied by the Illinois that the rock floor is best known.

We begin the table at the head of the present Illinois, that the contrast between the new and the old valley may be brought out. For the low water altitudes and for the measurement of distances we are indebted to a report of the Chicago Drainage Commission, prepared by Mr. L. E. Cooley, an engineer of that commission. Records of borings showing the elevation of the rock floor have been obtained at the offices of the persons or companies who made them, except in the case of the Princeton artesian well. The record of this well was furnished by Mr. Jacob Miller, President of the Princeton Academy of Science. The Princeton well-boring is here included, since it is near the border of the present Illinois Valley and probably strikes the deepest part of the old channel. We are indebted to Professor J. A. Udden, of Rock Island, for the collection of records of wells at Bureau Junction, Hennepin, Putnam and Henry.

[1] It should be noted that the low water altitudes here given, taken from the report of the Missouri River Commission, average about four feet higher than in Gannett's Dictionary of Altitudes, Bull. U. S. G. S., No. 76. The altitudes given in the table for the Mississippi are from Gannett's Dictionary of Altitudes.

[2] The report of the Missouri River Commission for 1890 contains a description of a gorge 2000 feet or less in width and 60–75 feet in depth, which crosses the valley in an east to west direction, nearly at right angles with its present course.

[3] The river silts and sands extend only to elevation 790 feet. Beneath them is a hard clay seventy-five feet in depth. The description given in the reports of the Missouri Commission do not make clear whether it is a glacial deposit or an earlier formation.

ALTITUDES OF ROCK FLOOR AND PRESENT ILLINOIS.

| Location | Dist. Miles | Low water A. T. | Fall per mile | Rock Floor, A. T. |
|---|---|---|---|---|
| | | Ft. | In. | Ft. |
| Mouth of Kankakee River..... | 0.0 | 485.3 | | 483 ± |
| One mile below Kankakee River.................... | 1.0 | 481.6 | 44.04 | 479 |
| Head of Marseilles Pool....... | 11.7 | 477.9 | 3.80 | ? |
| Marseilles Dam.............. | 12.7 | 476.8 | | 468 [1] |
| Marseilles, below dam ........ | | 468.8 | 8.59 | 456–468 |
| Foot of rapids ...... ........ | 1.5 | 458.3 | 84.00 | 457 ± |
| Above Ottawa ⅔ mile ........ | 5.3 | 447.9 | 23.54 | 445 |
| Head of rapids............... | 6.7 | 444.9 | 5.37 | 440 |
| Head of pool ................ | 2.6 | 438.1 | 31.38 | 435 ± |
| Peru, at Zinc Works.......... | 7.3 | 438.1 [2] | | |
| | | 433.9 | 6.90 | 320 |
| Princeton, in buried channel... | | | | 270 |
| Bureau Junction (Bureau Creek Valley).................... | | | | 340 |
| Hennepin.................... | 13.6 | 438.1 [2] | | |
| | | 432.2 | 1.50 | 380 |
| Putnam, two miles from river.. | | | | 340 |
| Henry...................... | | | | 355 |
| Peoria (Bigham's artesian well) | 47.4 | 428.9 | 0.84 | 341 |
| Pekin, at City artesian well.... | 10.7 | 427.3 | 1.79 | 325 |
| Beardstown. Artesian wells... | 63.3 | 418.6 | 1.65 | 345 |
| Mouth of Illinois............. | 86.1 | 403.6 | 2.09 | ? |
| Bellefontaine, Missouri. Bridge foundation................. | 17.0 | 402.0 ± | | 295 |
| East St. Louis, Illinois. Bridge foundation................. | 24.3 | 380.0 | | 284 |

The causes for the very low altitudes of the rock floor, and also the slight descent of the present stream below Peru, merit careful consideration, while the irregularities in the rate of descent in the portion above Peru, need a word of explanation.

Taking these up in the reverse order we find the irregular descent above Peru to be plainly attributable to variation in resistance to erosion, presented by the stream bed. The rapids occur where the stream is cutting across hard rock ledges, while the pools occur in the softer strata, between these ledges. This valley, as is well known, once constituted the outlet of Lake Michigan and was then occupied by a stream having much

[1] River raised by dam. The dam rests on rock at 468 feet A. T.

[2] River raised by dam to 438.1 feet. The dam is located at Henry, Illinois, 13½ miles below Hennepin. The altitudes at points below Hennepin are given at the natural level of the river.

greater volume than the present river. This stream effected a great amount of erosion, but its duration was too brief to enable it to cut down its bed in the new portion of the valley, to a uniform slope. Mr. Cooley has well expressed the influence of the strata in his discussion of the old lake outlet:

"The ancient stream carved its grade according to the resisting material, steep in the Niagara limestone to Lake Joliet, steep in the Cincinnati limestone at the mouth of the Kankakee, light through the friable Coal Measures, to the resisting strata at Marseilles, and steep in the St. Peter's sandstone from above Ottawa to Utica, where the water-lime group checked the lakeward extension of the alluvial valley. . . .

"Below Utica a wide valley in the Coal Measures, narrowing toward the mouth in the resisting rock of the older formations, extends for 230 miles to the Mississippi, with a present fall of about 28 feet (31 feet). The sand and gravel of the ancient stream bed lie deep below the silts and ooze, the spoils of the land through which the comparatively insignificant modern stream struggles to maintain a channel and build up its bed and inadequate grades to present requirements. A wide expanse is there of shallow lakes, bayous, marshes and fens, reed growing lowlands, and low bottoms, which in a true alluvial stream adjusted to its work should be at ordinary extreme high water, but which are but little more than half way there" (Report to Chicago Drainage Commission, p. 2).

Mr. Cooley's words introduce us to a consideration of the cause for the low rate of fall below Peru. If we divide this portion of the valley into small sections, we find interesting contrasts. There is, between Peru and Peoria, a distance of sixty miles, an average fall of one inch per mile. This is distributed as follows:

| | | | |
|---|---|---|---|
| Peru to Hennepin, - | 13.6 miles. | Rate of fall, | 1.5 inches per mile. |
| Hennepin to Henry, | 13.5 miles. | Rate of fall, | 1.07 inches per mile. |
| Henry to Chillicothe, | 13.3 miles. | Rate of fall, | .55 inch per mile. |
| Chillicothe to Peoria, | 18.3 miles. | Rate of fall, | .26 inch per mile. |

From Peoria to Beardstown, a distance of seventy-four miles, the average fall is 1.67 inches and from Beardstown to the mouth, a distance of eighty-six miles, it averages a little more than two inches per mile (2.09). Even this, the most rapid rate shown in the lower Illinois is remarkably small, compared with that of the Mississippi. The fall in that stream in the 222 miles from the mouth of the Illinois to Cairo, being 133 feet, or about 7.18 inches per mile.[1] We seem to have in the lower Illinois Valley a partially obliterated lake in which the outlet has worked its head up the valley to the vicinity of Peoria, with a decrease in slope headwards. Then comes Peoria Lake, between Peoria and Chillicothe, at the head of which is a silt-filled district, in which the river shows an increase in slope headwards to Peru, the old head of the pool or lake. The only available data concerning the amount of filling is obtained at the Santa Fé bridge at Chillicothe, where it is probably much lighter than nearer the head of the old pool. The bridge foundations are reported to have reached the bottom of the river silts at a depth of thirty feet below the bank, or about twenty feet below the bed, there being coarse sand and gravel at lower depths.[2] A series of test borings along the valley is needed to bring out satisfactorily the condition of the valley bed at the beginning of the present period of deposition.

It is a question whether the lake outlet was adequate to produce a channel with such extremely low grade as this valley presents between Hennepin and its mouth. Another possible factor should be considered, that of a warping of the valley subsequent to this period of excavation.

This leads us to the discussion of the attitude of the floor of the preglacial valley. By reference to the above table it will be observed that the valley floor at Princeton is but 270 feet A. T., while the lowest known point in the valley bottom opposite St. Louis, forty miles below the mouth of the Illinois and 260 miles below Princeton, is 284 feet A. T. or fourteen feet higher than at Princeton. It is barely possible, but scarcely probable, that there exists, opposite St. Louis, a channel sufficiently deep to give a fair gradient for the valley floor from Princeton to St. Louis. A gradient of but three inches to the mile would require a

[1] The distance we have given is about that of the high water stage. Cooley's report to the Chicago Drainage Commission gives 238 miles as the distance along the river channel. This would reduce the fall per mile to 6.70 inches.

[2] Cooley's Report to Chicago Drainage Commission, p. 58.

channel sixty-five feet deeper opposite St. Louis than is yet known to us. It is doubtful if the lower end of the Illinois Valley has a rock floor as low as at Princeton. Borings in the middle of the valley at Beardstown reach rock at an elevation seventy-five feet higher than the rock floor at Princeton, though nearly 150 miles below Princeton. Several wells have been made in Beardstown, and they indicate a quite uniform level of the rock floor. It is possible, but hardly probable, that a much deeper channel exists at that point. Wells above Beardstown, at Pekin and Peoria, though situated in each case within one-half mile of the rock bluffs, reach a lower elevation than those at Beardstown before entering rock, while at Peru a well which is apparently in a small preglacial tributary of the Illinois, several miles from the main valley, finds the rock surface at a lower elevation than the wells at Beardstown. We may have, therefore, in this valley, a warping of the rock floor to such a degree that the slope has been reversed above Beardstown.

If we compare the elevation of the rock floor in this portion of the Illinois, with that of the Mississippi a few miles to the west, we find support for the view that this section of the Illinois valley is much depressed. The boring at Sabula, Iowa, 65 miles in direct line from Princeton, apparently tests better than any other boring, the limit of excavation in the Mississippi. The Sabula boring shows the rock floor to have an elevation 429 feet A. T., or 159 feet above that at Princeton. In case the upper Mississippi Valley connected with the valley at Princeton, through the Green river basin, its valley floor would have a fall of nearly 2½ feet per mile, or six times the rate of fall of the present upper Mississippi, and nearly thirty times the fall of the present Illinois just below Princeton.

About 150 miles further down we find no evidence that the Illinois and Mississippi differ greatly in the elevation of their valley floors. Thus wells at Ft. Madison, on the Mississippi, and at Beardstown, on the Illinois, separated by a distance of about 60 miles, and in the same relative position as the Sabula and Princeton borings, show only 20 feet difference in the altitude of the rock floor.

The available data seem, therefore, to point quite strongly to a depression in the portion of the Illinois valley north from Beardstown. To fully establish this depression, it will be necessary to make certain that there is no narrow gorge leading down the Illinois, with a rock floor sufficiently low to correspond with that at Princeton. If the absence of such a gorge were demonstrated by a full series of test borings across the valley at points below Princeton, there would still remain an element of uncertainty in the fact that a local deepening of the valley through glacial agencies may have been produced at Princeton during the ice invasion. We would remark, however, that the valley has a trend transverse to the direction of ice-movement and, therefore, unfavorable for erosion by the ice, or by subglacial streams.

The probability of northward depression in the Illinois valley being so strong, we will refer briefly to a possible cause for such a depression. To the general cause for northward depression, found in the weight of the ice-sheet, we have here an additional cause in the immense amount of drift deposited along the course of the old valley. This valley, from the vicinity of Pekin northward, past Princeton, is bordered by a very bulky moraine, which, for some distance northward from Princeton occupies the supposed old course of the Rock-Illinois. The drift in this region is rarely less than 200 feet, and probably reaches a depth of between 500 and 600 feet north of Princeton, where the moraine occupies the old valley. This weight, unlike the ice-sheet, still continues an obstacle to the return of the valley floor to its former altitude, if not as a direct cause of depression. It may be found that some depression has been produced by it since the date of the lake outlet. If so the very low gradient of this portion of the Illinois would be explained only in part by the greater volume of the lake outlet. Recent warping of the valley may become an important factor.

*The Wabash Valley.*—The few borings of which we have record along the Wabash below Covington, are situated in the middle of the valley and probably test its deepest portion. The altitudes of the valley floor and present stream at points where these borings have been made are as follows:

| | Present Stream | Valley Floor |
|---|---|---|
| Montezuma, Artesian well | 465 ± ft. | 400 ft |
| Clinton, Coal boring | 450 ± " | 370 " |
| Terre Haute, Oil wells | 445 ± " | 345–360 ft. |
| Vincennes, Artesian well | 400 ± " | 345 ft. ± |
| Shawneetown, Ill., Oil boring | 350 ± " | 240 " |

The altitude of the valley floor of the Wabash is apparently somewhat higher than that of the Illinois and Mississippi valleys in the same latitude, the difference in altitude is, however, not very marked.

In the district north from the bend of the Wabash at Covington several borings have been made which show a rock floor lower than those on the Wabash. One boring near Oxford, Indiana, enters rock at the extremely low elevation of 300 feet A. T. A few miles northwest from Oxford, in Iroquois county, Illinois, a boring is said to have reached a depth of 400 feet without entering hard rock. As its mouth is but 660 feet the rock floor here may fall below 260 feet A. T.[1] Unfortunately this record is not so trustworthy as the importance of the determinations of so low an altitude of rock floor would demand. The exact depth is somewhat uncertain and there is a possibility that the soft Cincinnati shales may have been entered near the base and not distinguished from the blue till of the overlying drift. The records of the Oxford borings are apparently trustworthy. The region north from Covington, Indiana, may present such a northward depression, as is exhibited by the portion of the Illinois near Princeton.

A few borings in the east central part of Illinois, nearly midway between the Wabash and Illinois, show a remarkably low rock surface. These may be in the line of a valley discharging southward to the Kaskaskia, or in tributaries of the Wabash or of the Illinois. A well at Monticello, in Piatt county, Illinois, reached a level but 352 A. T. without entering rock. One at Kenney, in western De Witt county, failed to find rock at 358 feet A. T. A boring made at Paxton, in Ford county, entered rock at 350 feet A. T., while one at Odell, in Livingston county, entered rock at 355 feet A. T. It appears from these data that

[1] Geol. of Illinois, Vol. IV. p. 237.

the preglacial channels of east-central Illinois have a sufficiently low depth to correspond with the low altitude at Princeton or at Oxford. These borings which show so low a rock floor all occur in a district very heavily covered with drift. The cause suggested for the low altitude at Princeton may find application in the entire field of heavy drift between Princeton and Oxford.

*The Lake Michigan basin and outlet.*—It is yet to be determined whether the Lake Michigan basin is connected on the south with a preglacial tributary of the Mississippi by a channel so low even as the floor of the Oxford borings. We have already noted that the most probable line for such a connection would be southward from Michigan city to the Wabash, near La Fayette, and thence west to Oxford. But the lowest altitudes found along this line, north from La Fayette, are much above that of the rock floor at the Oxford boring. The boring at Monticello, Indiana, enters rock at 467 feet A. T., that at Winamac at 490 feet and that at North Judson at 497 feet. The lowest altitude yet found near the border of the southern portion of the Lake Michigan basin is 350 feet A. T.

A line following the longer axis of the basin descends from 350 feet at Michigan city to about sea level opposite Racine, then rises above 200 feet A. T. opposite Milwaukee, north from which it descends to 289 feet below sea level, and continues below sea level nearly to the north end of the lake. As the lake bottom is probably coated to considerable depth with glacial deposits and lake sediments, the rock floor will show even greater range.

Cross sections of the basin show interesting variations. In the deep portion of the basin opposite Racine there is very little irregularity. The bottom is as smooth as it is in the southern end where the drift has concealed all the irregularities of the rock floor. East from Milwaukee the lake charts show a single narrow ridge in an otherwise smooth bottom. Between Port Washington, Wisconsin, and Muskegon, Michigan, a cross section presents the appearance of a series of escarpments facing westward like the Niagara escarpment of eastern Wisconsin. The highest points exceed 300 feet A. T. For some distance north of this line only slight irregularities of bottom appear. But the north end of the basin is very irregular in depth.

The low altitudes of the rock floor in northeastern Illinois and northwestern Indiana seem readily accounted for by a differential crust movement without the aid of glacial erosion. But in producing the variations in altitude displayed by the floor of the Lake Michigan basin glacial erosion was probably an important agency. With fuller light concerning the floors of the great valleys parallel with the lake basin there will probably be developed criteria for estimating, more accurately than is now possible, the effect of each agency which has been influential in the shaping of the lake basin.

*The Ohio Valley.*—Concerning this great eastern tributary of the Mississippi we have space for but a few remarks.

The lower portion of the Ohio valley has received, as yet, very little attention and we have data concerning the altitude of the rock floor at but one point below Lawrenceburg, Indiana, viz, Shawneetown, Illinois, where it is 65 feet below the present stream. At Lawrenceburg, Indiana, and Cincinnati, Ohio, the rock floor is but 50 to 75 feet below low water, or but little below the scour of the present stream. Above these points, so far as ascertained, the rock floor is usually within 30 to 60 feet of the present stream bed until we reach the upper Allegheny, when it drops down rapidly and leads through buried channels to the Lake Erie basin. The northern tributaries of the Ohio, being as a rule deeply filled with drift, are now flowing at considerable heights above the rock floor. The present streams show a much more rapid descent than the rock floors, even where the rock floors slope toward the Ohio. In the headwater portions of these south-flowing tributaries, the rock floor has been found in several instances to slope northward. This fact, together with the occurrence of deeply filled channels, leading across the present watershed, is thought to indicate that the drainage basin of the Ohio has been greatly enlarged, through the influence of the glacial invasions and deposits within the state of Ohio, as well as in Pennsylvania and western New York.

The depth of *preglacial* erosion in the upper Ohio region is a subject upon which differences of opinion have arisen among the several geologists who have investigated the region; it being maintained by some, among whom the present writer is included, that in consequence of the enlargement of the drainage area by a glacial invasion, a considerable part of the valley has been deepened below the limits of the preglacial rock floor. Others maintain that the deepening occurred shortly before the first ice invasion, during a supposed brief period of higher elevation than the present and is therefore *preglacial.* We can only refer the reader to the literature of this subject as presented by Carll, White, Stephenson and Chance, in the reports of the Pennsylvania Geological Survey, and more recently by Chamberlin, Wright, Foshay, Hise and Leverett, in the *American Journal of Science.*

Reviewing the data of the entire field we find that the valley floors of the Mississippi, Illinois and Wabash were excavated, prior to the first ice invasion, to a depth 50 to 200 feet below the present streams. The southern portion of these valley floors apparently slope southward, with a gradient not greatly different from that of the present streams, while the northern portions are considerably depressed. It seems probable, therefore, that the north part of the Mississippi basin stood relatively, if not absolutely, higher than now prior to the first ice invasion. The portion near the southern border of the glaciated district may have stood no higher than at present. The region drained by the Missouri, on the other hand, seems to have had, up to the time of the first ice invasion, a lower altitude than the present. There seems, on the whole, little evidence that much of the Ohio drainage basin has stood higher. The complications in this valley, resulting from the great increase of the size of the drainage basin, make it difficult to estimate the preglacial altitude, for the enlarged stream would require, independent of altitude, a deeper valley.

## AGE AND STAGE OF DEVELOPMENT OF THE PREGLACIAL VALLEYS.

In closing this discussion a few remarks seem necessary concerning the date of the uplift which inaugurated the channeling of the preglacial valleys and the stage of development which these valleys had reached when the ice invasion occurred.

The study of physiographic development carried on in the eastern part of the United States through the zealous labors of Davis, McGee and others has brought to light a strong array of evidence indicating that the valley channeling of the region under discussion was not begun until after the close of the Cretaceous, and that it may have been largely accomplished in the latter part of the Tertiary.

It is evident from the sharply outlined valley borders, and other reliefs of the region, that the drainage systems had not reached a stage of senescence, though the size of the valleys, or the the measure of work which the preglacial streams accomplished, is certainly several times as great as that of the post-glacial valleys. The preglacial valleys are not only deeper than the present valleys, but were also excavated, as a rule, in a more resistant material. The accompanying figure, furnished through the kindness of the state geologist of Iowa, serves to show the

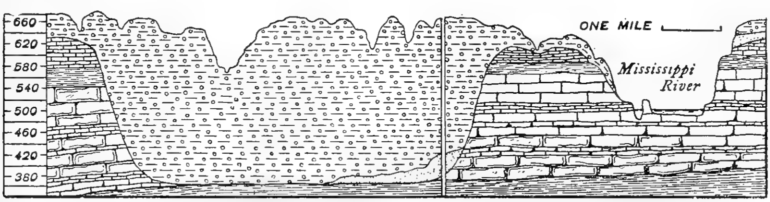



FIG. 1. Cross-section from Sonora, Illinois, to Argyle, Iowa, showing old and new channels of the Mississippi River. [Iowa Geological Survey.]

comparative sizes of old and new channels when cut in material of the same degree of resistance. It would apply equally well in other large valleys of this region, situated outside the limits of the later ice invasion. Within the limits of that invasion, the post-glacial valleys are much smaller than in the older drift territory. Where the present stream follows the preglacial channel in the older drift territory, it has usually removed the glacial deposits throughout the entire breadth of the preglacial valley, leaving only the portion of these deposits that lies below the level of its scour. The contrast in size of preglacial and present valleys in such cases is not great, though the work accomplished in removing the glacial deposits is no greater than in cutting the narrower valley in the rock, shown in the figure.

In places a preglacial valley is found to carry shelves of considerable breadth, now concealed beneath the present valley bottom, thus at Quincy and St. Louis a rock shelf extends entirely across the present bed of the Mississippi, with an altitude 60 feet or more above the deeper portion of the valley. The following tabular statement of data of the two bridges in St. Louis, furnished by Robert Moore, C.E., serves to show the existence of such a shelf at one bridge and its absence at the other. The Eads bridge is about three miles below the Merchant's bridge. Its west end is at the west bluff, while the west end of the Merchant's bridge is one-half mile from the west bluff. The shelf, therefore, extends at least one-half mile further into the valley than the length of the bridge.

ELEVATIONS OF ROCK FLOOR AT ST. LOUIS BRIDGES.

| | Eads Bridge | Merchant's Bridge |
|---|---|---|
| Bed Rock Pier 1, West Shore | 375.71 feet | 341.33 feet |
| Bed Rock Pier 2 | 341.91 " | 342.05 " |
| Bed Rock Pier 3 | 293.71 " | 339.93 " |
| Bed Rock Pier 4, East Shore | 284.30 " | 334.90 " |
| Extreme high water | 420.29 " | 422 (?) " |
| Extreme low water | 378.97 " | 380.50 " |

It is probable that such shelves as these are remnants of an old valley floor. Their full breadth is not known, hence we cannot judge whether they are mere fringes on the border of the deep channel, or are of such breadth as to reduce greatly the width of the deep channel. The data from the St. Louis bridges cover only about one-tenth, while those of the Quincy bridge cover one-sixth the breadth of the preglacial valley. If the shelves greatly reduce the width of the valley, their bearing upon the valley's history—its stages of uplift, etc.—may prove to be of considerable importance. It is as yet not certain whether the valley was deepened regularly during continuous uplift, or whether it was subject to periods of deepening, between which were periods of equilibrium, when the force of the stream was expended in broadening the channel.

An important feature connected with the development of the preglacial drainage of this region has received thus far but little attention, namely, *variations in stage of development* displayed by the drainage lines in different parts of the Mississippi basin. My attention was first called to the matter when studying southern Illinois, in the autumn of 1892. It was found that there is a great scarcity of deep buried valleys, compared with their number further north. It is only at rare intervals that a well on the uplands fails to strike rock within a few feet of the level of the upland plain. The main preglacial valleys of this region are cut to but moderate depths, seldom showing an excavation of more than 100 feet below border districts. Upon discussing this matter with Professor Chamberlin it was found that he had noted a similar feature in the unglaciated part of Missouri, near Sedalia. The greater part of the surface is unfurrowed by drainage lines. The few which occur have reached only an adolescent stage of development. The appearance is as if an uplifted base leveled region had been subjected to erosion for an insufficient time to allow well developed systems of drainage to be inaugurated. Further north (and especially in northern Illinois and the driftless area of Wisconsin) the preglacial systems had dissected the uplands quite thoroughly. though the altitude is not much greater than southern Illinois and scarcely so great as the region around Sedalia. From what is now known, it seems probable that the northern districts suffered uplift long before the southern. A thorough investigation of this matter will doubtless bring out a very interesting history, showing an increasing extent and degree of uplift proceeding from certain centers of upheaval, by which the peneplain of the Cretaceous and early Tertiary periods rose and became transformed into the more or less deeply channeled uplands of the early Pleistocene.

FRANK LEVERETT.

Denmark, Iowa, May 23, 1895.

# THE CLASSIFICATION OF THE UPPER PALÆOZOIC ROCKS OF CENTRAL KANSAS.[1]

[Continued from Vol. III., No. 6.]

## THE NEOSHO FORMATION.

Between the Cottonwood formation and the base of the first massive limestone, containing an abundance of flint in layers, is a series of gray limestones alternating with various colored shales, some of which are yellowish-gray in color, corresponding in lithological appearance, and containing a fauna similar to the Cottonwood shales, while others are olive and reddish in tint and non-fossiliferous. Interstratified are shaly limestones and dark gray hard limestones which contain an abundant Lamellibranch fauna. Numerous exposures of this formation occur in Chase county along the Cottonwood and its branches, and also to the northeast in the Neosho valley in Morris county. On account of the excellent exposures of this formation in the Neosho valley and its tributaries extending from three miles northwest to six miles southeast of Council Grove it is proposed to call this mass of rocks the *Neosho formation.* In the vicinity of Council Grove there are good exposures in the steep hills near the city and especially along Elm and Four Mile Creeks, which are western branches of the Neosho River south of Council Grove.

*Geologic section of the Neosho formation.*—In Chase county there are good exposures of this formation at the following localities: on "Crusher Quarry Hill," one and one-half miles west of Strong City; on the western side of the Cottonwood River opposite and above Clements; on Buckeye Creek, south of Cottonwood Falls; on Rock Creek, west of Bazaar; and on South Fork of the Cottonwood River, near Matfield Green. The Crusher Quarry Hill affords a good section of this formation; the Cotton-

[1] Published by permission of the Director of the United States Geological Survey.

wood limestone appears at the foot of the hill, near railroad level, while the first heavy stratum of flint and limestone of the so-called "Flint Hills" forms the brow of the bluff. The following section of the exposures on the slope and along the road up to the Crusher Quarry gives quite accurately the thickness of the various strata composing this formation:

| | | Feet. | | Feet. |
|---|---|---|---|---|
| No. 20. | Soil at top of bluff | 2 | = | 168 |
| " 19. | Massive light gray limestone containing an abundance of flint. The stratum quarried for the railroad crusher. | 19 | = | 166 |
| " 18. | Yellowish shaly limestone | 2½ | = | 147 |
| " 17. | Light gray limestone with an abundance of flint. The base of the first heavy flint limestone. | 1½ | = | 144½ |
| " 16. | At top fine yellowish shales with Cottonwood shale fauna; the lower shale are coarser. | 23 | = | 143 |
| " 15. | Massive limestone in some places 4 feet thick and quarried. Near Council Grove limestone, from 25–30 feet, below the base of the flint, containing *Pleurophorus*, and above the limestone are ferns. | 3 ± | = | 120 |
| " 14. | Mainly yellowish shales some greenish with thin, shaly limestones. | 36 | = | 117 |
| " 13. | At top limestone with *Pseudomonotis* 2′ 10″ in thickness; one layer of the limestone contains an abundance of small iron concretions. Below are shales. | 10⅔ | = | 81 |
| " 12. | Light gray limestone containing *Pseudomonotis*. | 1⅓ | = | 70⅓ |
| " 11. | Green and chocolate colored shales | 20 | = | 69 |
| " 10. | Light gray, shaly limestones- containing *Pseudomonotis* and other fossils. | 4 | = | 49 |
| " 9. | Shales, about 4′ or more in thickness | 4 | = | 45 |
| " 8. | Dark gray silicious limestone on weathered surface, very irregular with rough jagged prominences. | 2 ± | = | 41 |
| " 7. | Yellowish shales argillaceous containing some of the Cottonwood shale fauna. | 6 | = | 39 |

| | | | | | |
|---|---|---|---|---|---|
| " | 6. | Yellowish blocky shales - - - - - - containing a Lamellibranch fauna of *Pseudomonotis* and *Aviculopecten*, which in places appear to form a massive rough limestone similar to No. 8. | 5 | = | 33 |
| " | 5. | Greenish shales - - - - - - - - | 7 | = | 28 |
| " | 4. | Chocolate and drab shales - - - - - | 4 | = | 21 |
| " | 3. | Shaly limestones - - - - - - - - | 4 | = | 17 |
| " | 2. | Yellowish shales - - - - - - with abundant fossils in the lower part. *Cottonwood shales.* | 13 | = | 13 |
| " | 1. | *Cottonwood limestone* - - - - - - exposed just above railroad switch, 2[1] +. | | | 0 |

In the above section, the beds from No. 3 to No. 16, inclusive, with a total thickness of 130 feet are regarded as forming the *Neosho formation.* Stratum No. 8 which weathers to a very rough jagged surface, is somewhat similar in lithologic appearance to the "dry bone limestone" in the upper part of the Wabaunsee formation. This limestone has usually been considered magnesian,[2] but the chemical analysis reveals only a trace of magnesia, and to the presence of silica may be ascribed its roughness.[3]

*Palæontology.*—As described in the above section, the Neosho formation contains green, chocolate and yellow shales, and as the yellow shales approach the lithologic conditions of the Cottonwood, they frequently contain some of the Cottonwood fossils. No. 7 is one illustration of this statement, and the top of

[1] The thickness and lithologic characters of Nos. 3 to 7, inclusive, were obtained in part from the section at the east end of second railroad cut west of Crusher Hill. In the measurement of the lower part of the section I was assisted by Professor Erasmus Haworth of the University of Kansas.

[2] See Prel. Rept. Geol. Surv. Kans. p. 15, where No. 78 of Swallow, a "gray and drab porous limestone, 2 feet," 38 feet above the Cottonwood is evidently this stratum.

[3] The following analysis is by Mr. Warren Finney:

| | | |
|---|---|---|
| $SiO_2$ - - - - - | 15.99 | per cent. |
| $CaCO_3$ - - - - - - | 77.65 | " |
| $Al_2O_5$ - - - - - | 4.50 | " |
| $Fe_2O_5$ - - - - - - | 1.03 | " |
| $MgCO_3$ - - - - - | trace | |
| | 99.17 | " |
| $CO_2$ - - - - - - | 38.75 | " |

No. 16, at the summit of the formation just below the lowest stratum of massive limestone and flint, is another.

In the yellow shales of No. 7, exposed in the second railroad cut west of Crusher Quarry Hill, the following species were collected:

1. *Chonetes granulifera*, Owen. (a)
2. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea*, (Shep.) Keyes. (rr)
3. *Productus semireticulatus*, (Martin) de Koninck. (c)
4. *Derbya crassa*, (M. and H.) H. and C. (rr)
5. *Meekella striato-costata*, (Cox) White and St. John. (rr)
6. *Rhombopora lepidodendroides*, Meek. (a)
7. *Septopora biserialis*, (Swallow) Waagen. (rr)

In No. 16, immediately below the base of the flint at the brow of Crusher Hill, the following species were obtained:

1. *Chonetes granulifera*, Owen. (c)
2. *Derbya crassa*, (M. and H.) H. and C. (r)
3. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea*, (Shep.) Keyes. (rr)
4. *Productus* sp. (rr)
5. *Crinoid* stems. (r)

Certain layers of the coarser shales and limestones of this formation contain a fauna composed largely of Lamellibranchs, and from the yellowish blocky shales of No. 6, in the railroad cut west of Craik's Creek and Crusher Hill, the following species were collected:

1. *Aviculopecten occidentalis*, (Shum) Meek and Worth. (c)
2. *Pseudomonotis Hawni*, (Meek and Hayden). (c)
3. *Meekella striato-costata*, (Cox) White and St. John. (c)
4. *Pseudomonotis Hawni*, (M. and H.), var. *ovata* M. and H. (rr)
5. *Pinna peracuta* Shum. (?) (rr)
6. *Pleurophorus* cf. *oblongus*, Meek. (rr)
7. *Derbya crassa*, (M. and H.) Hall and Clarke. (rr)
8. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. (rr)
9. *Productus semirecticulatus*, (Martin) de Koninck. (r)
10. *Chætetes* cf. *carbonarius*, Worth. (rr)

11. *Spirorbis* sp. (r)
12. Cf. *Aclis robusta*, Stevens. (r)

In the light gray shaly limestones as exposed on the road up the Crusher Hill — No. 10 of the section — are the following species:

1. *Productus nebracensis*, Owen. (aa)
2. *Aviculopecten occidentalis*, (Shum.) Meek and Worth. (a)
3. *Pseudomonotis Hawni*, (Meek and Hayden). (a)
4. *Pleurophorus subcostatus*, Meek and Worth. (c.)
5. *Myalina perattenuata*, M. and H. (r)
6. *Myalina kansasensis*, Shum. (rr)
7. *Meekella striato-costata*, (Cox) White and St. John. (rr)
8. *Derbya* cf. *crassa*, (M. and H.) Hall and Clarke. (rr)
9. Cf. *Aclis Swalloviana*, (Gein.) Meek. (c)
10. *Spirorbis* sp. (c)
11. *Edmondia* sp. (rr)
12. *Bellerophon* sp. (rr)
13. *Discina* sp. (rr)
14. *Zaphrentis* sp. (rr)

On the banks of the South Fork of the Cottonwood River at Matfield Green, and by the roadside three-fourths of a mile north of the village are good exposures of a very hard dark gray to bluish shaly limestone. The presence of an abundance of a few species of fossils in this limestone has been noted at various localities and thus forms a characteristic feature of the formation. This horizon belongs, probably, to No. 12 or 13 of the Crusher Hill section, and at Matfield Green is the following fauna:

1. *Pleurophorus subcostatus*, Meek and Worth. (a)
2. *Productus nebrascensis*, Owen. (a)
3. *Aviculopecten occidentalis*, (Shum.) Meek and Worth. (a)
4. *Pseudomonotis Hawni*, (M. and H.) (c)
5. *Pseudomonotis Hawni*, (M. and H. var. *ovata*, M. and H. (c)
6. *Bellerophon* cf. *sublævis*, Hall, or *Urii*, Fleming. (a)
7. Small *Gastropod* cf. *Aclis* sp. (see fig. in Dana's Manual of Geology, Fourth Ed., p. 685, f. 1121). (c)
8. *Myalina* (?) *Swallovi*, McChesney. (c)
9. *Edmondia* cf. *nebrascensis*, (Geinitz) Meek. (r)

10. *Myalina kansasensis*, Shum. (rr)
11. *Myalina perattenuata*, M. and H. (rr)
12. *Pinna peracuta*, Shum. (rr)
13. *Bellerophon* cf. *Montfortianus*, N. and P. (rr)
14. *Allorisma* cf. *subcuneata*, M. and H. (rr)
15. *Schizodus* cf. *curtiforme*, Walcott. (rr)
16. *Macrochilina angulifera*, White (?) (r)

It will be seen from the above faunas that in this formation we have strata containing Carboniferous fossils only, alternating with strata containing a mixture of Carboniferous and Permian fossils. The yellowish shales with abundant specimens of *Chonetes granulifera*, Owen, contain only Carboniferous fossils, while the blocky shales and dark gray limestones contain such species as *Pseudomonotis Hawni*, Meek and Hayden, *Pleurophorus subcostatus*, M. and Worth., etc., which are usually considered characteristic of the Permian or Upper Carboniferous. On account of the predominance of the strata containing this mixed fauna it seems advisable to consider the Neosho as the lowest formation of the division generally called the Permo-Carboniferous. This classification would not differ greatly from that of Meek and Hayden, as defined in 1867 by Dr. Hayden when he stated that "Meek and Hayden regarded the beds . . . . . down so far as to include most, if not nearly all, of Professor Swallow's Lower Permian, as an intermediate connecting series between the Permian and Coal Measures, which, if worthy of a distinct name at all from the latter, should be called Permo-Carboniferous."[1]

[1] Am. Jour. Science, 2d series Vol. XLIV., p. 37. It will be remembered that Swallow called the "dry bone limestone" the base of his Lower Permian, which is about 62 feet below the base of the Neosho formation; and Meek and Hayden did not indicate a precise line of division. Some geologists consider that Meek in his Report on the Palæontology of Eastern Nebraska referred the Permo-Carboniferous and Permian of Kansas to the Carboniferous; but the writer understands that classification to apply only to Nebraska, for Meek said: "All of these strata under consideration along the Missouri . . . . . really belong entirely to the true Coal Measures; unless the division C, at Nebraska City, and some apparently higher beds below there on the Missouri, may possibly belong to the horizon of an intermediate series between the Permian and Carboniferous, for which, in Kansas, Dr. Hayden and the writer proposed the name Permo-Carboniferous" (Final Rept. U. S. Geol. Surv. Neb. and adjg. Territories, 1872, p. 130).

*Comparison of the Neosho formation with Swallow's section.*—The Neosho formation includes the upper 25 feet of bed No. 79 of Swallow's section and extends to the base of No. 62—the "fifth *cherty limestone*."[1]

These beds all belong in Swallow's Lower Permian, and he gave the thickness as ranging from 111 feet 7 inches to 148 feet 7 inches. Swallow's bed No. 76, which he described as a "soft blue and gray coralline limestone, 3 feet, containing *Monotis Halli*, and *Americana*, *Productus Norwoodi*, *Synocladia biserialis*, *Thamniscus dubius* (?), *Edmondia Hardni*, *Phillipsia Cliftonensis*,"[2] 49 feet above the top of the *Fusulina* limestone, is clearly No. 10 of our section, 45 feet above the Cottonwood limestone. Again, bed No. 68 of Swallow, described as a "hard blue and buff magnesian limestone, containing numerous Permian *Acephala*" from 72 feet 7 inches to 77 feet 7 inches above the *Fusulina* limestone, is probably No. 12 of the Crusher Hill section. Six feet above this limestone Swallow noted a "light buff and drab argillo-magnesian limestone"—No. 66—containing "*Monotis* and *Bakevellia*," and the limestone noted at the top of our No. 13, eight feet above No. 12, probably belongs to the lower part of Swallow's bed No. 66. The limestone—No. 64 of Swallow—is near the horizon of our No. 15, and below the cherty limestone. Swallow described shales containing "*Synocladia biserialis*, *Productus Norwoodi*, *Orthisina Shumardiana*," which are the same as the shales with the Cottonwood fauna called No. 16 of the Crusher Hill section. It will be seen that there is a close agreement between the thickness and lithological characters of the section west of Strong City and the beds of Swallow's section, the upper ones of which he described from exposures near Fort Riley on the Kansas River.

*Comparison with Meek and Hayden.*—The Neosho formation on the Kansas River includes the upper 22 feet of Meek and Hayden's No. 23 and terminates at the base of their No. 18, to which Meek and Hayden assigned a thickness of 96 feet.[3] Below

[1] Prel. Rept. Geol. Surv. Kans., pp. 14–16.

[2] Ibid., p. 15.

[3] Proc. Acad. Sci. Phil., Vol. XI., p. 17.

Fort Riley, Meek and Hayden did not find continuous exposures, therefore they underestimated the thickness of the rocks between the Manhattan limestone[1] and the base of the lower flint at Fort Riley. They noted at Fort Riley, however, the shales just below the lower flint with the Cottonwood fossils, and they state that No. 19 "contains near the upper part fragments of Crinoid columns, *Synocladia biserialis*, *Spirigera*, *Productus Norwoodi*, *Chonetes mucronata* [*C. granulifera*], *Orthisina Shumardiana*, *Orthisina umbraculum*, etc., with teeth of *Petalodus Alleghaniensis*."[2]

These yellowish fossiliferous shales, which represent No. 16 of the Crusher Hill section, are well exposed below the massive limestone and flint stratum at the Quartermaster's Bridge at Fort Riley.

### THE CHASE FORMATION.

Succeeding the Neosho formation are massive limestones and flints separated by beds of variously colored shales which form the region known as the "Flint Hills" of Kansas.

Topographically this is a conspicuous region. Steep hills and bluffs capped by layers of heavy limestone and flint form quite extensive plateaus in which the streams have eroded deep and narrow valleys. Professor Broadhead said this region "might appropriately be termed the Permian mountains."[3]

*Three flint horizons.*—The formation contains three prominent massive limestones with interstratified layers of flint which cap the conspicuous bluffs and produce the characteristic topographic features of the country. These flinty limestones and the interstratified shales, which are 265 feet in thickness, cover the greater part of the western half of Chase county and are well exposed in bluffs along the Cottonwood River and its tributaries. The name *Chase* is therefore considered appropriate for this formation.

In the Cottonwood Valley the lowest of these limestones and flints caps the Crusher Hill west of Strong City, and for convenience in describing the formation this horizon may be called

[1] Manhattan limestone is the local name of the Cottonwood stone in the Kansas River valley.

[2] Ibid., p. 17.

[3] Trans. St. Louis Acad. Sci., Vol. IV., Pt. III., p. 484.

the *Strong flint*, which varies in thickness from 35 to 45 feet From 110 to 115 feet above the base of the Strong flint is the base of the second massive flint with a heavy limestone above. The horizon is well exposed along the McPherson branch of the A., T. & S. F. R. R., and in the Jones' quarries from one to two miles northeast of Florence. This may be called the *Florence flint and limestone*. The flint strata are 22 feet thick and are separated near the center by a white cellular limestone from one to two feet thick, while above the flint are 40 feet of buff limestone, the lower and upper portions of which are generally more or less shaly, with a massive ledge forming the central portion. The highest flint and limestone is well exposed along the bluffs of the river and small streams near Marion, and its base is about 123 feet above the base of the Florence flint. Near Marion at the base of the flint horizon is a flinty limestone about 4 feet thick, followed by 13 feet of yellowish shales, capped by a zone 10 feet thick, composed of two strata of limestone separated by shales, the limestones containing large irregular concretions which weather to a brown color. The flint is not as uniform in occurrence as in the Florence and Strong flints, so at some localities this horizon is represented simply by a prominent light gray limestone nearly free from flint, and occasionally the particles in the concretionary limestone are small and inconspicuous. As a rule, however, the concretions are large and the stratum may be readily traced across the country either from its exposure in bluffs or streams, or from the line of loose brown concretions crossing the prairie. This limestone has been traced by the writer along its line of outcrop from the center part of Butler county across Chase and Marion counties into Morris county.

This flint and concretionary limestone is the highest prominent flint ledge in the upper Palæozoic of Kansas. It forms a marked stratigraphic horizon that is of great assistance in determining the areal geology of eastern central Kansas, and on account of the good exposures of this zone near Marion City, the horizon has been called the *Marion flint and concretionary limestone*.

*General geologic section of the Chase formation.*—From the comparison of a large number of individual sections has been prepared the following general section which gives the thickness and lithologic character of the various strata composing the Chase formation.

| No. | Description | | Feet. | Feet. |
|---|---|---|---|---|
| No. 20. | Massive limestone containing large flint concretions which weather brown and contain *Productus* and a few other fossils. It is composed of two layers separated by a thin shale, *Marion concretionary limestone.* | | 10 | = 265 |
| " 19. | Yellowish shales containing a few *Brachiopods.* | | 13 + | = 255 |
| " 18. | Light gray limestone generally containing flint. *Marion flint.* | | 4 | = 242 |
| " 17. | Yellowish, chocolate and greenish shales with occasional layers of thin limestone. | | 62 ± | = 238 |
| " 16. | Buff shaly limestones containing *Lamellibranch* fauna. | | 22 | = 176 |
| " 15. | Massive buff limestone. *Florence limestone* | | 5 + | = 154 |
| " 14. | Buff shaly limestone containing an abundant *Brachiopod* fauna. | | 15 | = 149 |
| " 13. | Massive limestone with layers of flint. | *Florence flint* | 10 | = 134 |
| " 12. | White cellular limestone | *Florence flint* | 2 | = 124 |
| " 11. | Massive limestone with layers of flint. | *Florence flint* | 10 | = 122 |
| " 10. | Yellowish, chocolate and greenish shales | | 31 | = 112 |
| " 9. | Light gray limestone containing an abundance of small *Lamellibranchia.* | | 2 ± | = 81 |
| " 8. | Shales not well exposed | | 12 ± | = 79 |
| " 7. | Shaly buff limestones containing large *Brachiopods;* sometimes a massive limestone. | | 10 ± | = 67 |
| " 6. | Shales, not well exposed | | 15 ± | = 57 |
| " 5. | Massive gray limestone | *Strong flint.* | 3 ± | = 42 |
| " 4. | Limestone with an abundance of coarse flint and some large brown concretions | *Strong flint.* | 10 (?) | = 39 |
| " 3. | Yellowish and rather coarse shale | *Strong flint.* | 3½ | = 29 |
| " 2. | Massive light gray to whitish limestones containing some flint | *Strong flint.* | 18 | = 25½ |
| " 1. | Light gray limestone with plenty of flint in regular layers.[1] | *Strong flint.* | 7½ | = 7½ |

[1] The several beds of the above section are described mainly from exposures near the following localities: Marion concretionary limestone and flint near Marion and Burns; shales of No. 17, east of Cedar Creek near Wonsevu, Chase county; Florence limestones and flint near Florence and Ft. Riley; shales of No. 10, on Middle Creek above Elk, Chase county; Lamellibranch limestone, No. 9, near Four Mile and Six Mile Creeks in the southern part of Morris county; shales and shaly buff limestones of Nos. 6–8 near Cedar Point, Cottonwood Falls and Matfield Green; and the complete series of the Strong flint two miles northeast of Council Grove.

*Palæontology.*—Certain beds of the Chase formation contain numerous fossils which may be divided into two faunas; one composed principally of large Brachiopods and the other of small Lamellibranchia.

The different layers of the Strong flint are sparingly fossiliferous; and at no locality has any considerable number of specimens been obtained. The following species have been noted:

1. *Enteletes hemiplicatus*, (Hall) H. and C.
2. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb.
3. *Chonetes granulifera*, Owen.
4. *Meekella striato-costata*, (Cox) White and St. John.
5. *Productus nebrascensis*, Owen.
6. *Derbya crassa*, (M. and H.) H. and C. (?)
7. *Pseudomonotis Hawni*, (M. and H.)
8. (?) *Glauconome*, sp.
9. *Echinoid* spine.
10. *Bryozoan* sp.[1]

In the upper part of the Strong flint on the south side of Elm Creek, about three miles west of Council Grove is a very fossiliferous stratum. It is a shaly bluish limestone which probably belongs in No. 3 or the lower part of No. 4 of the Chase formation. The following species were collected at this locality:

1. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. (aa) = *A. argentea*, (Shep.) Keyes.
2. *Derbya crassa*, (M. and H.) H. and C. (a)
3. *Derbya multistriata*, (M. and H.) Prosser. (c)
4. *Productus nebrascensis*, Owen. (c)
5. *Pseudomonotis Hawni*, M. and H. (c)
6. *Aviculopecten occidentalis*, (Shum.) Meek (c)
7. *Rhombopora lepidodendroides*, Meek (a)
8. *Aviculopecten McCoyi*, M. and H. (rr)
9. *Septopora biserialis*, (Swallow) Waagen. (c)
10. *Fenestella Shumardi*, Prout. (a)
11. *Myalina perattenuata*, M. and H. (rr)
12. *Myalina recurvirostris*, M. and W. (?) (rr)

[1] These species were collected at the quarry on the Crusher Hill, west of Strong City and from the high hill two miles east of Alma.

13. *Macrodon sangamonensis*, Worth. (?) (rr)

14. *Phillipsia*, sp. (rr)

In the shaly limestones of No. 7 a few species of large Brachiopods were obtained. West of the Dunlap schoolhouse, two miles north of Matfield Green, the following species were collected:

1. *Derbya multistriata*, (M. and H.) Prosser.[1]
2. *Aviculopecten occidentalis*, (Shum.) Meek (rr)
3. *Myalina recurvirostris*, Meek and Worth (?) (rr) shells poorly preserved.
4. *Myalina perattenuata*, M. and H. (?) (rr)

In addition at other localities has been found the following species:

5. *Spirorbis* sp.
   Probably the *S. orbiculostoma* of Swallow.[2]

The light gray limestone of No. 9 contains an abundance of a few species of small Lamellibranchia which constitute a characteristic Permian fauna. An exposure west of Wolf Creek, on Sec. 15 of Four Mile township, Morris county, afforded the following species:

1. *Pleurophorus subcuneatus*, M. and H. (a)
2. *Bakevellia parva*, M. and H. (c)
3. *Yoldia* (?) *subscitula*, M. and H. (rr)
4. *Edmondia Calhouni*, M. and H. (?) (r)
   Small specimens similar to the form figured by Geinitz as belonging to this species (see Fig. 2, Pl. II., Carb. und Dyas, Nebraska).
5. *Nautilus eccentricus*, M. and H. (?) (c)
6. *Aclis Swalloviana*, (Geinitz) Meek. (r)
7. Small *Gastropod* cf. *Orthonema* sp. (rr)
   Specimens showing *Stylolites* structure.

The limestones interstratified with the Florence flint contain

[1] The striæ and characters of these specimens apparently agree with the form noted in some of the early papers as *Orthisina umbraculum*, Schloth, sp. (?) for which Meek and Hayden proposed the specific name *O. multistriata* (Proc. Acad. Nat. Sci. Phil., Vol. XI., p. 26).

[2] Described without figure in Trans. Acad. Sci. St. Louis, Vol. I., p. 181.

a small number of species; the following list having been obtained from the bluffs along the railroad northeast of Florence:

1. *Productus semireticulatus*, (Martin) de Koninck. (c)
2. *Productus costatus*, Sowerby. (rr)
3. *Derbya multistriata*, (M. and H.) Prosser. (r)
4. *Chonetes granulifera*, Owen. (c)
5. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea*, (Shep.) Keyes. (rr).
6. *Bryozoa*, sp. (rr)
7. *Coral*, sp. (rr)

   From other exposures have been obtained the following additional species:

8. *Meekella striato-costata*, (Cox) White and St. John. (c)
9. *Chænomya minnehaha* (Swallow) M. and H. (?) (rr)
10. *Productus nebrascensis*, Owen. (rr)
11. *Sedgwickia* (?) *altirostrata*, Meek and Hayden. (rr)
12. *Phillipsia*, sp. (r)

Probably the most fossiliferous zone of the formation is No. 14, the buff shaly limestones between the Florence flint and the massive limestone. It is essentially a Brachiopod fauna in which there is an abundance of a few large species. In the old quarry one mile northeast of Florence is the following fauna:

1. *Derbya multistriata*, (M. and H.), Prosser. (aa)

   This is probably the species identified by Dr. Newberry, as *Orthisina umbraculum* from the beds of similar age in Morris county.[1]

2. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. (aa)
3. *Productus semireticulatus*, (Martin) de Koninck, var. *Calhounianus*, Swallow. (a)

   Meek considered Swallow's *P. Calhounianus* a synonym of *P. semireticulatus*;[2] but in the Cottonwood and Kansas sections it can usually be distinguished from the *P. semireticulatus*, and it seems distinct enough to be considered a variety.

[1] Rept. Macomb Exp. Exped., p. 21.

[2] Final Rept. Nebraska, Pt. II., p. 161.

No. 3. General appearance of the Fort Riley limestone near the top of the bluff north of Fort Riley, Kansas. Above the Fort Riley limestone are thinner limestones in which fossils are common.

4. *Meekella striato-costata*, (Cox) White and St. John. (a)
5. *Derbya crassa*, (M. and H.) H. and C. (c)
6. *Straparollus* (*Euomphalus*) *subquadratus*, Meek and Worth (c)
7. *Meekella* (?) *Shumardiana*, (Swallow) Williams. (c)
8. *Spirifera* (*Martinia*) *planoconvexa*, Shum. (c)
9. *Aviculopecten occidentalis*, (Shum.) M. and W. (rr)
10. *Straparollus* (*Euomphalus*) *subrugosus*, M. and W. (?) = *S. catilloides*, (Con.) Keyes. (rr)
11. *Pseudomonotis Hawni*, M. and H. (rr)
12. *Schizodus* cf. *Wheeleri*, (Swallow) Meek. (rr)
13. *Allorisma subcuneatum*, M. and H. (rr)
14. *Sedgwickia altirostrata*, M. and H. (rr)
15. *Chænomya minnehaha*, (Swal.) M. and H. (rr)
16. *Polypora submarginata*, Meek. (rr)
17. *Fenestella Shumardi*, Prout (?) (rr)
18. *Chætetes*, sp. (c)
19. Segments of *Crinoid* stems. (r)

From other exposures in the vicinity of Florence, the following additional species were collected:

20. *Myalina kansasensis*, Shum. (rr)
21. *Myalina perattenuata*, M. and H. (rr)
22. *Pinna peracuta*, Shum. (?) (rr)
23. *Septopora biserialis*, (Swallow) Waagen (rr)
24. *Phillipsia sangamonensis*, M. and W. (?) (rr)
25. *Spirorbis* cf. *permianus*, King. (r)
26. *Edmondia*, sp. (rr)
27. *Archæocidaris*, plates and spines. (c)
28. *Chonetes granulifera*, Owen. (rr)
29. *Aviculopecten* cf. *carboniferous*, (Stevens) Meek. (rr)
30. *Straparollus* (*Euomphalus*) cf. *pernodosus*, M. and Worth. (rr)
30. *Bryozoa*, sp. (rr)

In some localities certain layers of the shaly buff limestones —No. 16 of the section—overlying the more massive limestone contain a Lamellibranch fauna composed of a large number of a few Permian species. The best localities noted for this zone are in the quarries of the shaly limestones on the Kansas River, one mile west of Junction City and north of Fort Riley. Only a limited time was available for collecting at these localities, but the following list was obtained which would be increased by by more careful search:[1]

1. *Bakevellia parva*, M. and H, (a)
2. *Pleurophorus subcuneatus*, M. and H. (c)
3. *Pleurophorus*, sp. (a)
   This is probably the species listed as *Solemya* by Meek and Hayden[2] in their Kansas valley section.
4. *Aviculopecten occidentalis*, (Shum.) Meek and Worth. (c)
5. A small *Gastropod* smooth, internal impressions with seven whorls which taper regularly to the apex. cf. *Loxonema Geinitziana*, King (Mon. Perm. fossils, Pl. XVI., f. 31).
6. (?) *Euomphalus*, sp. (r).

The chocolate and greenish shales—No. 17—overlying the Florence shaly limestones are not fossiliferous; but the yellowish shales contain a few species.

In the Marion flint or limestone—No. 18—is a limited number of fossils which are principally Brachiopods. The following species were obtained in the city of Marion or its vicinity:

1. *Productus semireticulatus*, (Martin) de Koninck, var. *Calhounianus*, Swallow. (r)
2. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea*, (Shep.) Keyes. (r)
3. *Pinna peracuta*, Shumard. (rr)
4. *Bryozoa*, sp. (rr)
5. *Archæocidaris* spines and plate. (r)

[1] It was in this zone, near Junction City and Fort Riley, that Professor Hay found the *Nautiloidea*, three species of *Metacoceras* and one *Phacoceras* which were described by Professor Hyatt (Geol. Surv., Texas, 2d. An. Rept., 1890, pp. 336, 339, 340, 347) Later, the *Phacoceras Dumbli* was changed to the genus *Stenopoceras* (*Ibid.*, 4th An. Rept., 1893, p. 446). For reference to their stratigraphic position see Professor Hay (Trans. Kans. Acad. Science, Vol. XIII., pp. 37, 38; and Eighth Bien. Rept. State Board Agri., Kansas, Vol. XIII., p. 104, fossils of No. 12 of the Fort Riley section).

[2] Proc. Acad. Nat. Sci., Phil., p. 17, fauna of Bed No. 11.

While in the yellowish shales—No. 19—between the flint and concretionary limestone are:

1. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea*, (Shep.) Keyes. (c)
2. *Productus semireticulatus*, (Martin) de Koninck. (r)
3. *Derbya multistriata*, (M. and H.) Pros. (?) (rr)
4. *Derbya crassa*, (M. and H.) H. and C. (r)
5. *Septopora biserialis*, (Swallow) Waagen. (r)
6. *Myalina recurvirostris*, M. and W. (rr)
7. *Archæocidaris*, sp. (c)
8. *Aviculopecten*, sp. (rr)
9. (?) *Edmondia*. sp. (rr)
10. *Crinoid* stems.[1]

Finally, in the massive concretionary layers, and in the concretions themselves, are fossils among which Brachiopods are the most numerous and characteristic. The following species were obtained in Marion county:

1. *Athyris* (*Seminula*) *subtilita*, (Hall) Newb. = *A. argentea* (Shep.) Keyes. (rr)
2. *Aviculopecten occidentalis*, (Shum.) M. and W. (?) (rr)
3. *Edmondia*, sp. (rr)
4. *Productus semireticulatus*, (Martin) de Koninck. (rr)
5. *Derbya multistriata*, (M. and H.) Prosser. (r)
6. *Septopora biserialis*, (Swallow) Waagen. (r)
7. *Archæocidaris, sp.* (c)
8. *Crinoid* segments.

Palæontologically the Marion concretionary limestone is an important stratigraphic horizon for in the higher fossiliferous rocks Brachiopods are seen at rare intervals and rapidly disappear. The fauna of the succeeding rocks consists almost entirely of Lamellibranchia and is composed of species which are

[1] Professor Broadhead stated that at Marion, "*Aviculopecten occidentalis* and *Fusulina cylindrica* were the only fossils seen" (Trans. St. Louis Acad. Science, Vol. IV., Pt. III., p. 492). I have not yet seen *Fusulina* as high as the Marion horizon and Meek and Hayden did not find them above a thin limestone which they reported as thirty-five feet above the horizon of the Cottonwood limestone (Proc. Acad. Nat. Sci. Phil., Vol. XI., p. 17, No. 22), which would locate it in the lower part of the Neosho formation.

quite universally considered as Permian. As previously stated, the Marion flint and concretionary limestone form a horizon which is readily traced in the field, as well as a clearly marked stratigraphic line, so that it is well adapted to serve as the line of separation between two formations. In fact it is the only sharply defined stratigraphic line in this part of the series, and such a classification is further supported by the almost entire disappearance of Brachiopods, although a few specimens continue somewhat higher in accordance with similar facts noted in reference to other formations.

*Comparison of the Chase formation with Swallow's section.*— It is perfectly clear from a comparison of the sections that the horizon termed the *Strong flint* in the Chase formation comprises beds No 62–58 inclusive of Swallow, to which he gave a thickness varying from thirty-six to sixty-three feet, and which is called forty-two feet in the Chase formation. The flint stratum at the base of the Chase formation, No. 1 of the section, equals No. 62 of Swallow's list which he called the "fifth *cherty limestone*" and described as "a light drab and buff cherty magnesian limestone,[1] twelve feet" containing "*Productus Calhounianus, Chonetes mucronata, Orthisina* like *umbraculum, Athyris* like *subtilita* and *Crinoids*," near Fort Riley.[2] Swallow called his bed No. 58 the "fourth *cherty limestone*" which corresponds to No 4 of the Strong flint, and he assigned it a thickness varying from ten to twenty-four feet.

The *Florence flint* represents bed No. 54 of Swallow, the "third *cherty limestone*" which he described as "light buff and magnesian, forty feet" containing "*Productus Calhounianus, Orthi-*

[1] The following analysis by Mr. Warren Finney shows that it is not a magnesian limestone.

| | | |
|---|---|---|
| $SiO_2$ | 03.01 | per cent. |
| $Al_2O_3$ | 11.73 | " |
| $CaCO_3$ | 86.35 | " |
| $MgCO_3$ | trace | " |
| $Fe_2O_5$ | trace | " |
| | 101.09 | " |
| CO | 38.32 | " |

[2] Prel. Rep. Geol. Surv., Kansas, p. 14.

*sina Shumardiana*, *Spirifer* like *lineatus*, *Orthisina* like *umbraculum*" exposed "near Fort Riley, Cottonwood and Fancy Creek."[1]

Swallow estimated the thickness of the beds between the fourth and third cherty limestones, which correspond to the beds between the top of the Strong and the base of the Florence flint, as ranging from forty-nine to sixty-eight feet which in our section is called seventy feet. Again, Swallow estimated the thickness of the beds ranging from the base of the fifth to the third cherty limestone, which represent the beds between the base of the Strong and Florence flints, as varying in thickness from 85 to 131 feet, while in the Chase formation they are assigned a thickness of 112 feet. Swallow reported six feet of shales above the Florence flint and then a massive limestone which he described as "a buff porous magnesian rock[2] in thick beds," containing "*Productus Calhounianus*, *Orthisina Shumardiana*, *Archæocidaris*, *Bakevellia*, etc., eight to ten feet . . . . near Fort Riley, Cottonwood and Fancy Creek" for which he proposed the name "*Fort Riley limestone*." On account of the excellent exposures near Junction City and Fort Riley, Swallow's name, "*Fort Riley limestone*," is an appropriate one for the Kansas Valley region, while in the Cottonwood Valley it is represented by the Florence limestone.[3]

After comparing numerous sections, it does not appear that the massive ledge of limestone exposed in the various ravines and bluffs of this region always represents the same bed; in fact we also find that the higher shaly limestones appear in cer-

[1] Prel. Rep. Geol. Surv., Kansas, p. 14. The "Fancy Creek" mentioned frequently by Professor Swallow is supposed to be the one north of the Kansas River in the northern part of Riley county.

[2] This limestone contains a small percentage of magnesia as is shown by Mr. Finney's analysis:

| | | |
|---|---|---|
| $SiO_2$ | 10.01 | per cent. |
| $Al_2O_3$ | 3.74 | " |
| $CaCO_3$ | 83.53 | " |
| $MgCO_3$ | 2.17 | " |
| $Fe_2O_5$ | trace | " |
| | 99.45 | " |
| $CO_2$ | 36.66 | " |

[3] For the first statement of this correlation see PROSSER; Bull. Geol. Soc., Amer., Vol. VI., p. 49 f. n.

tain localities as the conspicuous massive ledge. It is important to bear the above statement in mind in stratigraphic work in regard to this horizon, for a greater uniformity of appearance in outcrop has been assigned to this limestone than actually exists.

Above the Fort Riley limestone Swallow also reported variously colored shales and marls sixty-four and a half feet in thickness before reaching the base of the "second *cherty limestone*"—bed No. 44—which he described as "hard, bluish drab and very cherty, four feet. *Productus*, *Myalina* and *Spirifer*" exposed on the "Cottonwood and Carey Creek."[1] This bed is probably the *Marion flint* of the Chase formation which answers quite well to the above description. The base of the Florence flint is a clearly marked stratigraphic line, and Swallow assigned a thickness of from 118½ to 120½ feet to the beds between the bases of his third and second cherty limestones, while in the Chase formation, from the base of the Florence flint to that of the Marion, it is given as 126 feet. From sixteen to twenty-four feet above the top of the second cherty limestone is bed No. 40 of Swallow which he called the "first *cherty limestone*" and characterized it as "a brownish-buff magnesian limestone with cherty concretions, four feet. *Productus Calhounianus*, *semireticulatus* (?), *Athyris subtilita ?*, *Archæocidaris*," exposed on "Cottonwood and Carey Creek."

It is inferred that this "first cherty limestone" of Swallow is the *Marion concretionary limestone* of the Chase formation, and it will be noticed that Swallow mentions "cherty concretions" instead of simply "chert" as in his description of the other cherty limestones, although he does not refer to the prominent stratigraphic feature of this bed.

Finally, Swallow gave the total thickness of the beds from the base of his fifth cherty limestone—No. 62—to the top of the first cherty limestone—No. 40—as ranging from 223½ to 279½ feet.[2] These beds include all the cherty limestones of

[1] Prel. Rep. Geol. Surv., Kansas, p. 13. The Carey Creek frequently mentioned by Swallow is supposed to be the creek of that name in the eastern part of Dickinson county.

[2] In the section there are a few beds to which no thickness was assigned by Swallow, but it is supposed those were regarded as local and simply a modification of the other beds so that their thickness was considered in those beds.

Swallow and represent those which we have described as the Chase formation, with a thickness of 265 feet. The Chase formation is confined to what Swallow called the Lower Permian, and he drew the line separating the Lower from the Upper Permian at the top of bed No. 31 which he gave as from 49 feet 1 inch to 82 feet 3 inches higher than the bed which we regard as representing the top of the Chase formation.

*Comparison with Meek and Hayden.*—The Strong flint corresponds to bed No. 18 of Meek and Hayden, which they described as a "light gray and whitish magnesian limestone containing *Spirigera*, *Orthisina umbraculum* (?), *O. Shumardiana*, *Productus Calhounianus*, *Acanthocladia americana* and undetermined sp. *Cyathocrinus;* lower part containing many concretions of flint. Fort Riley and on Cottonwood Creek, whole thickness about 40 feet;"[1] while in the Chase formation we have called it 42 feet. Again, the Florence flint is bed No. 14 of Meek and Hayden, which they give as 38 feet thick, while the Florence or Fort Riley massive limestone is No. 12, which they state "forms distinct horizon near summit of hills in vicinity of Fort Riley, also seen on Cottonwood Creek—7 to 8 feet." Number 11 of Meek and Hayden represents the shaly limestones above the massive Florence limestones (No. 16 of the Chase section) which they describe as a "light grayish and yellow magnesian limestone in layers and beds, sometimes alternating with bluish and other colored clays, and containing *Solenomya*, a *Myalina* near *squamosa*, *Pleurophorus* (?) *subcuneata*, *Bakevellia parva*, *Pecten*, undt., and a *Euomphalus* near *E. rugosus;* also a *Spirigera* allied to *S. subtilita* but more gibbous, *Orthisina umbraculum* (?), *O. Shumardiana*, etc. Locality, summit of the hills near Fort Riley and above there; also seen on Cottonwood Creek—25 to 35 feet." Meek and Hayden gave the thickness of the beds from the base of the lower flint—No. 18—to the top of these buff, shaly limestones—No. 11—as ranging from 182 to 193 feet; while in our section of the Chase formation the thickness of the same beds is given as 176 feet. Meek and Hayden considered that the base of the Permian could

[1] Proc. Acad. Sci. Phil., Vol. XI., p. 17.

not be lower than the top of No. 11, although it might be still higher and include No. 10.[1]

Meek and Hayden apparently failed to notice the Marion flint and concretionary limestone, which probably forms a part of their No. 10, so it is not possible to compare closely their section with the upper part of the Chase formation.

*Comparison with Hay's Fort Riley section.*—Professor Hay has described a section near Fort Riley[2] which probably includes all of the rocks referred to the Chase formation. The Strong flint is No. 5 of Hay's section, which he termed "the lower flint beds" or the "Wreford limestone," 25 feet thick.[3]

The Florence flint is No. 9 of Hay, which he called "the upper flint beds," from 25 to 30 feet in thickness; and 15 feet higher in his massive "Fort Riley main ledge"—No. 11—6 feet thick, capped by shaly limestones from 30 to 40 feet in thickness. Then come 50 to 60 feet of shales, and at the top of the section is No. 14 which is described as composed of "impure limestones with some flints and numerous geodes," 10 feet in thickness. It is probable that this highest bed represents the Marion flint or concretionary limestone, which apparently occurs in the bluff above the railroad cut west of Chapman. According to Professor Hay, the thickness of the rocks from the base of the Wreford

[1] Proc. Acad. Sci. Phil., Vol. XI., pp. 20, 21, where it is stated that, "If we do not admit the existence in this region of an intermediate group of rocks, connecting by slight gradations the Permian above with the Coal Measures below, and must draw a line somewhere, below which all is to be regarded as Carboniferous, and all above as Permian, we should certainly, upon palæontological principles alone, carry this line up as far as the top of division No. 11. . . . . Indeed the fact that some of the Permian types occurring in No. 10 were first introduced in beds below this, containing many Carboniferous species would seem to indicate that even No. 10 may possibly have been deposited just before the close of a period of transition from the conditions of the Carboniferous to those of the Permian epoch."

About the same time Meek and Hayden stated in the American Journal of Science —"We think only the Upper Permian of their section [Swallow and Hawn] really represents the Permian rocks as developed on the other side of the Atlantic" (Second series, Vol. XXVII., Jan. 1859, p. 35); while the Lower Permian of Swallow they called Permo-Carboniferous.

[2] Eighth Bien. Rept. State Board Agri. Kansas, p. 104.

[3] This horizon as exposed in the Kansas River Valley was discussed by Prosser in the Bull. Geol. Soc. Am., Vol VI., pp. 47, 48.

limestone to the top of the impure limestone at the summit of the section—No. 14—varies from 213 to 238 feet. However, the Professor underestimated the thickness of the rocks from the base of the Wreford limestone to the base of the upper flint at Fort Riley by about 27 feet,[1] and if this be added to the 238 feet it will give a thickness of 265 feet, which is exactly the thickness which we have assigned to the Chase formation.

### THE MARION FORMATION.

Succeeding the Chase formation are thin, buff limestones and shales; higher, marls and shales with gypsum; and lastly, colored shales and marls which continue to the base of the brown Dakota sandstones of the Cretaceous. These rocks cover the greater part of Marion county and are exposed in many places so it is proposed to call them the *Marion formation.* The natural opportunities are not as favorable for constructing an accurate section here as in the Chase formation, on account of the comparatively level character of the region, presenting few steep bluffs and strata that may be readily traced across the country. The rocks composing the formation are estimated to have a thickness of 400 feet.

Some 50 to 60 feet above the Marion and concretionary limestone is a buff limestone which contains large numbers of small Lamellibranchia and twenty feet higher is a buff limestone containing large Lamellibranchia. In some localities near this horizon is a limestone containing *Pleurophorus* in which are large concretions; these are well shown on sections 34 and 27, north of Wonsevu. On Turkey Creek, south of the Smoky Hill Valley and Abilene, is a conglomerate rock from 15 to 20 feet thick, which is some 150 feet above the base of the formation. On the south bank of the river opposite Abilene is a buff limestone containing Lamellibranchia, which is probably a little below the conglomerate.

*Palæontology.*—In the Marion formation but few Brachiopods

[1] Professor Hay gave 77 feet as the thickness of the rocks from the base of the lower flint (Wreford limestone) to the base of the upper flint beds; while I found the thickness of the same rocks to be near 104 feet on the hill at Fort Riley.

have been found, and the most abundant and characteristic fossils are the small Lamellibranchia which are not uncommon in the lower part, but gradually become rare in the upper portion until fossil forms almost entirely disappear.

In the grayish limestones in the lower part of the formation the following species, from numerous localities in Marion and Morris counties, have been obtained:

1. *Pleurophorus subcuneatus*, M. and H. (aa)
2. *Bakevellia parva*, M. and H. (c)
3. *Yoldia subscitula*, M. and H. (rr)
4. *Macrochilina* cf. *angulifera*, White. (rr)
5. *Pleurophorus subcostatus*, M. and W. (?) (rr)
6. *Nautilus eccentricus*, M. and H. (?) (rr)
7. *Schizodus curtus*, M. and W. (r)
8. *Schizodus ovatus*, M. and H. (r)
9. *Dentalium Meekianum*, Geinitz. (?) (rr)

A little higher are buff limestones which contain large Lamellibranchia as follows:

1. *Aviculopecten occidentalis*, (Shum.) Meek. (aa)
2. *Myalina permiana*, (Swallow) M. and H. (a)
3. *Pseudomonitis Hawni* (M. and H.) (a)
4. *Pseudomonitis Hawni* (M. and H.) var. *ovata*, M. and H. (r)

In Township 22 S., Range 6 E., Sec. 18, west of Wonsevu, a limestone near the top of the hill west of Cedar Creek, contains the fauna given below:

1. *Pseudomonotis Hawni* (M. and H.) var. *ovata*, M. and H. (r)
2. *Pseudomonotis Hawni* (M. and H.) (c)
3. *Pseudomonotis* cf. *variabilis*, Swallow. (r)
4. *Pleurophorus subcuneatus*, M. and H. (c)
5. *Nautilus eccentricus*, M. and H. (?) (r)
6. *Aviculopecten occidentalis*, (Shum.) M. and W. (rr)
7. *Yoldia subscitula*, M. and H. (rr)
8. *Nuculana bellistriata*, Stevens, var. *attenuata*, Meek. (rr)
9. *Derbya multistriata*, (M. and H.) Pros. (?) (c)
10. *Septopora biserialis*, (Swal.) Waagen. (?) (rr)

From the buff limestones and shales on the south bank of the Smoky Hill River, south of Abilene, and not far below the Abilene conglomerate, the following species were collected:

1. *Pleurophorus subcuneatus*, M. and H. (a)
2. *Bakevellia parva*, M. and H. (c)
3. *Edmondia Calhouni*, M. and H. (?) (c) As identified by Geinitz (see Pl. II., Fig. 2 of Carb. und Dyas Nebraska).
4. *Yoldia subscitula*, M. and H. (rr)
5. *Schizodus curtus*, M. and W. (?) (rr)
6. *Nucula* cf. *Beyrichi*, v. Schauroth; also cf. *N. parva*, McChesney. (a)
7. *Aviculopecten* (?) sp. (rr) } very imperfectly preserved.
8. *Septopora* (?) sp. (rr) } very imperfectly preserved.
9. Small *Gastropod* cf. *Aclis Swalloviana*, (Geinitz) Meek. (r)

Above this horizon the fossils are less frequent and in the upper part of the formation seem to completely disappear.

*Comparison of the Marion formation with Swallow's section.*—The Marion formation commences with bed No. 39 of Swallow, but I have not been able to clearly identify the different beds of his section with the various strata of this formation as in the Chase, Neosho, and Cottonwood formations. Swallow described bed No. 23 as "bluish-drab shale, with calcareous concretions," below which are limestones "full of Permian *Acephala* and *Cephalopods*,"[1] and gave this bed as from 49 feet 1 inch to 103 feet 9 inches above the top of his first cherty limestone, which I have considered as the representative of the Marion concretionary limestone. The thickness of the rocks between the concretionary layer of bed No. 23 and the base of the formation indicate that it may be the upper concretionary layer which I have described northeast of Wonsevu. From 16 to 48 feet higher is the base of a "calcareous conglomerate" 1 to 24 feet thick—bed No. 17—and above this is a "concretionary limestone," 2 to 15 feet in thickness, which are stated to occur in "Fancy and Turkey Creeks and Cottonwood."[2] The maximum thickness of the rocks from the base of the calcareous conglom-

[1] Prel. Rept. Geol. Surv. Kans., p. 12.

[2] Ibid., p. 11.

erate to the base of our Marion formation, according to Swallow, is 151 feet 7 inches, which indicates that the conglomerate we noted in Turkey Creek, south of Abilene, and estimated as 150 feet above the base of the Marion formation is the "calcareous conglomerate" of Swallow. From 61 to 124 feet higher is the top of Swallow's Permian; but Professor Mudge stated that all of Swallow's Triassic system, except the two upper beds—Nos. 3 and 2—should be referred to the Permian.[1] Calling bed No. 4 of Swallow the top of the Permian, the beds of his section corresponding to those of the Marion formation have a thickness ranging from 334 feet 11 inches to 544 feet 7 inches.

*Comparison with Meek and Hayden.*—The conglomerate noted on Turkey Creek south of Abilene is apparently bed No. 9 of Meek and Hayden which they described as a "rough conglomerated mass, composed of fragments of magnesian limestone and sandstone, with sometimes a few quartz pebbles, cemented by calcareous and arenaceous matter . . . . south side Smoky Hill River, ten or twelve miles below Solomon's Fork, 18 feet."[2]

From the base of this conglomerate limestone to the apparent base of the Dakota sandstone of their section—bed No. 2—is 388 feet. If their concretionary limestone—bed No. 9—which, according to the description and locality agrees with the one seen south of Abilene, be 150 feet above the base of the Marion formation, then making this correction in their estimate of thickness would give 538 feet as the thickness of the Marion formation.

CONCLUSION.

The length of this paper precludes any complete discussion of the geologic position of these formations and their correlation with deposits of similar age in different parts of the world, therefore such a review must be deferred until the detailed geo-

[1] First Bien. Rept. State Board Agri. Kansas, 1878, p. 66 and f. n., where the Professor said, "the other numbers [aside from 2 and 3] of his Triassic belong to the Permo-Carboniferous." Professor Mudge did not attempt to separate the Permian and Upper Carboniferous, for he said, "These two groups may be described together, as there is no line of division, either by physical deposits or fossils" (*ibid.*, p. 70).

[2] Proc. Acad. Nat. Sci., Philadelphia, Vol. XI., p. 16.

logic report of the region is published. In order to appreciate the questions involved in the correlation of these formations, it is important to mention briefly the proposed classifications which have appeared within the last few years.

After the publication of the final views of Meek and Hayden in 1872, which referred especially to the Upper Palæozoic of southeastern Nebraska,[1] the next important announcement was that of Dr. Newberry at the Berlin International Geological Congress in 1885, where he is reported to have stated that "He had traversed all the States and Territories of the Union, and had examined the so-called Permian in many localities, but, in his judgment, it could not be separated from the Coal Measures.

It is true that in the upper Carboniferous strata certain genera of mollusks appear, which are regarded as characteristic of the Permian, such as *Monotis*, *Bakevellia*, *Pleurophorus*, etc., but these are associated with and outnumbered by the most characteristic Coal-measure forms, such as *Spirifer cameratus*, *Athyris subtilita*, *Productus semireticulatus*, etc., and were by these inseparably bound to the Carboniferous system."[2] As far as the palæontology is concerned we have shown above that the statement of Dr. Newberry is entirely incorrect in regard to the range of the Brachiopods in Kansas. We have not seen *Spirifer cameratus* above the top of the Wabaunsee formation, or the last two species above the Chase formation. However, the most misleading part of the statement is that these Brachiopods outnumber the Lamellibranchia in all of these deposits. In the Neosho and Chase formations possibly the Brachiopods are the more abundant; but in the Marion formation they are extremely rare, a few specimens of *Derbya* only having been found, and the Permian Lamellibranchia are conspicuously the dominant fossils.

In 1889, Dr. Th. Tschernyschew, the able Director of the

[1] Final Rept. U. S. Geol. Surv. Nebraska and portions of adjacent Territories. The field work upon which this report was based, was accomplished during 1867, and the report was submitted for publication on March 1, 1868, but was delayed until 1872 (see pp. 3, 139).

[2] The Work of the International Congress of Geologists, 1886, p. 29. Dr. Newberry's statement of the absence of the Permian in America was published in the Am. Jour. Sci., 3d series, Vol. XXX., December, 1885, p. 469.

No. 4. Near view of the Fort Riley limestone North of Fort Riley, Kansas.

Russian Geological Survey, stated that he agreed with Waagen in considering the Nebraska City beds, in southeastern Nebraska, similar in age to the Artinsk sandstone group of the Ural Mountains, which he called Permo-Carboniferous.[1]

In 1891 appeared Waagen's exhaustive work on the geological classification of the Upper Palæozoic rocks of the Salt-Range in northern India,[2] in which the author shows the striking relations "that undoubtedly exist between the American Coal Measures and the deposits of the Salt-Range."[3] Waagen followed Neumayr and made two large divisions of the Palæozoic; for the upper division, which included the Carboniferous and Permian systems, he proposed the name, "Anthracolithic epoch" which he defined as equivalent to Neumayr's "Upper Palæozoics."[4]

Waagen prepared a table giving his views of the correlation of the Upper Palæozoic strata of the Salt-Range with similar deposits of other countries,[5] and the Permian system was composed of the Permo-Carboniferous, Rothliegendes, and Magnesian Limestone groups. The correlation of the American deposits are of special interest to us, and represents that part of the table to which we shall refer. Waagen, for North America, drew the dividing line between the Carboniferous and Permian systems at the top of the "Upper Productive Coal Measures" and referred the "marine beds of Plattsmouth [Nebraska] and beds below (up to about 2000 feet in thickness) down to the

[1] Mém. Com. Géologique, Vol. III., No. 4, p. 366. In Murchison's description of he geology of Russia, the Artinsk sandstones were referred to the Carboniferous (Geol. Russia in Europe and the Ural Mts., Vol. I., 1845, p. 129). The correlation and palæontology of the Nebraska City beds have been carefully discussed by Professors Marcou, H. B. Geinitz and Meek, and the consideration of this question is reserved for a later paper. Professor Hicks at a later date briefly described deposits in Gage county, in the southern part of Nebraska, which probably belong to the Permo-Carboniferous or Permian of Kansas (Am. Naturalist, Vol. XX., 1886, pp. 881–3; abstract in Proc. Am. Asso. Adv. Science, Vol. 35, 1887, pp. 216, 217).

[2] Mem. Geol. Surv. India, Palæ. India. Ser. XIII., Salt-Range Fossils, Vol. IV., Pt. II., Geological Results, Calcutta.

[3] Ibid., p. 201.

[4] Ibid., p. 241.

[5] Ibid., "Tabular view showing the relations of the Salt-Range Upper Palæozoic strata to the deposits of other countries," op. cit., p. 238.

Productive Coal Measures," to the Permo-Carboniferous group. The upper part of the group was correlated with the Artinsk stage of Russia.

This group would include at least the Wabaunsee formation of Kansas which contains a fauna practically identical with that of the Upper Coal Measures, and as far as the deposits of Kansas are concerned there seems to be no reason for considering the formation as of Permian or Permo-Carboniferous age. The "red and gray sandstones and shales of Nebraska City" are correlated with the Rothliegendes by Waagen, who clearly regards them as younger than the Artinsk stage. Then the "red sandstones and shales of Texas" containing Vertebrates and Cephalopods, which have been described by Cope and White,[1] are referred to the lower part of the Magnesian limestone which forms the upper group of Waagen's Permian system. Finally, the "limestones and shales, with *Pseudomonotis hawni* (—*speluncaria*) of Kansas, red gypsum beds of Texas" are regarded as equivalent to the remaining portion of the Magnesian limestone group and consequently represent the upper part of the Permian system.

It may be said in general in reference to Waagen's correlations that so far as the North American deposits are concerned he carried the Permo-Carboniferous group too low. If it be considered better to put all the beds in either the Carboniferous or Permian system, it might be just as well to refer the deposits generally called Permo-Carboniferous to the Permian.[2] If such correlation be agreed upon then in Kansas, the line separating the Cottonwood and Neosho formations would become the line of division between the Carboniferous and Permian systems. In the Cottonwood formation is the massive *Fusulina* limestone[3]

[1] EDWARD D. COPE: Trans. Am. Phil. Soc., 1888, Vol. XVI., pp. 285–288.

CHARLES A. WHITE: The Texan Permian and its Mesozoic types of fossils. Bull. U. S. Geol. Surv., No. 77, 1891, pp. 39, Pl. IV.

[2] In this connection see a paper by Professor James P. Smith on "The Arkansas Coal Measures in their relations to the Pacific Carboniferous province" (The JOURNAL OF GEOLOGY, Vol. II., 1894, pp. 187–205). On the "Correlation Table" at the close of the paper (p. 204) the "Permo-Carboniferous of Kansas and Nebraska" is referred to the Permian.

[3] The *Fusulina* limestones of Europe and Asia belong either in the Upper Carboniferous or lower Permian, hence, the massive Cottonwood limestone with its millions of

with the fossiliferous shales above, which is an excellent formation to be traced in the field, and so would furnish a well-marked line for separating the two systems in areal geology.

In 1890, Professor W. F. Cummins divided the Texan Permian[1] into three formations or beds, as he called them, and named them in ascending order the Wichita, Clear Fork, and Double Mountain beds.[2] In the succeeding report the upper formations of the Coal Measures were named the Albany, Cisco, and Canyon,[3] the Albany being the higher and just below the Permian according to Professor Cummins' classification. The report also contains plates showing the classification of the Carboniferous and Permian,[4] and lists of fossils from the Coal Measures.[5] The Permian is more fully described than in the preceding reports and is accompanied by sections and references to the palæontology[6] as elaborated by Dr. White.[7] The fossil plants collected in the upper part of the Wichita formation were identified by Professor I. C. White and Fontaine as essentially the same as the flora described by them from the beds above the Waynesburg Coal in West Virginia which they had referred to the Permian.[8] In 1893 Professor Cummins again discussed the Permian formations of Texas, reviewed the history of the discovery of Permian rocks in this country, and the question of their correlation with the Permian of Europe and Asia.[9] In this report

*Fusulinas*, which is near the close of their range in Kansas, may be considered as near the line of division between these two systems. See Dr. E. Kayser's Text Book of Comparative Geology, English ed., 1893, pp. 127, 144, 162. On p. 147 Kayser says "west of the Mississippi . . . . the Upper Carboniferous is represented by limestones rich in *Fusulina* with an abundant marine fauna."

[1] For an earlier summary of the papers describing the Permian of Texas, see Professor R. T. Hill; Bull. U. S. Geol. Surv., No. 45, 1887, pp. 62–69.

[2] Geol. Surv. Texas, First An. Rept., pp. 186–189; and LXIX., LXX.

[3] Second An. Rept. Geol. Surv. Texas, 1891, pp. 372–375.

[4] *Ibid.*, pp. 361, 373.

[5] *Ibid.*, Particularly pp. 393, 394.

[6] *Ibid.*, pp. 394–424.

[7] Bull. U. S. Geol. Surv., No. 77.

[8] Bull. Geol. Soc. Amer., Vol. III., 1892, pp. 217, 218.

[9] Geol. Surv. Texas, Fourth An. Report., pp. 212–232.

it is stated: "It is still too early to attempt exact correlation, but it is quite probable that the Albany division of my Coal Measures will prove to be the same as the beds at Fort Riley, Kansas."[1] Professor Cummins further said that the *Phacoceras Dumbli*, Hyatt which is found at Fort Riley, Kansas, came from "the very top of the Albany division in Texas . . . . and as the form is supposed to have but a short range in time it would go far to assist in correlating the strata."[2] If Professor Cummins be correct in the above correlation, then it is probable that the Albany formation ought to be correlated with the Permo-Carboniferous of Kansas.[3]

In reviewing these reports Professor Marcou correlated the Albany division with the Nebraska City deposits of Nebraska, and the Cisco division he considered as related to the Plattsmouth group of Nebraska.[4] While Professor Smith draws the line between the Coal Measures and the Permo-Carboniferous through the upper part of the Cisco formation, including in the Permo-Carboniferous the "uppermost Cisco beds of Texas, with *Ammonites* (*Popanoceras*) *Parkeri*, Heilprin," which he correlates with the Artinsk stage.[5]

After reviewing all the published opinions regarding the correlations of the Upper Palæozoic of the United States and after a consideration of the fauna and the lithological and stratigraphical characters of these formations as exposed in Kansas, it seems well to classify them as indicated on the chart on p. 797. Consequently we would refer the Wabaunsee and Cottonwood formations to the Upper Coal Measures. The Neosho and Chase formations are transitional from the Upper Coal Measures to the Permian, as first defined by Murchison for Russia, and belong to the division which has generally been called Permo-Carboniferous, in this country. In accordance with the views of the majority of

[1] Ibid., p. 222.

[2] Ibid., p. 223.

[3] Professor Cummins is not sure but that "the Wichita and Albany divisions are but different facies of the same formation" (ibid., p. 223).

[4] Am. Geol. Vol. X., 1892, p. 369; see "Table of Classification" on pp. 376, 377.

[5] JOURNAL GEOLOGY, Vol. II., 1894, p. 194; see "Correlation Table" on p. 204.

present European geologists familiar with this problem it is probably better to include the Permo-Carboniferous rocks of Kansas in the Permian series.[1] We see no decided objection to such a classification, while the appearance and the prominence of the *Pseudomonotis* fauna in the Neosho formation furnishes a strong reason on the biologic side for such correlation. The Marion formation belongs to the undoubted Permian and contains only fossils which are characteristic of that series.

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UNION COLLEGE,
Schenectady, N. Y., July, 1895.

[1] The classification of the Permian as a subdivision of the Carboniferous period or system is in accordance with the usage of the U. S. Geological Survey (See Tenth An. Rept. U. S. Geol. Surv., p. 66).

TABLE SHOWING THE STRATIGRAPHIC POSITION AND CHARACTER OF THE FORMATIONS COMPRISING THE UPPER PALÆOZOIC OF CENTRAL KANSAS.

| Period | Series | Formation or Stage | Stratigraphic Characters of the Different Beds | Characteristic Fossils | Thickness of Beds | Total Thickness | Thickness of Formation |
|---|---|---|---|---|---|---|---|
| Cretaceous | | *Dakota*[1] (Meek and Hayden) | Massive dark brown or red sandstones. | Fossil plants. | | | |
| Carboniferous. | Permian. | *Marion* (Prosser) | Variously colored shales and marls. Colored shales and marls alternating with beds of gypsum. Buff limestones and marls. | | 250± | 1390 | 400± |
| | | | *Abilene conglomerate.* | | 20± | 1140 | |
| | | | Shaly buff limestones with *Pleurophorus.* | *Pleurophorus subcuneatus, Bakevellia parva, Edmondia Calhouni, Nucula sp.* | 130 | 1120 | |
| | | | Buff limestones which contain large *Lamellibranchia.* | *Aviculopecten occidentalis, Myalina permiana, Pseudomonotis Hawni.* | | | |
| | | | Grayish (?) limestones containing plenty of *Bakevellias*, near this horizon in some localities a concretionary limestone. Thin buff limestones with a few *Derbyas.* | ............................ *Pleurophorus subcuneatus, Bakevellia parva, Schizodus curtus, Schizodus ovatus, Nautilus eccentricus, Yoldia subscitula.* | | | |
| | | *Chase* (Prosser) | *Marion concretionary limestone;* containing large brown concretions. | *Athyris subtilita, Productus semireticulatus, Derbya multistriata.* | 10 | 990 | |
| | | | Yellowish shales, few *Brachiopods.* | *Athyris subtilita, Productus semireticulatus, Derbya crassa, Septopora biserialis.* | 13+ | 980 | |
| | | | *Marion flint;* light gray limestone generally containing flint. | *Productus semireticulatus,* var. *Calhounianus, Athyris subtilita Archæocidaris sp.* | 4 | 967 | |

[1] Perhaps the base of the Dakota should be referred to the Mentor beds of Professor Cragin. (See Am. Geol., Vol. XVI., Sept. 1895, pp. 162, 163.)

TABLE SHOWING THE STRATIGRAPHIC POSITION AND CHARACTER OF THE FORMATIONS COMPRISING THE UPPER PALÆOZOIC OF CENTRAL KANSAS.—*Continued.*

| Period | Series | Formation or Stage | Stratigraphic Characters of the Different Beds | Characteristic Fossils | Thickness of Beds | Total Thickness | Thickness of Formation |
|---|---|---|---|---|---|---|---|
| Carboniferous. | Permian. | *Chase* (Prosser) | Variously colored shales with thin layers of limestone. | | 62± | 963 | |
| | | | Buff shaly limestones with *Lamellibranch* fauna. | *Bakevellia parva*, *Pleurophorus subcuneatus*, *Aviculopecten occidentalis.* | 22 | 901 | |
| | | | *Ft. Riley* or *Florence limestone;* a massive buff limestone. | | 5+ | 879 | 265 |
| | | | Buff shaly limestones containing an abundant *Brachiopod* fauna. | *Derbya multistriata*, *Athyris subtilita*, *Productus semireticulatus* var. *Calhounianus*, *Meekella striato-costata*, *Straparollus subquadratus*, *Derbya crassa*, *Meekella* (?) *Shumardiana*, *Spirifera planoconvexa*, *Chætetes sp.* | 15 | 874 | |
| | | | *Florence flint;* a massive limestone with prominent layers of flint. | *Productus semireticulatus*, *Chonetes granulifera*, *Derbya multistriata.* | 22 | 859 | |
| | | | Yellowish, chocolate and greenish shales. | | 31 | 837 | |
| | | | Light gray limestone with a fauna of small *Lamellibranchia.* | *Pleurophorus subcuneatus*, *Bakevellia parva*, *Edmondia Calhouni* (?) | 2± | 806 | |
| | | | Shales. | | 12± | 804 | |
| | | | Shaly buff limestone containing large *Brachiopods.* | *Derbya multistriata*, *Aviculopecten occidentalis.* | 10± | 792 | |
| | | | Shales. | | 15± | 782 | |

TABLE SHOWING THE STRATIGRAPHIC POSITION AND CHARACTER OF THE FORMATIONS COMPRISING THE UPPER PALÆOZOIC OF CENTRAL KANSAS.—*Continued.*

| Period | Series | Formation or Stage | Stratigraphic Characters of the Different Beds | Characteristic Fossils | Thickness of Beds | Total Thickness | Thickness of Formation |
|---|---|---|---|---|---|---|---|
| Carboniferous. | Permian. | *Chase* (Prosser) | *Strong flint;* two strata of light gray limestone containing an abundance of flint in layers, separated by a massive whitish limestone. | *Enteletes hemiplicatus, Athyris subtilita, Chonetes granulifera, Meekella striato-costata.* | 42 | 767 | |
| | | *Neosho* (Prosser) | Yellowish shales with *Brachiopod* fauna. | *Chonetes granulifera, Derbya crassa, Athyris subtilita.* | 23 | 725 | 130 |
| | | | Massive gray limestone with *Pleurophorus.* | | 3+ | 702 | |
| | | | Yellowish shales with thin shaly limestones. | | 36 | 699 | |
| | | | Limestone with *Pseudomonotis* at top and bottom, with shales between. | *Pseudomonotis Hawni.* | 12 | 663 | |
| | | | Green and chocolate colored shales. | | 20 | 651 | |
| | | | Light gray shaly limestones containing *Pseudomonotis.* | *Productus nebrascensis, Pseudomonotis Hawni, Aviculopecten occidentalis, Pleurophorus subcostatus.* | 4 | 631 | |
| | | | Shales. | | 4 | 627 | |
| | | | Dark gray silicious limestone, weathers to very rough surface. | | 2+ | 623 | |
| | | | Yellowish shales with *Brachiopods.* | *Chonetes granulifera, Productus semireticulatus, Rhombopora lepidodendroides.* | 6 | 621 | |
| | | | Yellowish, blocky shales containing a *Lamellibranch* fauna. | *Pseudomonotis Hawni, Aviculopecten occidentalis, Meekella striato-costata.* | 5 | 615 | |

TABLE SHOWING THE STRATIGRAPHIC POSITION AND CHARACTER OF THE FORMATIONS COMPRISING THE UPPER PALÆOZOIC OF CENTRAL KANSAS.—*Continued.*

| Period | Series | Formation or Stage | Stratigraphic Characters of the Different Beds | Characteristic Fossils | Thickness of Beds | Total Thickness | Thickness of Formation |
|---|---|---|---|---|---|---|---|
| (?) Carboniferous. | Permian. | *Neosho* (Prosser) | Greenish and chocolate shales. | | 11 | 610 | |
| | | | Shaly limestones. | | 4 | 599 | |
| | Upper Coal Measures. | *Cottonwood* (Prosser) | *Cottonwood shales;* yellowish shales, in the upper part unfossiliferous but containing nodules of gypsum (?); the lower part very fossiliferous. | *Chonetes granulifera, Derbya crassa, Athyris subtilita, Productus semireticulatus, Meekella striato-costata.* | 14 | 595 | 20 |
| | | | *Cottonwood limestone;* light gray massive limestone containing in the upper part immense numbers of *Fusulina.* | *Fusulina cylindrica.* | 6 | 581 | |
| | | *Wabaunsee* (Prosser) | Shales. | | 40 | 575 | 575± |
| | | | "*Dry bone limestone;*" a drab to bluish silicious limestone which on weathering forms a rough surface. | | 10± | 535 | |
| | | | Shales and marls interstratified with limestones. Some of the limestones form thick, massive strata. In the lower part an occasional thin stratum of coal. | *Chonetes granulifera, Productus splendens, P. cora, P. nebrascensis, Spirifer planoconvexus, Athyris subtilita, Hustedia mormonii, Spirifer cameratus, Pinna peracuta, Derbya crassa, Meekella striato-costata, Spiriferina kentuckensis.* | 525± | 525 | |
| | | *Missouri* (Keyes) | | | | | |

# THE VOLCANICS OF THE MICHIGAMME DISTRICT, OF MICHIGAN (PRELIMINARY).

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THIS name is given to a series of volcanic rocks occurring on the Upper Peninsula of Michigan, between Townships 42 and 47 N., and Ranges 30 and 34 W. They are included between the Paint (Mequacumecum) and Michigamme Rivers, and are intersected by their tributaries, the Fence (Mitchigan), the Deer, and the Hemlock Rivers.

*Previous work in this area.*—The chief interest in the area has been due to the occurrence of iron ores in the sedimentary rocks associated with the volcanics. The iron deposits first discovered in this region were those lying along the Paint River near Crystal Falls, just outside of the immediate area under discussion, and were briefly mentioned by Major T. B. Brooks in his report on the iron-bearing rocks of Michigan.[1] Apparently little attention was paid to the district for some time after this, except by the prospectors, who gradually advanced with their test pits to the north, until the deposits along the Michigamme to the northeast and at Amasa to the northwest were found.

In his report of work done on the Upper Peninsula between 1881–4, which has just appeared, Rominger[2] refers those iron deposits occurring along the Michigamme River in Township 43 N., Range 31 W., Section 4, and Township 44 N., Range 31 W., Sections 33 and 34, to the Huronian, corresponding to the rocks of the Quinnesec ore range, to which reference had been made in previous publications.[3] The volcanics were not recognized as such, but were called diorite.[4]

[1] Geol. Sur. of Mich., Vol. I., Part I, p. 182, 1873: he writes, "Too little is known about the Paint River district . . . . to enable me to give anything of interest regarding its geological structure. The Huronian rocks are extensively developed there, and contain deposits of hard hematite ore."

[2] Geol. Sur. of Mich., Vol. V., p. 32, 1895.

[3] Ibid., Vol. IV., p. 82, 1881.

[4] Ibid., Vol. V., p. 37.

The mining district of Amasa is of quite recent development, and as far as I am aware no attempt has thus far been made to refer the deposits to any definite geological horizon.

During 1892, Messrs. W. N. Merriam and H. L. Smyth, with their assistants, were engaged in tracing out the iron-bearing formation in this region. Smyth worked in the northeast along the Michigamme River, and Merriam west of the Michigamme River and southwest of the Deer River. When their work was finished the two areas were not connected in the north by about twelve miles, and a narrow belt separated the mapped areas to the south.

During the season of 1894, I was engaged, with the assistance of G. E. Culver and S. Weidman, in completing this area, preparatory to extending the work into the Menominee iron district. Many of the facts of the field occurrence mentioned in the following article were observed and recorded by Merriam and assistants, and were subsequently verified by my own observations of last season in a different portion of the area, and by visits to localities in the areas previously surveyed.

*Succession.*—A résumé of the ascending succession is as follows: The area considered is oval in outline, about twenty-five miles long and twelve miles wide, extending in a N.W.–S.E. direction (Pl. I.) The center of this oval is occupied by an elliptical area thirteen miles long by three miles wide, of the oldest rocks of the district, consisting of granite and gneiss, cut by numerous basic dikes. This is surrounded by a quartzose limestone formation, with an estimated thickness of 1500 to 2000 feet.[1] In places the quartz almost disappears and we get a limestone. In other places we have an almost pure quartzite. The formation disintegrates very rapidly, and to this fact can probably be attributed the lack of outcrops over the greater portion of the area which it is supposed to underlie. Overlying the limestone we find, both to the east and west of the ellipse described, a great series of volcanics with an average thickness of about 3000 feet. Their greatest development is to the west of the ellipse, where the average thickness is 4000 feet. It appears probable that these two areas

[1] H. L. SMYTH: Relations of the Lower Menominee and Lower Marquette Series in Michigan. Am. Jour. Sci., 3d Ser., Vol. XLVII., p. 217, January 1894.

are connected around the ellipse both to the north and south, forming a belt completely encircling it. The volcanics are in turn enclosed by a zone of sedimentaries, for the most part quartz-

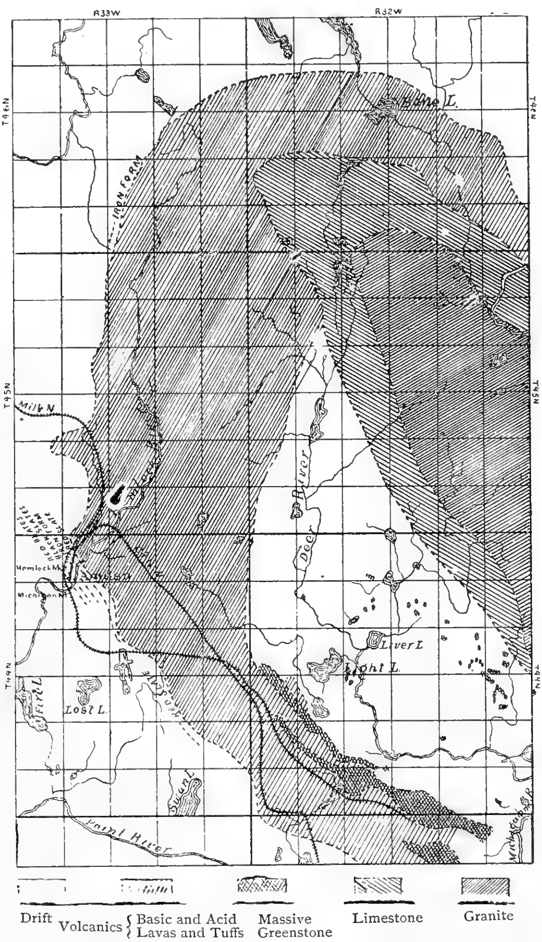


PLATE I.

Preliminary map of part of the Michigamme district. Scale 1 in to 4 miles.

ite and slate, which is throughout characterized by the greater or less amount of iron which it contains. It is known as the Michigamme jasper, from its typical development at Michigamme

Mountain.[1] Test pits are common where it outcrops, and at Amasa it contains iron in quantities sufficient to be mined. This series is also characterized by its marked magnetic properties. It was chiefly due to this property that it was found possible to connect the widely separated outcrops by means of the dip needle and of the dial compass.

The entire district is heavily covered with drift, showing in many places beautifully developed glacial topography. This mantle conceals so much of the country rock that the outcrops are very scarce, thus very greatly increasing the difficulties of the geologist.

Owing to the incompleteness of the work the structure of the area and the correlation of its rocks will be left for a future report. It can be stated, however, that the volcanics are of Huronian age.

*Volcanics.*—Those discussed in this paper lie in general to the west of the Archean core, and between Bone Lake on the north and Crystal Falls on the south. They are the rocks which predominate in, and are by far the most characteristic for, this district, the sedimentaries playing only a very subordinate rôle. The belt in which they are found varies in width from three-fourths to four and one-half miles. The apparent enormous thickness which this would give to the series in the widest part of the belt, since the dip of the rocks is about 75°, has been greatly increased by the minor crumplings and thrusts to which the series has undoubtedly been subjected. The very considerable thickness may be partly explained by supposing the volcanics to have accumulated in the immediate proximity of the vents from which they were ejected. If we accept an average thickness of 4000 feet, we will probably not overestimate it.

Since the flows are all now on edge, and erosion has left only isolated fragments of flows and accompanying tuffs, it is only possible to study them in cross section. Owing to this fact the topography is very rough, the elevations in most cases corresponding to the massive rocks, though thoroughly consolidated breccias form some of the highest hills. That these rocks are

[1] Loc. cit., p. 217.

true volcanics could not be doubted for a moment by any one seeing them *in situ* or even in hand specimens. They exhibit the vesicular character and flow structure of modern lavas, and interbedded with them we find great masses of breccia and tuff, composed of dense and scoriaceous fragments of rock similar in appearance to the rocks of the lava flows. A fact to be noted is that remarkably few undoubted dikes have been observed. This may be due to some extent to the disposition of the strata.

Both basic and acid igneous rocks are represented in the Michigamme district by lava flows and pyroclastic deposits. The basic volcanics comprise those altered pre-Tertiary equivalents of the basalts and andesites known as melaphyres and porphyrites. In the following pages they are called apobasalts and apoandesites. The acid rocks include originally holocrystalline porphyritic rocks, quartz porphyries, and devitrified equivalents of the rhyolites, which are here called aporhyolites.[1]

The apobasalts are by far the most common of the volcanic rocks. Their colors are various shades of green, dark olive-green prevailing. Upon weathering the green rock is usually covered by a thin crust, in which gray, brown, and even pinkish tints prevail.

The lavas vary in coarseness from dense aphanitic rocks to those which are medium-grained. No coarse-grained rocks are found among the interbedded flows and tuffs.[2] Some of the most characteristic volcanics are fragments in the pyroclastics. The most constant volcanic characteristic is the presence of a well-marked amygdaloidal structure, the rounded or more less irregular shaped amygdules ranging from those of almost microscopical size up to others larger than a pigeon's egg. Some of the rocks are so full of these vesicles as to be truly scoriaceous.

[1] F. BASCOM: The Structures, Origin, and Nomenclature of the Acid Volcanic Rocks of South Mountain. JOURN. GEOL., Vol. I., No. 8, p. 828, Nov.–Dec. 1893.

[2] In the southern portion of the area occur great continuous masses of coarse-grained rocks, which are undoubtedly closely related to the volcanics. At the present stage of the investigation it is, however, undecided just what this relation is. It is presumed that they represent great fissure flows, with which eruptive activity here began, and which were subsequently followed by the extrusion of the thinner lavas and ejection of the lapilli and ashes forming our present breccia and tuff deposits. Their general distribution is shown on the accompanying sketch map, Pl. I.

Thin sections of the rock show a characteristic ophitic structure, with in places a flow structure around the amygdules brought out by the feldspar microlites. The angular interstices between the well preserved lath-shaped crystals are filled by irregular pieces of fibrous green hornblende, with here and there epidote, zoisite, less chlorite, and grains of titanite, the result of the alteration of the original augite and titano-magnetite, and also of any original vitreous base which may have been present. The presence of a base is indicated by the presence of chloritic material between some of the feldspars, seemingly the alteration product of the base in which the crystals were imbedded. Moreover the sharply bounded walls of the amygdules may indicate the former presence of glass.[1] Olivine has in no case been observed. The feldspar is very fresh, only beginning to become slightly turbid through development in it of a few grains of epidote and flakes of chlorite. Rarely does any original magnetite remain, and in such cases the rock is very noticeably darker.

*Apoandesite.*—The apoandesites include those rocks which, while intimately associated with and very closely related to the apobasalts, differ from them in their porphyritic habit, having labradorite as phenocrysts.

In thin section the large automorphic phenocrysts of slightly altered plagioclase lie in a very fine grained matrix, composed of long slender feldspar microlites separated by crystals of magnetite,—though in most cases it has entirely disappeared,—and the alteration products of the original augite and base, fibrous green hornblende, epidote, zoisite, chlorite, and brownish grains of a mineral which has a higher single and double refraction than the epidote, and is presumed to be titanite. Measurements made against the twinning plane of the plagioclase phenocrysts give an average extinction angle of 25°, indicating the feldspar to be labradorite.

The character of the microlites I have not been able to determine with sufficient accuracy. The alteration which most of them have undergone makes the task of searching for suitably

[1] J. J. SEDERHOLM: Studien über archæische Eruptivgesteine aus dem südwestlichen Finnland. Tsch. Mit. XII., p. 113. 1891.

oriented and sufficiently fresh sections upon which to make measurements an exceedingly tedious one. The rocks frequently show a flowage structure caused by the parallel arrangement of the microlites around the phenocrysts and amygdules. The minerals of the andesite have suffered the same changes as those of the basalts. Andesitic fragments are also very common in the tuffs, although in no place do we have a true andesite tuff or breccia.

As is seen from the description of the freshest and most characteristic of the basic volcanics, the mineral constituents have undergone very far reaching alterations, the result of which has been to produce most commonly epidote, zoisite, fibrous green hornblende, chlorite, and less quartz, feldspar and calcite. More advanced alteration results in rocks very similar to the basalts and andesites as described above, in which, however, the feldspar crystals are replaced by chlorite and epidote, the feldspar shapes being retained. In such cases the ophitic structure shows nicely in ordinary light, but between crossed nicols the feldspars break up into aggregates of chlorite and epidote, completely concealing the characteristic structure of the rock. The very fine grained lavas undergo the same alteration, producing a very tough light green rock which does not show at all the structure of an eruptive rock, as they are frequently found free from amygdules. In the very fine grained rocks the production of so much epidote and titanite in minute grains, by their high single refraction, causes the rock to appear almost opaque in thin section.

In addition to these changes, which have been for the most part merely the replacing of one mineral by another, the rocks have been subjected to considerable pressure and shearing, which have in many places given them a more or less perfect schistosity. In such cases the flattening of the amygdules is especially noticeable.

The amygdules are filled by nearly the same minerals as those which occur secondarily in the rock mass itself. Arranged in order of frequence of occurrence they are as follows: Epidote, zoisite, chlorite, quartz, calcite and feldspar. The nonoccurrence of zeolites is very noticeable, since they are so common in the altered modern basalts, and also occur in basalts as old as those of South Mountain[1] and of Keweenaw Point.[2]

The amygdules usually stand out well from the body of the rock when filled with infiltrated products or when weathering has left them empty, giving the rock, in the first case, from a short distance, the appearance of porphyry, in the second, a decidedly scoriaceous look.

A columnar structure so common in the modern equivalents of such rocks is noticeably absent. A spheroidal structure, however, having the same appearance as that described by Lawson,[3] Williams[4] and also by Cole[5] and Gregory,[6] is quite common in the lavas. It was in no case observed in the fragmental deposits.

*The breccias and tuffs.*—Flow breccias formed of angular basalt fragments imbedded in a matrix of the same material are found, but since they preserve the main character of the ordinary basalt flows which have just been described, they will not be discussed in the following passages. The pyroclastics are very common and quite characteristic, the characters of the beds being best shown on the weathered surfaces. On these the light grayish green fragments of varying size and more or less

[1] G. H. Williams: The Volcanic Rocks of South Mountain in Pennsylvania and Maryland, Am. Journ. Sci., 3d Ser., Vol. LXIV., p. 491, 1892.

[2] Raphael Pumpelly: Paragenesis and Derivation of Copper and its Associates on Lake Superior, Am. Journ. Sci., 3d Ser., Vol. II., p. 188, 1871; also Geol. Sur. of Michigan, Vol. I., Part II., pp. 19–46, 1873; Geol. of Wisconsin, Vol. III., p. 31, 1880.

R. D. Irving: The Copper-bearing Rocks of Lake Superior, Mon. V., U. S. Geol. Sur., p. 89, 1883.

[3] A. C. Lawson: Report on the Lake of the Woods, Geol. and Nat. Hist. Sur. of Canada (New Ser.), Vol. I., pp. 52–3, 1885.

[4] G. H. Williams: The Greenstone-schist Areas of the Menominee and Marquette Regions of Michigan, Bull. U. S. Geol. Sur., No. 62, p. 166, Fig. 26, 1890.

[5] G. A. J. Cole and J. W. Gregory: On the Variolitic Rocks of Mt. Genevre, Q. J. G. S., Vol. LXVI., p. 311, Fig. 4, 1890.

[6] J. W. Gregory: On the Variolitic Diabase of the Fichtelgebirge, Q. J. G. S., Vol. LXVII., p. 48, Fig. 2, 1891.

In these last two papers the illustrations of the structure are especially characteristic.

angular shape stand out well from the brownish red matrix. A fresh surface shows the fragments to be light green, and the cement a darker green. The fragments vary in size from bowlders to minute ones which fill in the interstices between the larger ones and thus serve to make the mass compact. They are for the most part not amygdaloidal, but very dense, although those which are amygdaloidal and even scoriaceous do occur mixed with the dense fragments, and in places equal them in quantity. The basalt and andesite appears to be equally well represented in the pyroclastics.

These deposits show in places a well-developed banding caused by interbedding of layers in which coarse and fine fragments alternately prevail, illustrating well the varying intensity of the volcanic discharges. Gradation could also be traced from the coarse breccias to the delicately banded portions which are exactly analogous to the fine sand and ash beds of the modern Tertiary and recent volcanoes. These fine sand and ash beds are not, however, composed of crystal elements, but as far as the observations go are composed solely of very fine rock fragments. In such places the difference between the thickness of the ash beds and of the tuff is naturally very great. The average thickness of the ash beds observed was about three feet. In the same exposure the tuffs are from 50 to 100 feet thick. The thickness of the more massive layers could not be determined. Especially good opportunities for observing the varying relations between tuff and ash beds is offered by the third cut on the Milwaukee & Northern Railway west of Balsam, Michigan; south of the lake in Sec. 5, Township 43 N., Range 32 W., Michigan, the tuff and lava flows are very well exposed. The pyroclastics seem to predominate in the northwestern portion of the region in the neighborhood of Amasa.

It is almost needless to state that these pyroclastics have undergone a great amount of alteration, and yet the thin sections of some of the rock fragments are the freshest and prettiest seen. The changes which have taken place were purely of a metasomatic nature, and as water is the chief agent in such changes, these began in the interstices. In the case of the fragments, then, the alteration would naturally proceed from the outside inwards, and ordinarily at an equal rate all around the fragment, following its contours. In this way we get zones of different mineralogical composition, depending upon degree of alteration. This secondary zonal structure can be observed in almost any of the sections made from the breccias, but the concentric structure of many of the fragments is especially well shown on large weathered exposures.

The alterations which the fragments have undergone are the same which have taken place in the basalt and andesite flows, and the prevailing light green color of the fragments has resulted from the production of the same light colored secondary minerals. As in the lava flows, some of the denser rocks have become almost opaque, and have usually a lighter green color than the less altered fragments. An especially well preserved fragment shows the perfectly fresh feldspars lying in a dark brown isotropic glassy base. Where this is very thin, globulitic devitrification products can be seen, and there also the base is no longer isotropic, but very faintly doubly refracting.

In addition to the rock fragments a few rare ones of large plagioclase crystals were found in a tuff, and also in one case a fragment of a violet brown augite, the only specimen of fresh augite thus far found in any of the volcanics.

As was stated above, the cement is usually darker in the hand specimen than the pieces of rock imbedded in it. Under the microscope this condition is found to be reversed. The fragments as described above remain opaque or nearly so, whereas the cement becomes transparent. It is found to be composed for the most part of the same secondary minerals as occur in the fragments,—epidote, zoisite, fibrous green hornblende, chlorite, quartz, feldspar, and a great deal of brownish titanite in rounded aggregates and grains, never in crystals. Calcite is less common than one would expect, but in some cases it forms almost exclusively the cement. Muscovite is rare. Zeolites were found to be wanting in the tuffs as well as in the lavas.

The exact mode of deposit of these basaltic and andesitic breccias and tuffs, that is, whether they are true æolian deposits or are masses which were brought together by the action of water, will in some cases have to remain undecided. It is supposed that the major portion is a true æolian pyroclastic deposit.

That certain of the pyroclastics have, however, been deposited through the mediation of water is shown by specimens from 50 N., 1270 W., Sec. 34, Township 45 N., Range 33 W., near Amasa, which is a true basalt conglomerate. In these rocks the pebbles are decidedly rounded, but consist of characteristic volcanic fragments, as is shown by the amygdaloidal structure. The most of the pebbles are thoroughly impregnated with iron in the form of magnetite, giving them a black color. Under the microscope the feldspar skeletons are occupied now by chlorite and muscovite, and the portions between the skeletons is a mass of magnetite grains, in rare cases with a little hematite.

The cement is chiefly calcite and quartz in which is developed a large amount of chlorite and muscovite, and in which occurs also magnetite, though the last is more common in the fragments. No pieces of undoubted sedimentary rocks were observed in the conglomerate.

*The acid volcanics.*—These play a very subordinate rôle, occurring in such small quantity as to make it impossible without very great exaggeration to place them on the accompanying map. Their relations to the basic volcanics are obscured by lack of exposures, but in no case were they observed as dikes in the latter. The trend of the ridges formed by the acid rocks agrees with the general strike of the banding in the basic tuff deposits, and they are presumed to represent acid flows and tuffs interbedded with the basic lavas and pyroclastics.

On fresh fracture they are black, grading with advancing alternation into chocolate brown to reddish rocks. The weathered surface varies from white to reddish. This has in one case brought out very well the fluxion banding of the rock.

Their structure is very pronouncedly porphyritic, the quartz and feldspar crystals standing out plainly from the groundmass, which is usually dense with somewhat resinous luster. Under the microscope they are found to be typical quartz porphyries, with here and there an oval area representing amygdaloidal cavities, which are now filled with secondary quartz. The phenocrysts are for the most part corroded dihexahedral crystals of quartz, with less commonly phenocrysts of plagioclase and orthoclase. These lie in a fine grained groundmass, which is holocrystalline and composed of feldspar and quartz, with some zircon in small crystals, and here and there magnetite.

The quartzes average perhaps the size of a small pea, and hence are macroscopically quite plain. They frequently stand out on the fractures and show their crystal form, and in other cases we see the angular cavities out of which they have fallen. In the thin sections the crystal contours are seen to be more or less rounded, with here and there embayments of the groundmass projecting into them. The crystal form is, however, clearly marked. In some cases the individuals have been broken before the cooling of the magma, the fragments being seen to conform to one another. That some of them have been subjected to pressure is shown by the slight undulatory extinction and by the separation of the black cross of uniaxial minerals into hyperbolæ. The quartzes are quite clear though they contain some inclusions of groundmass and numerous liquid inclusions in which there are dancing bubbles. The liquid inclusions have very commonly an hexagonal form, corresponding to the contours of the enclosing quartz. The possession of an imperfect rhombahedral cleavage is very noticeable in a number of the quartzes, and especially those which, being on the edge of a section, are very thin. (Fig. 1.) The quartz phenocrysts in all the porphyries, with the exception of those from two localities, are surrounded by zones of varying widths, considerably lighter than the remainder of the groundmass. They have the same optical orientation as the phenocrysts, and therefore extinguish with them. In those sections in which the zones occur they are found around every quartz individual.

The feldspars present are orthoclase and plagioclase, the latter apparently predominating. They occur usually in rounded crystals, very rarely in grains with irregular more or less angular contours. They are always altered, and have associated with them the secondary products calcite, epidote, muscovite and chlorite, and by their alteration alone could be readily distinguished from the clear quartz. Moreover, the quartz and feldspar can be distinguished at a glance in certain sections by the occurrence of the aureoles around the quartz. In no case was an aureole observed to occur around a feldspar.

No ferro-magnesian minerals are found in the porphyry, nor is their former presence indicated by any secondary product. The secondary minerals contained in the porphyries are chlorite, calcite, epidote, muscovite and biotite.

FIG. 1.—Micro-drawing of quarts, multiplied 47 diameters, showing cleavage.

The microscopic character of the dense groundmass varies according to the mode of association of its two chief elements, the quartz and feldspar, and we thus get the varieties of prophyry named after the resulting structure.

The commonest variety is the quartz-porphyry with microgranitic groundmass (Porphyre granulitique of Michel-Lévy). A second variety is the quartz prophyry with micropoikilitic[1] groundmass. The microgranitic structure is too well known to warrant a description of it here. The micropoikilitic structure which is present in the porphyries seems, however, to be a phase which is somewhat different from any thus far described or figured, and therefore deserves to be described more at length.

[1] J. P. IDDINGS: The Eruptive Rocks of Electric Peak and Sepulchre Mountain. 12th Ann. Rep. U. S. G. S., p. 589.

G. H. WILLIAMS: On the Use of the Terms Poikilitic and Micropoikilitic in Petrography. Journ. of Geol., Vol. I., No. 2, pp. 176–9. Feb.–Mar., 1892.

It is hoped that an opportunity for working this up more in detail will present itself in the near future. In the meantime I shall rely on the following brief description, and more especially upon the accompanying photographs (Pl. II., Figs. 1 and 2), to

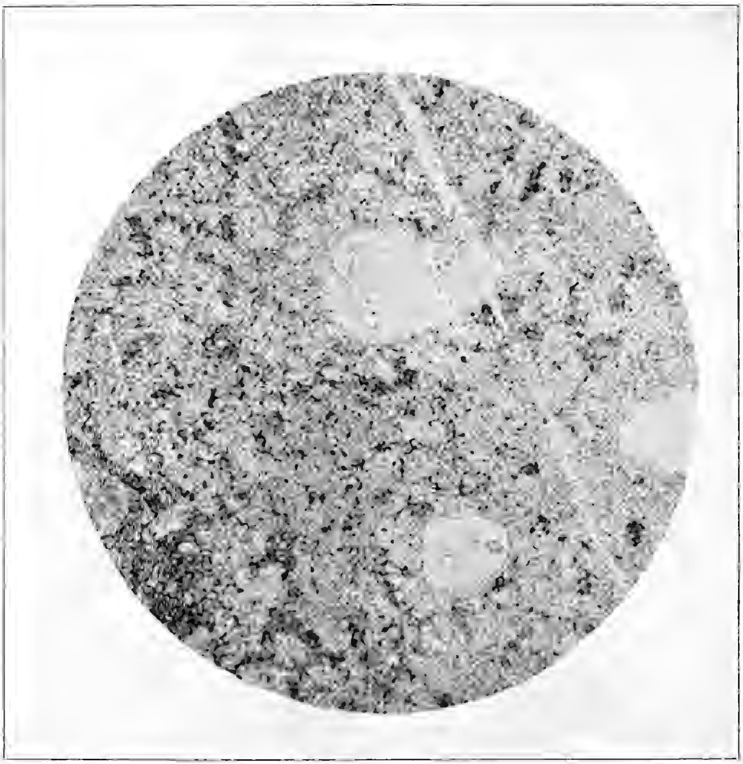

PLATE II.

FIG. 1.—Micropoikilitic quartz-porphyry, showing the peculiar structure of the groundmass in ordinary light. Magnified 18 diameters.

give a correct idea at least of the appearance of it under the microscope.

The structure of the groundmass can be seen even in ordinary light; it is brought out better when the field is partly shaded, so as to bring out the varying relief of the minerals (Pl. II., Fig. 1); and best of all between crossed nicols (Pl. II., Fig. 2). The groundmass is then seen to be made up of reticulating areas of clear quartz, in which lie imbedded irregular pieces of feldspar. The quartz occurs in irregular areas, extending in all directions in long slender or short broad portions, these extensions jointing again farther on or being connected by crosspieces, all enclosing irregular pieces of feldspar. The network of quartz is best brought out when it shows its highest polarization color, as then the feldspar is for the most part dark. The pieces of feldspar in such a quartz area do not all have the same orientation, as is shown by the varying extinction angle, though a goodly number do extinguish simultaneously. The boundaries between the quartz areas, which can only be seen between crossed nicols, are bridged over in some instances by the pieces of feldspar. The main point is that the quartz is the base, the feldspar imbedded in it, and that in those uniformly polarizing quartz areas the included feldspar pieces show varying optical orientation. Therefore, the structure is not a true micropegmatite, according to the generally accepted definition.

Around the porphyritic quartzes there is a zone having exactly the same structure as the groundmass, and the connection of the quartz of the crystal and that of the zone is well shown by the continuation of the quartz with it, and the consequent agreement in orientation (Pl. II., Fig. 2). The lack of a uniform optical orientation of the feldspar fragments is made especially apparent when the quartz is cut perpendicular to the c axis, and consequently remains dark between crossed nicols. Under the above circumstances we see certain feldspar grains polarizing in the zone around the quartz, and as the stage revolves new fragments lighten as those which polarized in the previous position of the stage become dark. The feldspar seems to have no effect upon the groundmass. It certainly is never surrounded by zones, as is the quartz. An explanation for these micropoikilitic zones should, then, also explain the structure of the groundmass.

The irregular areas in the groundmass are certainly in some cases, and probably in most cases, the result of tangential sections through one of these micropoikilitic zones surrounding the quartz phenocrysts. The micropoikilitic structure has been held in some cases to be of secondary origin.[1] I can find, however, no evidence whatsoever which indicates a secondary origin for the structure in these rocks. On the other hand, there is like-

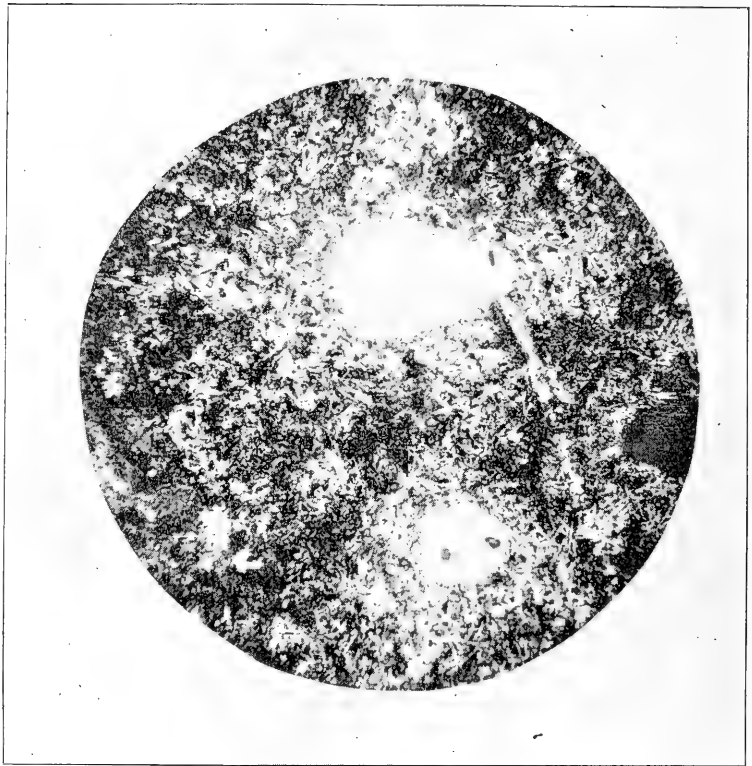

PLATE II.

FIG. 2.—The same section in polarized light, showing the micropoikilitic zone around the quartz phenocrysts. The irregular small dark spots in the white network of quartz are the feldspar grains. Magnified 18 diameters.

wise an absence of evidence proving unquestionably its primary character. Rather, however, than accept an explanation which

[1] R. D. IRVING: The Copper-bearing Rocks of Lake Superior. Mon. V., U. S G. S., p. 99, 1883.

F. BASCOM: Structures, Origin and Nomenclature of the Acid Volcanic Rocks of South Mountain. JOURN. OF GEOL., Vol. I., No. 8, p. 816. Nov.–Dec., 1893.

requires the production of secondary quartz and the influencing of it by the phenocrysts — similar to the frequently described oriented enlargements of quartz grains in sandstones and quartzites — it seems more natural to suppose that after the crystallization of the phenocrysts when the lava was extruded, there began a rapid crystallization of the mineral elements from the remaining magma, resulting in the production of the feldspar in very imperfect crystal individuals, with the quartz as a cement, the orientation of the latter being determined by the quartz phenocrysts. In other words, the quartz continued to grow, retaining its previous orientation, its continuity interrupted, however, by the feldspar grains.

*Aporhyolites.*— Intimately associated with the above described quartz-porphyries we find rocks very similar in every way to them macro- and microscopically, as far as the mineral constituents are concerned, so that the description of the quartz-porphyries will answer for the aporhyolites. It is only upon the presence of a well-developed perlitic parting, which is taken as indicating the presence of an original glass, that they are classed with the rhyolites. These perlitic cracks are now well brought out in ordinary light by the chlorite flakes found along them. Between crossed nicols these disappear and the groundmass resolves itself into a fine-grained mosaic of quartz and feldspar.

*Tuffs.*—The only acid tuff found is formed from the rhyolite. On its weathered surface it is white and exceedingly rough. This roughness is due to great extent to the weathering and subsequent leaching out of the feldspar, giving the rock an almost scoriaceous appearance. Its brecciated character is admirably shown by the difference in weathering of the fragments and cement. The latter being very siliceous is more resistant than the rhyolite, and stands out from the rock as white ridges marking the outlines of the fragments. Under the microscope in ordinary light the tuff is seen to be composed of angular fragments of rhyolite, in which is a well developed perlitic parting, and of angular pieces of quartz and feldspar, both orthoclase and plagioclase, held together by a cement of quartz.

*Conclusions.*— It will be seen from the foregoing preliminary description of the volcanic rocks of the Michigamme district, that in this district we find well preserved evidence of true volcanic activity, in the presence of amygdaloidal lava flows and volcanic breccias and tuffs. These are comparable in every way in their external appearance to the ejectamenta of Tertiary and recent volcanoes. Like these, also, the rocks vary from very basic (basalts) to those containing a high percentage of silica (rhyolites).

That they have undergone more or less alteration as a result of their age alone was to be expected, but it is remarkable that in spite of their age and the dynamic action to which they must also have been exposed—since we now find the flows on edge—they should remain so fresh and retain so perfectly their characteristics as volcanic rocks. The age of these deposits has been determined to be Huronian.

This adds one more to the localities in America in which the occurrence of associated basic and acid volcanics of pre-Cambrian age have been described microscopically.[1]

That such pre-Cambrian volcanics are by no means rare in

[1] M. E. Wadsworth: Notes on the Min. and Pet. of Boston and Vicinity. Proc. Bos. Soc., Nat. Hist., Vol. XIX., pp. 217–237. 1877. Geology of the Iron and Copper District. Bull. Mus. Comp. Zoöl., Vol. VII. (Geol. Ser. 1), No. 1, p. 157. 1880. Did not observe the felsitic porphyries interbedded with the basic rock on Keweenaw Point, and described later by Irving, but described the conglomerates made up of trachytic and rhyolitic fragments (p. 120).

J. S. Diller: The Felsites and their Associated Rocks North of Boston. Bull. Mus. Comp. Zoöl., Vol. VII. (Geol. Ser. 1), No. 2; and Proc. Boston Soc. Nat. Hist., Vol. XX., pp. 355–368. January 1880.

R. D. Irving: The Copper-bearing Rocks of Lake Superior. Mon. V., U. S. G. S. 1883.

Andrew C. Lawson: Report on the Geology of the Lake of the Woods Region. Geol. and Nat. Hist. Sur. of Can. (New Ser.), Vol. I., CC. 1885; and Geology of the Rainy Lake Region. Geol. Sur. of Can., 1887–8, F., p. 182.

E. Haworth: A contribution to the Archean Geol. of Missouri. Am. Geol., Vol. I., pp. 280–297, 363–382. 1888.

T. G. Bonney: Notes on a part of the Huronian Series in the Neighborhood of Sudbury, Can. Q. J. G. S., Vol. XLIV., pp. 32–45. 1888.

G. H. Williams: In Bell: On the Sudbury Mining District. Geol. Sur. of Can., 1890–1, F. App. L, pp. 55–82. The Greenstone-schist Areas of the Menominee and Marquette Regions of Mich. Bull. 62, U. S. G. S., 1890. The Volcanic Rocks of South Mountain in Pennsylvania and Maryland. Am. Journ. of Sci., 3d Ser., Vol. XLIV., pp. 482–496. December 1892.

America can be seen by referring to the brief reports of their occurrence in the Eastern townships of Quebec and in New Brunswick and Nova Scotia, which have been made by Bailey,[1] Ells,[2] Fletcher,[3] Matthew,[4] Selwyn,[5] and Low.[6]

Similar areas are known in Newfoundland, especially from the peninsula of Avalon, through the reports of Howley,[7] Jukes,[8] and Murray.[9]

Somewhat younger are the acid and basic volcanics described by Shaler[10] from Maine, Matthew[11] from New Brunswick, and Bayley[12] from North Haven, Maine.

Basic volcanics alone of Huronian age have been described from the Penokee area, Wisconsin, by C. R. Van Hise,[13] and to judge from Bell's[14] reports, occur in considerable quantity to the north of Lake Huron and around the shores of Hudson's Bay.

[1] Can. G. S., 1870–1, pp. 13–240; 1877–8, DD.; 1878–9, D.; Proc. Am. Asso. Adv. Sci., 29th meeting, 1880, pp. 415–421.

[2] Can. G. S., Vol. II., J., New Ser., 1886; 1882–4, E.; 1879–80, D.; 1877–8, D.; 1878–9, D.

[3] Can. G. S., Vol. II., P., New Ser., 1886.

[4] Can. G. S., Vol. II., Rep. 3, pp. 387–391, 2d Ser., 1888. Q. J. G. S., London, Vol. XXI., pp. 422–434, 1865. Can. G. S., 1870–1, pp. 13–240; 1878–9, D.

[5] Proc. and Trans. Royal Soc. of Can. for 1882–3, Vol. I., Sec. 4, pp. 1–13.

[6] Can. G. S., 1882–4, F.

[7] G. S. of Newfoundland for the year 1881, pp. 6–23.

[8] Ibid., 1839–40, pp. 160.

[9] Ibid., pp. 111–136. G. S. 1872, pp. 279–297.

[10] Prel. Rep. on the Geol. of Cobscook Bay. Am. Journ. Sci., 3d Ser., Vol. XXXII., p. 40. 1886. Geol. of Mount Desert. Ann. Rep. U. S. G. S., Vol. VII., p. 1042. 1889.

[11] Rep. on the Upper Silurian and Kingston (Huronian) of Southern New Brunswick. Geol. Sur. of Can., Rep. 1877-8 E.

[12] The Spherulitic Volcanic Rocks of North Haven, Maine. Bull. Geol. Soc. of Am. Vol. VI., 1894, p. 474.

[13] IRVING AND VAN HISE: Penokee Iron-bearing Series of Michigan and Wisconsin. Mon. 19, U. S. G. S., p. 410. 1892.

[14] Can. G. S., Reps. for 1876–7, p. 213; 1877–8 C.; 1779–80 C. The Geol. and Economic Minerals of Hudson's Bay and Northern Canada. Proc. and Trans. Royal Soc. Can., Vol. II., Sec. 4, p. 241. 1884.]

Wadsworth [1] has also described basic volcanics from Newfoundland, and Walcott [2] has mentioned their occurrence in the Algonkian of the Grand Canyon series, stating that according to Iddings' examination they are true doleritic basalts.[3]

The volcanics of the Michigamme district can be closely paralleled with similar rocks in Finland and Sweden, described in detail with full recognition of their volcanic origin by J. J. Sederholm [4] and by Otto Nordenskjöld.[5]

Numerous descriptions of such occurrences have appeared within the past years from the English geologists,[6] and all of them have recognized in full their identity with the younger volcanics, and have usually applied the names in use for the younger to their older equivalents. Wadsworth [7] was the first in America to follow and advocate this simplification of the nomenclature. In 1892, Williams' [8] article upon the South Mountain Volcanics appeared.

In all other countries the generally accepted nomenclature has been a dual one, one term for a pre-Tertiary rock and another

[1] Notes on the Rocks and Ore Deposits in the Vicinity of Notre Dame Bay, Newfoundland. Am. Jour. Sci., 3d Ser., Vol. XXXIII., pp. 94–104. 1884.

[2] Algonkian Rocks of the Grand Canyon of the Colorado. JOUR. GEOL., Vol. III.. No. 3, p. 325, April–May, 1895.

[3] Loc. cit., p. 330.

[4] Studien über Archæische Eruptivgesteine aus dem Südwestlischen Finland, Tsch. Min. and Pet., Mitt. XII., pp. 98–142. 1891.

[5] Über Basische Ergussgesteine aus dem Elfdalener Porphyrgebiet. Bull. Geol. Inst. Univ. of Upsala, Vol. I., No. 2, pp. 105–112. 1893. Über Archæische Ergussgesteine aus Småland. Ibid., pp. 133–255.

[6] For references to their papers see GEIKIE: Anniversary Address, Q. J. G. S., Vols. 47 and 48, 1891–2. Most of their papers are to be found in the files of the Q. J. G. S. and Geol. Mag. and Memoirs of Geol. Sur. of Great Britain.

[7] Notes on the Min. and Pet. of Boston and Vicinity. Proc. Bos. Soc. Nat. Hist., Vol. 19, p. 236, 1877; ibid. 1878, pp. 309–316.

On the Classification of Rocks. Bull. Mus. Comp. Zoöl., Vol. V., No. 13, pp. 275–287. 1879.

Geol. of the Iron and Copper Districts. Bull. Mus. Comp. Zoöl., Vol. VII., Geol. Ser., No. 1, p. 157, 1880.

Prel. Descr. of the Peridotites, Gabbros, Diabases, and Andesites of Minn. Geol. and Nat. Hist. Sur. of Minn., Bull. No. 2, 1887.

[8] Am. Jour. Sci., 3d Ser., Vol. XLIV., p. 486. 1892.

for its post-Tertiary equivalent,—in spite, too, of the fact that the great resemblance between such rocks has been frequently emphasized.

In a paper published in 1893, upon the acid rocks of the region described in the preliminary paper by Williams,[1] Miss Bascom[2] proposes "to call the acid volcanic rocks whose structures prove them to have once been glassy, *aporhyolites*, while those which have consolidated at a sufficient depth to secure a holocrystalline groundmass should be termed *quartz-porphyries*, whether ancient or modern lavas," the moment which is to determine the use of the name being the "specific alteration known as devitrification." Thus, using the term rhyolite in its present sense, extended however so as to include its pre-Tertiary equivalents, we may have rhyolites of all ages, and likewise aporhyolites of all ages. It was proposed also to apply the prefix *apo* to all other devitrified rocks.

Independently of Miss Bascom, and shortly after her paper appeared, Nordenskjöld proposed, before the Students' Association of Natural Science of the University of Upsala,[3] the names *eorhyolite*, *eobasalt*, etc., for the old equivalents of the rocks known as rhyolites, basalts, etc. It appears to me preferable to use the nomenclature proposed by Miss Bascom, both on the grounds of priority and of expressiveness, as the name indicates in what condition we will find the rocks, whereas the names proposed by Nordenskjöld would merely mean an addition to petrographical literature of new names to express conditions which are already expressed by names at present in use. Thus under eorhyolites we have rocks placed in opposition to the neorhyolites, which as a result of their age are probably very much altered, though this condition is not necessary for the correct application of the term as I understand it. It is possible that at some time there may be found an insignificantly altered rock which must be classed with the eorhyolites. On the other hand, we will undoubtedly

[1] Loc cit.

[2] The Structures, Origin, and Nomenclature of the Acid Volcanic Rocks of South Mountain. JOUR. OF GEOL., Vol. I., No. 8, p. 829. Nov.–Dec., 1893.

[3] Loc. cit., p. 292, meeting on November 18, 1893.

find rocks which are apo- but not eorhyolites. Moreover, the idea of time is inseparably connected with the names proposed by Nordenskjöld, and it is very desirable to eliminate this altogether from petrographical nomenclature. Again, unless there is to be a decided gain from the use of new terms, we might just as well continue to use the terms which have been so long in use, as felsite, etc., as these already imply a difference in age and condition of preservation. According to Miss Bascom, we can consistently class devitrified rocks, whether pre-Cambrian or recent, under aporhyolites and apobasalts, and their fresh equivalents likewise, whether pre-Cambrian or recent, under the accepted term rhyolite, basalt, etc.

J. Morgan Clements.

Madison, Wis.,
May 29, 1895.

# THE INFLUENCE OF DÉBRIS ON THE FLOW OF GLACIERS.

THE behavior of ice under various conditions is frequently illustrated by experiments with pitch or other similar viscous fluids or plastic solids. If sand or other similar substance is distributed through pitch its plasticity will be reduced. When sufficient sand is added, the pitch will no longer flow under conditions that will cause clear pitch to readily change its shape. The reason for this is manifest; by mingling a rigid substance with one that is plastic the rigidity of the latter will be increased. As the percentage of rigid material increases the compound substance acquires more and more of its characteristics. Let us apply this principle to glaciers.

Ice under pressure behaves as a plastic solid. When a mass of ice, unsupported at the sides, is sufficiently large, it will change its shape of flow under the influence of its own weight. Although objections have been raised to each of these propositions, I shall for the present consider them demonstrated.

The study of glaciers, especially of the Alpine type, has shown that they flow after the manner of plastic solids. That is, there is a differential motion of molecules, or of particles, throughout the mass. In most instances, it seems safe to assume no two points, in a cross section of a glacier, will move at the same rate for any considerable time.

If we conceive of a glacier composed of clear ice moving at a given rate, and introduce débris—earth, sand, stones, bowlders, etc.—into it, without altering other conditions, the effect will be to decrease the rate of flow, since rigid substances are added to one that is plastic. If we gradually increase the percentage of débris, the ice becomes less and less plastic and finally acquires such rigidity that under the conditions normally influencing the movements of glaciers, it will cease to flow. If the débris instead of being uniformly commingled with the ice, is introduced irregularly, local changes in the rate of flow, and even local stagnation may be produced.

Stating this principle in the form of a proposition we have: The rate of flow of glacier ice, under given conditions, will depend on the percentage of débris commingled with it, and be least when the percentage is greatest. The nature of the débris, whether coarse or fine, smooth or angular, etc., will modify the result, but this need not be considered at present.

I shall attempt to indicate briefly the bearings of this principle in explaining certain glacial phenomena. What follows, however, is of the nature of suggestions to glacialists, rather than an effort to discuss the various problems touched upon.

*Glacial erosion and subglacial deposition.*—In the upper portion of a mountain valley that has been occupied by a glacier, as for example, Bloody Cañon, California,[1] the grade is frequently steep and the rocks intensely glaciated and but lightly covered with débris; lower down in the same valley, the grade decreases, and the bottom is deeply filled with débris that was deposited beneath the former glacier. In such an instance, the rate of flow of the former glacier was greatest in the upper portions of its courses and decreased down stream. In the upper portions also, the percentage of débris in the basal layer of ice was least and increased toward the extremity of the glacier. The swifter current and light change of débris in the upper portion of the glacier would favor erosion; while farther down its course a decrease in the rate flow, especially of the basal portion, would result both from loss of grade and also because of an increase in the percentage of contained débris. The débris-charged ice in contact with the rocks would be retarded and when the percentage of foreign material in it became sufficient would cease to flow. The heavily charged and stagnant bottom layer would increase in thickness as more débris was brought from up the valley or descended through crevasses and moulins in the ice. When the ice finally melted the débris accumulated in its basal portion would be left as a ground moraine.

The increase in rate of flow, in the instance above cited, from

[1] Eighth Ann. Rep. U. S. Geol. Surv. 1886–7, pp. 337–340.

the densely charged bottom layer to the clearer ice vertically above, might be gradual or abrupt, according as the percentage of débris decreased gradually upwards or had a sharply defined upper limit. When the change was abrupt, a plane of shear might be established. Whether a glacier charged at its base with débris, shall erode or deposit at a given locality depends on its rate of flow. The rate of flow is controlled by several factors, one of the most important being the percentage of débris contained in the ice. If the débris-charged ice in contact with the rocks beneath moves at all it will cause abrasion; if so heavily charged with débris, however, that it is rigid under the forces to which it is subjected, it will remain stationary and not only cease to erode but protect the rocks beneath, and lead to the accumulation of débris. A glacier may, therefore, erode in one portion of its course and in another portion accumulate débris in its stagnant bottom layer. Also, a decrease in the rate of flow may cause débris-charged ice to stagnate at a locality where erosion was previously in progress; while an increase in the rate of flow might lead to the removal of a previously stagnant layer.

If a glacier occupies a valley in which there is a change from a precipitous to a gentle slope, the rate of flow on the precipitous slope, other conditions being the same, will be greater than below, and may be sufficient to carry forward an amount of débris which would cause stagnation when the more gentle slope was reached. A glacier might, then, erode the rocks over which it passed in one portion of its course and farther on, accumulate débris in its basal portion so as to cause stagnation, without an increase in the amount of foreign material carried. Whether a glacier shall erode or deposit, depends, therefore, on a ratio between strength of current and the percentage of débris in its basal portion.

Clear ice in flowing over ordinary rocks has but slight if any power to abrade them. If débris of the kind commonly present in glaciers, is added to the ice, other conditions remaining the same, its erosive power will be increased until the percentage of débris is sufficient to materially check the flow, and will then decrease as motion becomes less and less, and finally cease when stagnation results. The conditions most favorable for abrasion seem to be when the bottom layer of a glacier is lightly charged with small, hard and angular rock fragments. Other factors than those just mentioned, however, influence the abrasive power of glaciers; as, for example, the pressure with which the débris is held against the rocks over which it is moved. In the middle course of a glacier, pressure is normally greater than near its extremity, where active waste is in progress; greater abrasion might, therefore, be expected to occur in its middle course than near its extremity. The firmness with which débris is held in its icy matrix, also influences it action as an abrading tool. It is reasonable to suppose that in a névé region the stones in contact with the rocks beneath, would be held less securely than in the compact ice of a glacier proper. This may be one reason why the upper portions of formerly névé-filled amphitheaters are frequently without smoothed and striated surfaces. Weathering in such situations, however, is more active than in lower regions; which may, perhaps, account sufficiently in many instances for the absence of ice abrasion referred to.

*Unconsolidated deposits beneath glaciers.*—In the well-known instance of Muir glacier, the ice, at its extremity, rests on unconsolidated gravel. That the gravel well beneath the ice, however, in this and other similar instances, is really unconsolidated may be questioned. It is more reasonable, perhaps, to assume that such subglacial gravel is bound together by ice, and really forms a part of the glacier that rests upon it, but owing to excess of rocky material remains stagnant and allows the less highly débris-charged ice above to flow over it. Although this may be the explanation of the conditions now presented, in the example referred to, it does not explain how the ice first advanced upon the gravel.

The gravel beneath Muir glacier was deposited by streams, in an unconsolidated condition, previous to the advance of the ice upon it, and differs both in character and in the manner of its accumulation from a ground moraine.

A glacier advances, as has been shown by Professor Reid, owing to the more rapid flow of the surface portion, which carries it over and beyond the ice previously forming the terminus. The more rapid flow of the surface as compared with the basal portion, is, no doubt, due, as commonly stated, to an increase in friction toward the bottom. The basal portion generally, however, contains more englacial débris than the superior portion and for this reason would also be retarded. As fresh ice is carried beyond the extremity of a glacier, it is more and more exposed to conditions which favor melting and thus, if the ice contains débris, tends to increase the percentage of foreign material in the portion that remains unmelted. The ice thus advanced, in its turn, becomes basal and is buried as the ice from above continues to descend.

Even in the case of a glacier composed of clear ice, advancing in the manner just cited, upon an unconsolidated gravel bed, the basement layer would become charged with gravel as a result of the contact and thus caused to stagnate. The ice at the bottom being densely charged with débris might remain stationary until melted and thus protect the gravel below from the erosive action of the ice flowing over it.

*Terminal moraines.*—In the case of an ice stream which contains englacial débris, the increase in the rate of melting toward its extremity will, as already stated, cause an increase in the percentage of débris in the portion that remains unmelted. As the melting of a glacier is mainly superficial, a concentration of englacial débris is brought about by the débris first becoming superglacial and then falling into crevasses and other openings. As the percentage of débris increases in the wasting extremity, the flow of the ice is retarded, and stagnation finally results. Usually, also, in the case of Alpine glaciers, there is a gradual decrease in volume and also in gradient toward their extremities, which again leads to a decrease in their rate of flow and favors stagnation. The presence of a large percentage of englacial débris in the extremity of a glacier, however, will cause stagnation under conditions that would allow a clear ice-stream to flow on. A dam of débris-charged ice is thus formed which will check the advances of clearer ice from above, and cause it to increase in thickness and expand. The effects of such a check will vary with conditions.

In the case of a growing glacier, the increasing volume of ice above the dam, would cause it to rise and flow over the obstruction, which would then become subglacial. If the glacier was slowly wasting away, its terminus might remain stationary for a time and increase in thickness and then continue to diminish, leaving its highly débris-charged extremity to slowly waste away and finally leave a terminal moraine. The delicate balancing between conditions which cause a glacier to advance, and those favoring recession, so frequently to be observed, would lead to many variations in the changes induced by the congestion of débris, above considered. This process will be again referred to in connection with the influence of débris on fluctuations in the lengths of ice streams.

It is frequently stated that terminal moraines are formed by the carrying forward of superglacial débris and its projection over the end of a glacier. Ridges of débris may frequently be seen about the extremities of glaciers, which are receiving additions in this manner. Such ridges usually have smooth outer slopes and when the ice withdraws from them, the sides left unsupported, acquire even slopes, also, owing to the sliding down of the material; their crest lines are sharp, but frequently undulating in the direction of their length. Terminal moraines of this character are in reality aprons of débris, analogous to talus slopes at the bases of steep cliffs.

Moraines of another type illustrated by the great terminal which crosses New Jersey, Pennsylvania, etc., have broad, hummocky surfaces, with basins between, and originate from the melting of débris-charged ice. Their irregularities in relief are due to the unequal melting of the ice that held the débris, and the concentrations of the foreign material in depressions after it became superglacial, in the manner now well shown in the broad moraine-covered border of Malaspina glacier. Irregularitie would also result from inequalities in the distribution of the débris while yet englacial.

Two types of lateral moraines, corresponding in the manner of their accumulation, with the two varieties of terminals just cited, may also be recognized.

The influence of débris on the behavior of glaciers that advance upon a plain and build morainal embankments, like those at the mouth of Bloody Cañon, California, might be traced, but space forbids such an extension of this paper.

*Variations of glaciers.*—Much attention is now being directed to fluctuations in the lengths of glaciers. As is well known, many Alpine glaciers alternately advance and retreat in the course of a few years, or remain stationary for a term of years and then undergo marked variations. These changes are usually considered to be due directly to variations in meteorological conditions. Glaciers in the same group, however, which, so far as one can judge, are exposed to the same climatic changes, frequently fluctuate differently. One glacier may be advancing, while its neighbor, perhaps draining the same névé field, is retreating. What has been stated above, however, in connection with the stagnation of the extremities of glaciers, when congested with débris, suggests that fluctuations in their lengths may be due to other causes than climatic changes.

Advances and retreats of the end of a glacier may evidently result from (1) variations in the rate at which snow is accumulated on its névé, (2) to changes in its rate of melting, and (3) to fluctuations in its mean rate of flow.

1. Variations in the accumulation of snow on the névé of a glacier may be considered as causing pulsation, or "waves," which would progress throughout its length and on reaching its extremity cause an advance or retreat. How an increase or decrease in the rate of accumulation on a névé would affect a glacier flowing from it, can, at present, only be conjectured. But it is reasonable to suppose that a moderate "wave" produced in this manner would become less and less well defined the greater the extent of the glacier it traversed, and its final effect on the length of the glacier be inappreciable. Marked changes in the volume of a névé would, however, unquestionably affect the glacier flowing from it and cause variations in its length. The opposite changes exhibited in

neighboring glaciers may also be explained in this way. For example, two glaciers subjected to the same climatic influences, but of unequal length, or if of the same length but of different mean velocity, would advance at different times in response to the same impulse, for the reason that the time required for a "wave" to reach their extremities would be different.

The effects of variations in névé regions on the length of the glaciers flowing from them, have recently been discussed by Professor Reid in this JOURNAL[1] and need not be considered further at present.

2. Variation in the rate at which glaciers melt, might be considered as a factor in studying the halts, advances and retreats observed at their extremities; but meteorological observation in Alpine valleys and the behavior of the ice streams entering the same valleys, do not show an intimate connection.

3. The rate of flow of glacier ice is influenced, as already stated, by the percentage of débris mingled with it. The increase in the percentage of débris near the end of a glacier, may as we have seen, cause it to become stagnant and form a dam of débris-charged ice. When this occurs the terminus of the glacier will become stationary. If the current from above is sufficient to cause the ice to rise, and flow over the obstruction, an advance of the terminus will result. When the energy of the glacier is feeble, it may be held in check for a while, perhaps adding to the height of the débris-charged ice that retains it, and then retreat. The withdrawal of a glacier from its stagnated extremity is perhaps a more varied process than an advance beyond it. The extremity of a glacier that has been checked in the manner here considered, will be covered with superglacial débris. The effect of a surface covering on the wasting ice is varied. As is well known, a small amount of débris, especially if dark colored, will promote melting; while a larger amount will shield the ice beneath and assist in its preservation. For this reason, the abundantly débris-covered extremity of a glacier will waste more slowly than the less thoroughly covered portion farther up stream. In the case of a slowly retreating glacier

[1] Vol. III., 1895, pp. 278–288.

this may cause the clear ice above a débris-charged ice-dam to melt away, and form a new terminus which would in turn become congested and undergo a similar process once more.

An explanation is, then, suggested of the varying behavior exhibited by the extremities of glaciers, which is independent of fluctuation of climate. Two glaciers supplied in their névé regions with the same amount of snow, and alike in all respects except in the percentage of débris carried by them, would have the débris concentrated in their extremities at different rates and hence form débris-charged ice-dams at different periods, and consequently be checked and advance or retreat at different times and at different intervals. If in the case of two glaciers the amount of débris carried was the same, but other conditions varied, the fluctuation of their extremities would again vary. So diverse are the conditions controlling the flow of glaciers, that in no two instances could their fluctuations in length, due to the influence of débris, be expected to occur synchronously.[1]

*Drumlins.*—In the case of a mass of englacial débris, densest at its center and gradually becoming less and less abundant in all directions, it is evident that glacial motion will be least at its center and increase in all directions until the normal flow of clear ice under the conditions present will be reached. If the central portion of such a mass is sufficiently charged with débris, glacial flow will there cease and the stagnant portion be carried along, for a time at least, as englacial bowlders are carried. If such a stagnant nucleus should be situated at the base of a glacier, however, it would retain its position and the clearer ice above and on either side would flow past it. The "plucking" of débris from such a stagnant mass might lead to its removal, but if the advancing ice contained rock fragments, these on coming

[1] The considerations offered above, lead to the suggestion that a series of terminal moraines in a formerly glaciated valley, or a similar succession of ridges left by a continental glacier, are not necessarily evidence of repeated climatic oscillations, but may have been formed during a uniform and continuous meteorological change favorable to glacial recession. That is, a débris-charged glacier may retreat for a time, then halt, and again retreat, owing to its terminus becoming congested with foreign material, in response to a climatic change which would cause a glacier composed of clear ice, to recede continuously and without halts.

in contact with the débris-charged ice, would be retained, and thus add to the accumulation. The stagnant mass would be under pressure, and both by the addition of material and the removal or plucking away of material, would be given a shape which would present least resistance to the ice flowing past it, and its longer axis would be parallel with the direction of ice movement. That is, it would have the form characteristic of *drumlins*.

As already stated, when the ice at the base of a glacier is generally charged with débris, it may form a stagnant layer over which the clearer ice above will flow. On final melting, the débris in such a layer would form a ground moraine. If inequalities existed in the bottom over which the glacier moves, or the supply of englacial débris is not uniform, stagnant débris-charged ice may be concentrated at one locality and erosion occur at the same time at an adjacent locality. The same thread of the ice current may deposit at one time and erode at another time and *vice versa*, according as it loses or gains in percentage of contained débris or its energy is varied by other causes. When the supply of débris carried by an individual portion of a glacier is long continued, elongated mounds and even lengthy ridges may be formed. All phases presented by drumlins from those accumulated about boss of rock, to oval mounds, elongated hills and long narrow ridges, may apparently be accounted for by the behavior of débris-charged ice and variations in the volume or constancy of the supply of englacial material. There seems no good reason why we might not have drumlins formed of gravel, sand or loess, as well as of till.

While the explanations suggested in this paper may not all hold when more thoroughly considered, and when tested by observation and experiment, yet I feel confident that the principle on which they are based is valid and will be found important both in discussing theories of glacial motion, and in explaining the mode of origin of many glacial deposits.

ISRAEL C. RUSSELL.

## GLACIAL STUDIES IN GREENLAND. VIII.

*The Krakokta Glacier.*—Of the glaciers that descend northerly from Redcliff Peninsula, the Krakokta is the most important and instructive. It takes its rise in the north central portion of the nevè field of the plateau and descends a relatively long valley by a series of moderate cascades, rather than the single one which characterizes the descent of the glaciers previously described. The last of these cascades lies opposite the head of Bowdoin Bay, at the point where the plateau gives place to the lowland that connects it with the mainland. On descending this, the glacier spreads out upon the lowland into a broad, flaring foot, the right-hand portion of which immediately overlooks the head of the bay, while the central portion is forced into direct contact and conflict with the Tuktoo glacier which descends into the same lowland from the main ice-cap on the north, and the left-hand side spreads out upon the flats toward the head of McCormick Bay. In descending this lower cascade the ice is much broken and presents a very ragged aspect, but I did not observe that it differs in any notable way from the analogous ice cascades of southern glaciers.

The collision of the Krakokta and the Tuktoo glaciers, gives rise to a very interesting joint moraine. The Krakokta glacier coming from the south carries chiefly red sandstone in its basal layers. The Tuktoo glacier coming from the north carries chiefly gray crystalline rock. This contrasted material has been heaped up into a single sharp ridge, the south side of which is red from the dominance of the sandstone, while the north side is gray from the dominance of the crystalline rock. The contribution of each glacier is thus strikingly displayed. The dividing line between these contributions runs essentially along the crest of the moraine. Each glacier seems to have done an equable share of the work of forming the moraine. It should be said, however, that I only examined the eastern part of

FIG. 52.—Seracs of the lower cascade of the Krakokta glacier.

FIG. 53.—View of the lower part of the Krakokta cascade looking northwesterly. The dark line which crosses the figure near the center is a *joint* terminal moraine, formed by the contact of the Krakokta and Tuktoo glaciers, moving from opposite directions, the former from the south, the latter from the north. Beyond the moraine near the extremity of Tuktoo glacier, a small nunatak is seen at the right of the figure, around which the ice is depressed. The larger prominence in the center separates the Tuktoo glacier from the Sun glacier. The snow-cap on the heights at the left in the distance is the edge of the ice-cap of Prudhoe Land, and is continuous with the main ice-cap, which lies to the right.

the moraine and this remark may not apply to the western portion where the moraine seemed, from a distance, more deployed and complex. In the portion examined, the glaciers still press against the base of the moraine, but not forcibly. There is a slight valley between the moraine and the ice on either side, though this is not of such depth or steepness as to offer any serious difficulty in passing from glacier to moraine, or moraine to glacier on either hand. The moraine rises but little above the ice on either side, as will be seen by reference to Fig. 54, which is a view of the east end at the point where the glaciers are separated by the Sentinel nunatak.

The surface of the ice adjacent to the moraine is almost wholly free from débris. That which is contributed to the formation of the moraine is borne by the basal layers of the ice on either hand. In the vicinity of the moraine the layers of the ice are curved upwards. This upward curvature of the strata is not, however, confined to the edge of the ice in contact with the moraine, nor indeed to the immediate border of the glacier. In crossing the wide expanse of the foot of the Krakokta glacier, it was observed that the blue layers—which best indicate the stratification of the ice where débris is absent—were continually coming to the surface by an upward curvature which increased as the surface was approached. This gave a beautiful structural expression to the surface of the ice, the layers being delineated in long, graceful, curving lines, concentric with the border of the glacier. It seemed very manifest that, at least in this glacier, the blue and white bands, which appear as stratification in the vertical faces, assume the form of highly inclined folia on the glacier's surface, closely analogous, if not identical, with the much discussed "ribbon structure" of Alpine glaciers.

The eastern border of the foot of Krakokta glacier, between the point of junction with the Tuktoo glacier and the ice cascade previously mentioned, is unusually interesting from the varied relationships which it sustains to the terminal deposits. For some distance southeast from the point of contact with the Tuktoo glacier it lies opposite the Sentinel nunatak. For the rest of the distance around to the cascade it lies opposite the

FIG. 54.—A *joint* terminal moraine formed by the direct opposition of the Tuktoo glacier, which is seen on the right, and the Krakokta glacier, which is seen on the left. The point of view is opposite the east end of the joint moraine near the Sentinel nunatak looking westerly. The photograph shows the stratification of the ice and in some measure the upward curving of the layers near the moraine.

FIG. 55.—View of the northeastern border of the Krakokta glacier seen from a point near its junction with the Tuktoo glacier, looking southeasterly. A terminal moraine formed by the glacier occupies the right half of the foreground. On the left appears the lower part of the talus slope of the Sentinel nunatak. At its base and between it and the moraine is a stream which drains this part of the Krakokta and a part of the Tuktoo glacier. In the central portion of the figure the glacier is seen to have crept out upon its terminal moraine and to be overhanging the valley through which the drainage escapes to the Krakokta Cove at the head of Bowdoin Bay, which lies just beyond the center of the figure. The heights at the right are the northeastern promontory of the Redcliff peninsula.

northwestern limb of Bowdoin Bay, known as Krakokta Cove. In the portion opposite the Sentinel nunatak the ice does not push against the promontory, although it would do so if its border described a natural curve. The ice holds aloof, so to speak, and leaves space for a drainage stream and a terminal moraine. This is perhaps due to heat reflected from the nunatak.

This relationship may be seen in Fig. 55, as well as the much more interesting relationship of the glacier to its moraine. In the foreground, it will be observed that a fine terminal moraine has been formed outside the present border of the ice. In the center of the figure, however, it will be noted that the ice has advanced over this and has taken on a peculiar rounded border, much as though it were rolling forward over the moraine, while the bottom of the ice was being held back by friction. And this is not altogether an illusion, although the process scarcely amounts to rolling.

Quite in contrast with this aggressive disposition and this convex front is the concave front and retiring disposition shown only a few score rods back along the same border, where it falls behind the moraine shown in the foreground of Fig. 55. If we climb over this moraine and descend to the ice, we have the view shown in Fig. 56. It will be observed that the ice here has neither the tumid, advancing brow which it takes on a little farther east, nor the vertical wall which is common to the region, but a sloping face with a concave tendency. At the same time, the stratification assumes almost the regularity and symmetry of a musical staff. The amount of débris borne between the ice layers, as will be seen, is not very large, and seems to ill accord with the massiveness and coarseness of the moraine. It is to be noted, however, that the ice extends beneath the moraine, and that the latter may, therefore, owe its material largely to ice layers now concealed. The amount of buried ice could not be determined, but apparently its mass was large and constituted a considerable factor in the make-up of the moraine. On the melting of this the irregularities of the moraine will doubtless be accentuated.

Along this sloping border of the ice a suggestive view

FIG. 56.—View of the edge of the Krakokta glacier within the moraine seen in Fig. 55, showing a sloping, slightly concave border, and remarkably parallel stratification.

FIG. 57.—Near view of a portion of the sloping border of the Krakokta glacier, showing the strong individuality of the layers, and *perhaps* their individuality of motion.

(Fig. 57) was taken, which seems to bear upon the interpretation of the projection of the layers of the ice over each other alluded to in the descriptions of the two preceding glaciers. Attention was there called to the hypothesis that this projection was due to the superior melting of the débris-bearing layer. It seemed that there was no doubt as to the correctness of this interpretation in many cases, perhaps in most cases, but there appeared to be other cases in which the explanation was less satisfactory, if not untenable. In the photograph here taken, reproduced in Fig. 57, it will be seen that the under edge of several of the layers is notably cleaner and fresher than the outer edges which are roughened and débris-covered. The aspect is strikingly like that of layers which have moved over each other in such a way as to expose fresh under-edges. Unfortunately this particular feature did not attract my attention when on the ground, and I am only able to submit the evidence of the photograph for what it is worth. The strong individuality of the beds is at least worthy of note.

A short distance beyond the point where the ice is seen to be creeping over its moraine (Fig. 55), the border again retires within the moraine, and this continues perhaps half a mile in the course of which the moraine deploys into a fine series of conjoined morainic ridges, closely pressed together, but yet presenting distinct and sharp crests. These reach a height, according to a single aneroid measurement, of about 275 feet above the Cove and attain a breadth and massiveness which entitles them to rank among notable moraines. Here, however, as before, it was observed that ice was buried beneath the débris, and it was impossible to determine how far the massiveness of the moraine was rendered illusive by the included ice. There seemed ground, however, to believe that the melting of the concealed ice will cause a notable shrinkage of the moraine, and in doing this will greatly increase the irregularity of its surface. It will then doubtless become a typical "humpty-dumpty" moraine.

Following this stout moraine southward, the glacier is found again to be creeping out upon it. But here the ice not only

FIG. 58.—View of the east edge of the foot of Krakokta glacier, as seen from the moraine at the point where it is vanishing beneath the glacier.

creeps out upon it, but pushes entirely across it and down its outer slope until the glacier's foot rests essentially on the flat ground at the head of the bay. It has apparently made a descent on the outer slope of the moraine of more than 200 feet. Some allowance, of course, is to be made for the burial of the base of the glacier, and for illusions that may spring from the resting of the moraine on the edge of the ice. There is no room, however, to doubt that the moraine is really very massive, for the glacier is much crevassed where it crosses it, as shown partially in Fig. 58, and again in Fig. 59. Not only is it crevassed on the border, but the course of the overridden moraine may be traced along the surface of the glacier by the line of crevassing to which it gives rise. This crevassing was sufficiently pronounced to occasion some difficulty in crossing the upper surface of the glacier at the most remote point to which the ruptured tract could be traced, *i. e.* at the point where it merged into the crevassed field occasioned by the descent of the glacier from the upland, previously noted.

Fig. 58 shows the border of the Krakokta glacier at the point where the terminal moraine is disappearing beneath it. The ice wall on the right, which here resumes the vertical habit of the region, is notable for the distinctness and regularity of its stratification. It will also be noticed that here, as elsewhere, the beds at the base of the ice are inclined upwards. At the foot of the picture we catch a glimpse of the vanishing border of the moraine. In the center the crevassed border of the ice is seen very imperfectly—because of the oblique line of vision—as it descends the outer slope of the moraine. The border is riven into pinnacled masses and these are leaning and even toppling over as they descend the slope. The purity of the upper portion of the ice is in striking contrast to the dirtiness of the débris-set base. At the left and below there is a delta plain formed by wash brought from under the glacier at the foot of the cataract previously described.

If we now descend to this delta plain and ascend the heights opposite and reverse our line of vision, the general aspect of the upper surface of the glacier where it is creeping over the

FIG. 59.—View of the eastern border of the foot of the Krakokta glacier seen from the heights near the lower ice cascade.

moraine and down its outer slope may be viewed to advantage, as fairly well illustrated in Fig. 59.

We are here looking in a direction opposite to that from which we have approached in the preceding description. The right hand portion of the glacier in the middle foreground is the part which has pushed over the moraine, and crept down to the delta plain which occupies the low land at the right of the figure between the glacier and Krakokta Cove. The ice-strewn surface of the latter appears in the center of the picture. Near the middle of the picture the jagged edge of the glacier indicates the crevassing produced by its passage over the moraine. The line of crevassing across the upper surface of the glacier is not brought out in the picture. Beyond this jagged edge the moraine may be seen imperfectly as a dark mass. The promontory in the background is the Sentinel nunatak. The Bowdoin glacier lies at the right of this, debouching into the head of Bowdoin Bay. In the distance, at the right, are seen dimly two of the lobes of the main ice-cap. The latter covers the heights between these, but is not differentiated from the sky, in the photograph.

From the relations of the Krakokta glacier to its moraines it is obvious that, in recent years, it has been stationary or retreating at some points and advancing at others. The gains and loses very nearly balance each other. From the massiveness of the moraines and the manifest slowness of the glacial action it is probably safe to infer that the border has occupied nearly its present lines for a considerable period.

T. C. Chamberlin.

# *EDITORIAL.*

THE North Greenland Expedition of 1895, the primary object of which was to bring back Lieutenant Peary and his companions to the United States, left St. Johns on the 11th of July. The start had been planned for the first of the month, and the unfortunate delay made it necessary to omit the considerable stops which were to have been made in South Greenland for the purpose of studying the glaciers of that region. Brief stops were, however, made at Holstensborg, Godhavn, Jacobshavn and Atanikerdluk. Melville Bay was passed without notable incident, the water being nearly free from ice. Cape York was reached on the 30th of July, and Whale Sound on the 31st Here for the first time, no more than twenty-five or thirty miles from our goal, ice was encountered in such quantity as to stay our progress.

Mr. Peary's headquarters were reached on the 3d of August, where the main facts concerning his year's work were learned. The provisions which had been cached on the ice-cap for the trip of 1894, not being used that year, were relied upon for the journey of the succeeding season. In September 1894, after the departure of the Falcon, an attempt was made to visit the nearer caches. One of the objects of the visit was to get the provisions out from beneath the season's snow, so as to make them more accessible when the journey of the following spring should be begun. Although the same caches had been visited in the preceding July, and the provisions then raised to the surface of the snow, it was found in September that the snowfall of the summer had been so heavy that neither of the two most important caches could be found, even the signals having been completely buried. After this discovery little hope was entertained that search for the caches would be more successful in the following spring. As the buried caches contained the pemmican, which was to have been the chief article of food, and the alcohol, which was to have served as fuel, Mr. Peary was obliged to face the prospective loss of both. With this unpleasant outlook, the winter was passed.

Instead of giving up the proposed journey across the ice-cap, Mr. Peary made such provision for the trip as was possible, and on the first of April, accompanied by Lee and Henson, started for Independence Bay. As had been expected, the important caches were not found. In spite of this, the crossing of the ice-cap was successfully accomplished, the distal edge being reached on the 13th of May. The rest of the month was spent on the land about the bay. From lack of provisions a longer stay was impracticable, and the return journey across the ice was begun on the 1st of June and ended on the 25th.

The enterprise and courage with which Mr. Peary conceived and attempted to execute his plans would seem to have entitled him to more consideration at the hands of the powers that be. On two successive years his well matured plans have been thwarted by circumstances over which he had no control, and upon which he could in no way count.

While adverse circumstances have made it impossible for him to carry out in full his plans with reference to the north coast of Greenland, he has nevertheless accomplished much during his Arctic residence. He has twice (in 1892 and 1895) crossed the ice-cap from Inglefield Gulf to Independence Bay, and has gathered information concerning the inland ice, and the ice-free territory beyond, which possesses unique value. Further, he has mapped a considerable stretch of the coast west of Greenland, in the vicinity of his headquarters. The full value of this work will first appear when the map is published, but a few general statements will indicate something of its scope. It covers the coast from Cape Alexander (lat. 78° 10′) on the north, to Cape York (lat. 75° 55′) on the south. Within this latitude, the range in longitude is nearly 8°. The coast is very irregular, as may be inferred from the fact that its actual length, including the islands near the mainland, is about 1000 miles. A comparison of Mr. Peary's MS. map with the earlier charts of the same region reveals the extent and importance of the changes, which are so great as to make it apparent that the new map is really such, and not merely a corrected copy of the old. The modifications are so extensive that, were it not for the names, the new map and the last edition of the chart of the same region, issued by the Hydrographic Office, would hardly be taken to represent the same coast. In some places the general trend of the coast is altered many degrees. Many bays are mapped which have not hitherto found representation, and many indentations of the coast which have heretofore appeared on the charts, have been changed in position and size. Eleven islands which do not appear on the published charts referred to have been accurately located, and the position, shape and size of those heretofore represented have been corrected. A large number of glaciers, probably as many as 100, have been located with approximate accuracy, within the region where but ten were represented on the published chart referred to, and even these were in some cases in false positions and greatly exaggerated in size. Astrup's map of Melville Bay, already published, should be mentioned in this connection, since it was prepared while its author was a member of Mr. Peary's corps. Geographers will not fail to appreciate the magnitude and the importance of this cartographic work.

In addition to the map, Mr. Peary has kept a series of meteorological records, probably the most accurate and elaborate which have ever been secured in so high a latitude. Besides the more formal records, he has been observant of the behavior of winds about the ice-sheet, and in this way has come into possession of facts which are not without significance in connection with the problems of glaciology. He has made careful measurements of the rate of motion of one of the most active glaciers of the region, and has carried them through a sufficiently long period of time to give them especial value. He has brought back two large and choice meteorites from the coast east of Cape York, the study of which will possess much popular as well as scientific interest.

In quite another line important studies have been prosecuted to a successful issue. During his three years and a half of Arctic residence—adding the time of the earlier visit to that of the later—Mr. Peary has made a study of the Eskimos of North Greenland. During this time he has personally come into contact with almost every man, woman and child on the west coast north of the Danish possessions. He has lived among them in such a way as to get from them data which no temporary visitor could secure, and which no one, not understanding their language and not commanding their confidence, could hope to gain. As a result, he is in possession of much fuller knowledge of these people than any one else has ever been. The results of his study, when published, will be an important contribution to ethnology.

Indirectly, the expeditions which Mr. Peary has caused to be made into northern waters have not been without results. Five successive voyages, without accident, have shown that Arctic navigation, under proper management, is not so dangerous as has been supposed. Through those who have accompanied these expeditions much information has been secured touching the natural history, the geography and the geology of the regions visited. Some of these data have been published, while others have not yet appeared, but they must, nevertheless, be taken into account in enumerating the results of the several expeditions for which Mr. Peary has been responsible. It will be readily seen that the returns are, in the aggregate, very considerable, and that, although the object which was first in mind when the last expedition was planned has not been fully attained, the results which have been achieved cannot be looked upon as incommensurate with the outlay. R. D. S.

So far as concerns the geographical and geological work of the expedition which has just returned, it may be said that the coast of Greenland, from about 64° 25′ to 78° 45′, was seen at sufficiently close range to allow of a general study of its geographical features. This study was interrupted more or less by the fog which hung about the coast with exasperating persistency. Nearly the whole of the coast of Disco was seen under advantageous conditions. At Holstensborg, Godhavn, Jakobshavn and Atanikerdluk, opportunity was afforded for a cursory study of local geological features. At the last named place fossil leaves were collected in considerable numbers.

The month of August was spent between the parallels of 75° 50′ and 78° 45′, the latter being the most northerly latitude reached. Between these parallels nearly every mile of the Greenland coast was seen at close range, and a considerable number of glaciers were studied in detail. The American coast also was seen at intervals between the parallels of 78° 45′ and 71° 30′. While few stops were made on this side, the land was within sufficiently close view to make the recognition of its general features possible. Its contrast with the coast of Greenland in corresponding latitudes was most instructive.

In connection with glacial studies, some interesting facts were gathered in connection with glacier motion and glacier work. Some determinations were also made concerning the former extension of ice in relatively recent geological time, and concerning recent changes of level.

In other lines the expedition was successful. Of special interest are the two meteorites which were secured at a point a few miles off Cape York. The Falcon attempted to reach them in 1894, but was unable to do so on account of ice. The larger of the stones has a weight of something like three tons, while the weight of the smaller probably does not exceed one thousand pounds. Both appear to be wholly metallic. R. D. S.

What appears to be authentic information concerning the Jackson-Harmsworth polar expedition has been recently published by the London *Times*, from which paper the following facts are gleaned. The Windward reached inhabited lands about the middle of September in the course of her homeward journey. She has experienced an exceptionally severe winter in the Arctic regions, and the difficulties arising from extreme cold have been aggravated by the fact that she encountered a great amount of ice through which she was obliged to force her way. The information furnished by the dispatches indicates that on the 7th of September, 1894, the expedition arrived on the coast of Franz-

Josef Land, and the total equipment was safely landed. A few days later ice closed in about the Windward in such wise that she was unable to escape from the coast, and remained there through the winter. From this point the party began its northward journey on the 10th of March. By May they had established a depot of provisions as far north as latitude 81° 20′, which was about 100 miles beyond the point where the winter was spent. The outlook for the future work of the expedition is good, and it is believed that when the ship goes out again next year to meet the party, it will bring the welcome news of succesful exploration in the almost unknown area. The party is reported to be in good health and full of courage with reference to their future work.

R. D. S.

# *PUBLICATIONS.*

*Notes on some Eruptive Rocks from Gallatin, Jefferson and Madison Counties, Montana.* By GEORGE P. MERRILL, Proc. U. S. National Museum, Vol. XVII., pp. 637–673, Washington, 1895.

In these notes Professor Merrill has described some of the more interesting rocks of those collected by Dr. A. C. Peale and himself in the parts of Montana named in the title. The notes are arranged according to the geographical occurrence of the rocks rather than upon a petrographical basis, which latter would have been more convenient for reference. The rocks are in part extrusive, including basalt, several kinds of andesite and rhyolite; and in part intrusive, embracing a wide range, from syenite and diorite to peridotite and pyroxenite, and including a number of porphyritic rocks some of which are lamprophyres.

The andesites are normal for this region and are only briefly described. In the case of a hypersthene-andesite a complete chemical analysis is published. The rhyolites and basalts are normal, except for a quartz-bearing basalt like those found in other parts of western America. Diabase and diorite of various kinds are briefly mentioned. Several peridotites are described in considerable detail. They occur in areas of crystalline schists but appear to be of eruptive origin. The rocks are classed as wehrlite, hornblende-picrite, saxonite (harzburgite). Closely related to them in composition and mode of occurrence are certain pyroxenites, one of which is hornblende-hypersthenite, while another is websterite. The value of these descriptions is enhanced by complete chemical analyses, which fortunately have been made from very fresh material.

The special interest of the paper lies in the description of a number of lamprophyric rocks and of closely associated syenitic porphyries; besides several porphyritic rocks described as porphyrite (?), augite-porphyrite, and in one case as basalt (?) These descriptions are full and embrace the chemical composition of the rocks and also of some of the more prominent constituent minerals. One class carry phenocrysts of olivine and augite, but none of feldspar. The groundmass is extremely fine grained and is in part obscured by alteration products. It is basaltic to a great extent, but contains orthoclase in microscopic crystals, or else shows upon analysis a relatively high content of alkalies. Mica is also a prominent constituent in some instances. Professor Merrill's remark upon the mutual interference of the phenocrysts of augite and olivine, namely, that it "can be accounted for only on the supposition that neither mineral is a direct secretion from the magma, but that they are residuals of an earlier crystallization in which consolidation had proceeded so far that free growth was no longer possible," appears to the reviewer to be greatly in error. One need only mention the pegmatitic intergrowth of phenocrysts of quartz and orthoclase in certain obsidians and pumices, and the mutual penetration of pyroxene and hornblende in phenocrysts in some glassy andesites. Chemically the rocks belong with lamprophyres, and resemble some rocks found in the Absaraka Range, in the Yellowstone National Park.

The porphyrite-like rocks carry phenocrysts of plagioclase in addition to those of augite and olivine, and have a groundmass in which orthoclase occurs in connection with plagioclase. The syenitic rocks are closely associated with the lamprophyric ones: and in one case the chemical composition of the syenite is very similar to that of the sodalite-syenite of Square Butte, Highwood Mountains, Montana, as pointed out by Professor Merrill. The reviewer hopes to be able to present shortly in this JOURNAL an account of the closely related series of rocks occurring in the neighboring region of the Yellowstone Park, to which Professor Merrill has referred in his article.

J. P. I.

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*Highwood Mountains of Montana.* By WALTER H. WEED and LOUIS V. PIRSSON. Bull. Geol. Soc. Am., Vol. 6, pp. 389–422. Pls. 24–26. Rochester, April 1895.

The situation and topographic features of the Highwood Mountains are briefly described, and the geologic structure of the district is pointed out. The mountains consist of the denuded remains of volcanoes whose rocks show extreme differentiation of a highly alkaline magma. There are several volcanic cores now filled with massive granular rock. These are surrounded by tuffs and volcanic breccias with lava-flows and a great number of radiating dikes.

The main mass of mountains consists of basaltic breccias resting upon Cretaceous sediments, and also upon acidic tuffs and breccias, which are earlier than the basaltic rocks. The radial disposition of the dikes is one of the most marked characteristics of the geologic structure, and is well shown on the map. The soft Cretaceous strata consist of sandstones and clayey shales belonging to at least two groups; the lower referred to the Kootenia, the upper possibly representing a southward development of the Belly River formation. The strata are nearly horizontal or but slightly inclined away from the mountains. In the vicinity of the volcanic cores the sedimentary rocks are metamorphosed into dense hornstones and quartzites, quite like the baked Algonkian slates or Cambrian shales of Castle Mountain, or the metamorphosed Livingston beds about the volcanic core in the Crazy Mountains.

The chief interest of the region is in the character and occurrence of the igneous rocks, and in the differentiations of magmatic material that has taken place at each of the volcanic cores. The South and Highwood cores consist of syenite; from them radiate dikes of basaltic rocks, in part leucite or analcite-basalt; in part dark rocks with large plates of black biotite. Complementary rocks in the form of porphyries also occur. About the Highwood core the first rocks erupted were acidic tuffs and breccias, intermingled with flows of felsite and possibly phonolite. These were succeeded by breccias and lavas of basaltic material similar to the dikes just mentioned. The east core is of syenite, partly surrounded by basaltic lavas and breccias.

The Shonkin core is the largest in the district and consists of granular rock, in one place breaking up through basaltic breccia. The Arnoux core is of similar granular rock, which breaks through acidic tuffs and basaltic lavas.

Palisade Butte is a volcanic core of coarsely crystallized basic rock like that in Square Butte, and called shonkinite. It is a columnar mass topped by syenite which appears to have been extruded through the shonkinite. The rocks mentioned in connection with these cores have not yet been described in detail but are said to be of novel types and of great interest petrologically. At Square Butte, an eastern outlying mountain of this group, the character of the igneous rocks is such that they have been specially described. The butte is a flat-topped mass rising 1700 feet above its base. The igneous rocks form a laccolite once covered by Cretaceous strata, now almost completely bared of its covering. The topographic character of the mountain and the forms of erosion assumed by the rocks are shown in numerous illustrations.

The lower half of the rocky slopes of the mountain consists of dark-colored rock eroded into towers and spires, which are strongly contrasted with the light-colored upper half of the mountain, where the rock is in large masses and cliffs. The white rock is sodalite-syenite, already described by Lindgren, the petrographical characters of which are briefly reviewed. The dark rock is a new type of rock consisting of much augite and less orthoclase, besides olivine, biotite, albite, anorthoclase and accessory nephelite, sodalite and other minerals. The chemical composition of the rock, and that of the pyroxene are given, and the mineralogical features of the rock are fully described. The name shonkinite is proposed for the new rock. The two rocks of the laccolite form one mass, erupted at one time; the marked differences between them being the result of differentiation subsequent to their intrusion within the sedimentary rocks. The process of differentiation is discussed at length, and the opinion is expressed that no one simple process will explain all cases, but that a variety of factors must be taken into account, any one or all of which may operate to produce a given phenomenon. J. P. I.

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*The Laccolitic Mountain Groups of Colorado, Utah and Arizona.* By WHITMAN CROSS. Fourteenth Annual Report of the Director U. S. Geological Survey, for 1892–3. Washington, 1895. 84 pp., 10 Plates, 19 Figures.

Having become familiar with numerous instances of laccolitic intrusions in Colorado, and having noted how much doubt concerning their true nature existed in the minds of some foreign geologists, Mr. Cross has undertaken to present the facts already known of such bodies of igneous rocks, so far as concerns their occurrence in regions explored by himself and in the neighboring regions of Utah and Arizona. And in so doing he has endeavored to establish more clearly the various phases of laccolitic intrusions within sedimentary strata, and to describe the petrographical character of the igneous rocks that constitute such intrusive bodies. The paper first reviews in considerable detail the facts established by Gilbert regarding the laccolites of the Henry Mountains, and the theory he advanced in explanation of them. It also reviews the characters of the rocks from a study of the specimens collected by Gilbert and originally described by Dutton. According to modern nomenclature the rocks would now be called porphyrites, and the recent study with better thin sections confirms the conclusions of Dutton that the specimens collected from laccolites and dikes indicate no differences of composition or structure corresponding either to geographical or geological distribution, or to the size or form of the intruded masses.

The West Elk Mountains are described and the numerous instances of laccolitic mountain masses noted. Some of these masses were described by Holmes and Peale in reports of the Hayden Survey for 1873 and 1874. They have been more recently studied by Cross. The individual mountain masses of this group consist of homogeneous igneous rock, which in a number of cases is clearly shown to be intrusive within sedimentary strata, and is accompanied by sheets and dikes of the same eruptive rock. The character of the rock is very nearly the same as that of the Henry Mountain laccolites. The microstructures of the rocks of the different masses are practically the same, indicating that even the highest bodies solidified under a great load. The strata in which they have been intruded is Cretaceous, and the age of the intrusion is Tertiary.

The isolated mountain groups of San Miguel, La Plata, Carriso, El Late, Abajo and La Sal, which were studied by Holmes and Peale, are reviewed and their structure noted as that of laccolitic intrusions within nearly horizontal strata. The rocks in all cases are of the same general type of porphyrites. Intrusions within more or less disturbed strata of older age and also within the crystalline schists, which have been studied by Cross, are described. They occur in the Mosquito Range and the Ten Mile District. Here the igneous bodies form sheets and dikes, the rocks having the same general structural characters as in those previously described, but having a somewhat wider range of composition. Other occurrences of similar intrusions within the ranges of the Rocky Mountains are mentioned. In conclusion Cross points out the fact that while the rocks forming these intrusive bodies show considerable variation in composition, the great majority of them belong to one well marked structural type, that of porphyry ; and that this is plainly the result of the similarity of conditions of consolidation upon magmas which are much alike in their controlling elements. He adds that there is every reason to suppose that other eruptive provinces may be characterized by intrusive masses of other rock types. If the magma of another region were very different from that so common in the region described, another structural type might result from the same conditions of cooling. He points out the fact that the rocks of the plateau groups and those of the mountain area of Colorado differ in the relative abundance of alkalies, those of the latter area being higher in potash. These observations apply to all igneous rocks whether in the form of laccolites or not, and the rocks of the Yellowstone Park, whose analyses are placed in a table for comparison with those of the rocks Cross has described, are not laccolitic, but dike-like intrusions. Since Cross wrote this paper Pirsson and Weed explored the Highwood Mountains and published the description of the laccolite of Square Butte, whose rock is granular syenite and shonkinite, very different in structure and composition from the porphyries described by Cross.

In discussing the mineral composition of the rocks Cross lays stress on the fact that in some cases large orthoclase phenocrysts have clearly been crystallized after other constituents which do not appear as phenocrysts. He finds no evidence that any of these eruptive masses "absorbed" sedimentary masses. There is in fact almost no metamorphism of sedimentary rocks along the contact with these igneous bodies.

Owing to the great range in geological distribution and in size and form of masses of practically identical rocks, Cross concludes that the conditions of cooling or consolidation were almost the same throughout a wide (deep) zone, and that pressure as a function of depth has had very little influence within the limits represented. The rate of cooling must have been essentially the same for all masses, indicating that below a certain depth there is a zone in the earth's crust within which conditions of cooling are practically uniform. The upper and lower limits of this zone are not known, but it would seem as if a depth of several thousand feet must be necessary to secure a temperature so high and a rate of cooling so slow that the chilling effect upon an intruded magma should be no greater than that at a depth of 20,000 feet. We do not find that Cross considers the consequences of magmas having quite different temperatures when they reach the place of laccolitic intrusion, or that he discusses possible differences of temperature of the enclosing rocks due to local causes.

In describing the structure of laccolitic rocks, Cross discusses the terms *porphyritic* and *granular*, and expresses the opinion that they should be limited to purely formal ideas, without regard to the possible origin of the structures, and that they should not be confined to megascopic textures, but should be used for the same kinds of structure whether megascopic or microscopic.

As to the forms of laccolites he does not believe in limiting the term to those intrusive bodies only that occupy a perfectly regular position with regard to stratification planes, but would apply it to any intrusive body where the expansion of the body has taken place from a plane even approximately parallel to the bedding. In horizontal strata the lifting of the load by the intrusive force may be taken as the prime essential. The deviations from the type forms from accidental causes are many. With regard to the origin of laccolites Cross cites a number of facts which demonstrate that the horizon occupied by intrusive magmas are not determined by relative densities of the intruding lavas and of the invaded strata, as suggested by Gilbert, and assuming eruptive energy such as exists in active volcanoes he concludes in the words of James D. Dana that "no other cause could be needed for a flow to the surface in case of an open channel, or for a flow to any level in the strata at which a fissure might terminate; and this is true whether the lava be light or heavy." J. P. I.

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*Petrology for Students.* An introduction to the study of rocks under the miscroscope. By ALFRED HARKER. Published by Macmillan & Co., New York, 1895. Price $2.

As the author states in the preface this text-book is prepared especially for English students, nevertheless it will be found very useful for those beginning the study of petrography in this country, who wish a text-book written in English. No systematic account of the crystallographic and optical properties of minerals has been attempted, and for such information the student is referred to the translation of Professor Rosenbusch's volume on the rock-making minerals. But as an introduction to the study of the rocks themselves a number of useful observations of a general nature are presented upon the characters of minerals in thin section, and especially the latest methods of distinguishing the different varieties of feldspar. In treating so complex a subject as the optical properties of minerals in thin sections in such a condensed manner it is doubtful whether the author can meet the wants of a beginner. It serves, however, as a form of definition of the terms used throughout the book. It would seem that in neglecting the use of those methods of determination based on the optical phenomena observed with converging polarized light the author needlessly weakens the processes of petrographical diagnosis.

In his remarks upon the examination of rock sections the author shows his appreciation of the broad field of the science, which, as he says, is not merely an attempt to discover the composition of a rock, but to unravel its history as well. His clear understanding of the subject is also shown in his discussion of the classification of rocks, especially those of igneous origin. In the present chaotic condition of the nomenclature of rocks it will be difficult for any one, who does not succeed in reforming the whole system, to classify rocks to his own complete satisfaction or to the satisfaction of anyone else. In his attempt at simplification Mr. Harker has shown his independence to a considerable extent, while following in the main the classification of igneous rock adopted by Rosenbusch, though under a different terminology. Thus massive igneous rocks are subdivided into *plutonic*, *intrusive* and *volcanic*, corresponding closely to *tiefengesteine*, *ganggesteine and vulkanischegesteine*. In many other ways also the author follows the methods and principles of Rosenbusch. Under each of the three great divisions above named the rocks are arranged according to their mineralogical or chemical composition beginning with the most acid. The names used for varieties of rocks within different families are generally those expressing the mineralogical characteristics of the particular variety rather than those of a geographical character, which may already be in common use. But in most cases both names are given. The most noticeable instance of this is in the treatment of the peridotites.

In substituting the term *intrusive* for that of *ganggesteine* and in maintaining an independent grouping for certain varieties of intrusive rocks the author has not improved on the presentation of the case as made by Rosenbusch, and his remarks in introduction of his *intrusive* division are in the nature of an apology. Nor does his use of the term, acid intrusives, in distinction to that of porphyries and porphyrites, appear to be fortunate. Diabases are classed as intrusives. Under *volcanic* rocks no distinction is made between older and younger lavas, which certainly seems to be the only proper method of treatment. In this respect the classification follows the English usage. The fragmental products of volcanic action are described in connection with sedimentary rocks.

The descriptions of the various rocks embrace a general definition in mineralogical and structural terms, followed by an account of the constituent minerals and of the microstructure. Illustrative examples are chosen as far as possible from occurrences in Great Britain. The many references to the writings of British geologists and numerous others to the works of foreigners add greatly to the usefulness of the book for more advanced students.

The sedimentary rocks are divided into *arenaceous*, *argillaceous*, *calcareous* and *pyroclastic* kinds. Under the first division the general terms are defined, and the characters of the derived grains and of the authigenous constituents are discussed separately. In this way the general characteristics of all arenaceous rocks are given rather than the specific character of any one kind of rock.

In the chapter on argillaceous rocks the general definitions are first given, then the characters of the constituent minerals, followed by that of the structure. The description of illustrative occurrences serves to supply the need of some definite picture of different kinds of these rocks. The treatment of calcareous rocks is admirable for so condensed a statement. It deals first with the source and composition of these rocks, then the structure of organic fragments; followed by oolitic structure, the character of the matrix, and of deep-sea calcareous deposits. Finally metasomatic changes are described, and British examples cited. References to the literature of the subject are numerous and valuable. Pyroclastic rocks are briefly treated. Deposits due to chemical or to organic agencies are described in a few short paragraphs.

Under the head of metamorphism the author discusses the general principles of the subject, and then describes the changes produced by thermal metamorphism upon the different kinds of sedimentary rocks, and upon igneous rocks and the crystalline schists. This is followed by an account of the effects of dynamic metamorphism upon the minerals and structures of rocks. Very little space is devoted to the petrographical description of the various kinds of crystalline schists, which are grouped under the heads of crystalline schists, gneiss, granulites and eclogites. The basis of classification is structure.

The book shows careful preparation, and although the reviewer has taken exception to some features of it, he would recommend it to all those beginning the study of petrology. J. P. J.

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*Boletin de la Comision Geológica de México, No. 1 ; Fauna fossil de la Sierra de Catorce, San Luis Potosi.* By ANTONIO DEL CASTILLO and JOSE G. AGUILERA; pp. ix + 53, with twenty-four plates, Mexico, 1895.

The authors state that they propose in this work to confirm the existence of the Jurassic system in Mexico, describing the most characteristic forms that are common in the more accessible localities.

The introductory pages are devoted to a brief review of previous opinions concerning the stratigraphy and age of the formations in the Catorce district, with quotations from the writings of various geologists and travelers who have either visited the region or studied collections from it. The description of the fauna from the body of the work. in which sixty-five species and varieties of invertebrates are described, and nearly all of them are figured. Of these sixty-five forms, five are referred to the Brachiopoda, seventeen to the Lamellibranchiats (including nine Aucellæ), one to the Gastropoda, and forty-two to the Cephalopoda, of which thirty-eight are Ammonites.

The fossils are not all from one horizon, but are distributed through the upper two members of a series, consisting of three groups, as follows, beginning at the base :

1. Metamorphic argillaceous slates, without fossils.

2. Alternating sandstones and marly and argillaceous shales, rich in fossils.

3. Compact gray-ash colored limestones, more or less impregnated with silica, and containing nodules of black flint. The lower part of the group is argillaceous and has a shaly structure. Fossils rare.

The only fossil found in the upper compact limestone is an imperfect ammonite, supposed to be related to *Schloenbachia inflata*, but the calcareous and marly shales at the base of the upper group have yielded five species that are referred to Exogyra, Lucina, Phylloceros and two species of Hoplites. From a comparison of these forms with European species the authors conclude that the upper group probably represents the upper part of the lower Cretaceous, viz., the Aptian and the Albion.

Two divisions are recognized in the middle group (No. 2), of which the upper one, composed of shales and marly sandstones carrying more or less lime, is the principal Aucella bed of the series. The fauna of Aucella recognized are all Russian species, as follows : *Aucella bronni*, *A. bronni var. lata*, *A. pallosi*,, *A. pallosi*, *var. plicata*. *A. pallosi var. tenuistriata*, *A. volgensis*, *A. fischeriana*, *A. piriformis and A. terebratuloides.* These species which in Russia characterize various zones in the upper Jurassic and lower Cretaceous, are said to occur together in Mexico in beds, with a total thickness of not more than fifteen feet. Associated with them there are species of Lytoceras, Placenticeras, [?] Pulchellia and Olcostephanus.

The lower division of No. 2 consists of fine-grained sandstones and argillaceous shales. A single form of Aucella (*A. bronni*) is the only species that it has in common with the overlying division. Its fauna is very rich in Ammonites, especially in the genus Perisphinctes, of which sixteen species are recognized. The other Ammonitic genera represented are Rhacophyllites, Haploceras, Olcostephanus, Hoplites and Aspidoceras.

After discussing the somewhat discordant evidence of the fossils the writers conclude that this lowest fossiliferous bed should be referred to the upper Jurassic, while the upper division of No. 2, in which Aucellæ are so abundant, are believed to be Neocomian.

This important contribution to American Mesozoic palæontology, derives its chief interest from the bearing that it has on the geography of the continent during late Jurassic and early Cretaceous time and on the correlation of the lower Cretaceous fauna of the Pacific coast with that of the Texan region.

It is well known that on the west coast of the United States and British Columbia there is a great thickness of lower Cretaceous strata (Knoxville and Horsetown beds), characterized by an abundant marine fauna. In the Texan region there is another thick series of lower Cretaceous beds (the Comanche series), which is also characterized by a large but totally different marine fauna. The Texan facies of the lower Cretaceous is known to extend into Mexico and over a large part of that country as far west as Arivechi in Sonora. The absence of species common to the two faunas seems to indicate that they lived in different basins without free intercommunication, and this dissimilarity of faunas has prevented exact correlation of the strata.

Catorce, San Luis Potosi, where Castillo and Aguilera obtained the fossils they describe, is near the tropic of Cancer and in longitude 101° East, directly south of the principal Texan area of the Comanche series, and yet the fauna contain none of the characteristic Comanche types, but is related to the Pacific coast faunas. This relationship is especially shown by the abundanee of the genus Aucella which is essentially characteristic of the boreal and Pacific regions, though it is occasionally found outside of those areas. The forms of Aucella, figured from Catorce, though listed under different specific names, can nearly or quite all be duplicated in collections from the Knoxville beds of California. The ammonites also show a number of forms closely related to those of the Knoxville. The lowest fossiliferous zone at Catorce, however, with its numerous species of Perisphinctes, is probably older than the Knoxville. The only suggestion of relationship with the

Comanche series is in the lithological character of the upper limestones, which are described as compact, gray, more or less silicious, limestone with flints, a description that applies equally well to the Caprina limestone, near the middle of the Comanche series. In the almost complete absence of fossils, this limestone cannot now be identified with the Texan formation from the data furnished by the Mexican geologists. Mr. R. T. Hill,[1] however, in an incidental reference to the Catorce region, correlates the so-called "Hippurites" limestone of Mexico, which is probably the same as Castillo and Aguilera's upper limestone, with the Caprina. The same author also refers the lower fossiliferous beds of Catorce to the Trinity division of the Comanche series, but this reference is based on its stratigraphic position rather than either lithological character or faunal contents. From the known distribution of the Comanche series in that region it is at least possible that portions of the Texan and Pacific coast lower Cretaceous faunas may yet be found in direct statigraphic relation with each other in central Mexico.

With the occurrence of the Pacific lower Cretaceous fauna at Catorce, not a great distance from the Gulf of Mexico, and of the Texan or Gulf fauna in Sonora, much nearer to the Pacific, the question as to how the two faunas were kept separate becomes still more difficult. From the data now at hand the most plausible hypothesis seems to be that the sea transgressed the continent, first from one side and then from the other, but never quite crossed the shifting barrier.

T. W. STANTON.

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*Phylogeny of an Acquired Characteristic.* By A. HYATT. Proc. Am. Phil. Soc., Vol. XXXII.

Professor Hyatt's paper "Phylogeny of an Acquired Characteristic," is essentially a contribution to the philosophy of the Neo-Lamarkian school of evolutionists. It is in part a republication in substance of several earlier papers, with the matter now put into a more systematic shape. While primarily biological it possesses great interest for the geologist and perhaps merits a fuller review on that account as it is less likely to fall into his hands.

In the introductory chapter the author lays great stress on the importance of the study of the shells of Mollusca. After speaking of the relation of the shell to the animal, and of the different structures

[1] Am. Jour. Sci., Vol. XLV., 1893, pp. 311, 312, 324.

in the Cephalopod shell, he says: "All their parts, the shell proper, the siphuncle, the septa and the sutures are in correlation with each other and together make an index to the life history of the individual, which is unequaled in some respects among other existing or extinct animals." From the study of a single perfect specimen of a Cephalopod shell can be determined the particular characteristics of the individual at any stage of growth, from the embryonic condition represented by the protoconch, to the retrograde metamorphoses through which it may pass during old age.

The two sub-classes of the class Cephalopoda, Tetrabranchiata and Dibranchiata, with the four orders Nautiloidea, Ammonoidea, Belemnoidea and Sepioidea, are shown to have been differentiated from some common primitive stock, each order being specialized for its own peculiar habitat. The prominence of the depression or sinews in the aperture of the shell is correlative with the prominence of the hyponome or swimming organ of the Cephalopod, and therefore signifies the relative power of the animal as a swimmer. An open aperture is correlative with powerful arms for crawling on the bottom, while forms possessing shells with more or less constricted apertures must have had more or less limited powers as crawlers. In relation to the differentiation of the four orders the author says: "The *efforts* of the Orthoceratite to adapt itself fully to the requirements of a mixed habitat of swimming and crawling gave rise to the Nautiloidea; the *efforts* of the same type to become completely a littoral crawler evolved the Ammonoidea. The successive forms of Belemnoidea arose in the same way. But here the ground-swimming habitat and complete fitness for that was the object. The Sepioidea, on the other hand, represent the higher aims as well as the highest attainments of the Cephalopods in their evolution into surface-swimming and rapacious forms. We cannot seriously imagine these changes to have resulted from intelligent effort; but we can with Lamark and Cope picture them as due to efforts on the part of the animal to take up new quarters in its environment and thus acquire habits and structures suitable to the changed physical requirements of its surroundings and this position is better supported by facts than any other hypothesis."

The relationships of the Nautiloidea and Ammonoidea are next discussed. Many investigators have endeavored, and have failed, to arrange the palæozoic Nautiloidea in a single series, passing progressively from earlier straight forms, through arcuate to the closely coiled forms. Professor Hyatt is led to believe through his investigations, that instead of a single such series there are several, all originating from a primitive stock and each one passing progressively from the straight form through arcurate, loosely coiled to closely coiled forms.

The order Ammonoidea is in like manner a branch from the primitive stock. The author says: "Thus although both are orders and taxonomically equal, we cannot compare the whole of the Ammonoidea with the whole of the Nautiloidea, but only with a more or less perfect single series of that order." The Ammonoidea have primitive straight radicals, but they are few in number and become extinct in Devonian time, leaving several branches of closely coiled forms, the Goniatitinæ, from which the latter Ammonoids spring.

During the evolution of the Nautiloidea and Ammonoidea, the differentiation takes place most rapidly during the earlier periods of their phylogeny, and their differentiating parts are of more structural importance than later in the life-history. Professor Hyatt formulates these facts in the following general law of evolution: "*Types are evolved more quickly and there are greater structural differences between genetic groups of the same stock while still near the point of origin than appear subsequently. The variations or differences take place quickly in fundamental structural characteristics, and even the embryos may become different when in the earliest period of evolution, but subsequently only more superficial structures become subject to great variations.*"

This law however does not apply to the degenerate forms which appear during the stages of decline of the several genetic series.

In the phylogenetic series, characteristic modifications appear first in the later stages of growth of individuals. These modifications are transmitted to succeeding generations, but are progressively accelerated, appearing in earlier and earlier ontogenetic stages. The law of acceleration is formulated as follows: "*The ancestral characters are brought into contact with new adaptive characteristics, which are being continually introduced into the adult and adolescent stages of ontogeny, and these eventually replace the former which are crowded back to make room for them into earlier stages than those at which they first appeared, and in many cases the latter are reabsorbed and disappear during this process.*"

In the interpretation of the more or less uncoiled degenerate forms of the later phylogenetic stages of the Ammonoidea, the law of acceleration still governs the changes. During Jurassic time degenerate forms are local and the degeneration is exhibited only in the adult stages of the individual. In later Cretaceous time, the majority of the forms show degeneration wherever they occur, and this degeneration sets in in much earlier ontogenetic stages. The degeneration is exhibited by a reversion to earlier characteristics. The shell becomes straightened, looses its ornamentation and the sutures become more simple, but in all cases it can be shown from a study of the younger ontogenetic stages, that these degenerate forms spring from a closely coiled radical stock. In no case do retrogressive series give rise to secondary radicals which originate new series.

The second chapter is devoted to "Principles of Bioplastology," or the study of the correlation of ontogeny and philogeny. The chapter is made up largely of the explanation of technical terms. Five ontogenetic stages are recognized: (1) embryonic, (2) nepionic, (3) neanic, (4) ephebic, (5) gerontic. Each of these, except the embryonic, is divided into three substages the names of which are formed by the use of the prefixes *ana*, *meta* and *para*, as ananepionic, metanepionic and paranepionic. The corresponding phylogentic stages are designated by the use of the prefix *phylo*, as phylonepionic, etc.

The general adoption of a series of exact terms in investigations of this nature is a necessity, and no one is better fitted to propose these terms than Professor Hyatt. It is desirable that other investigators, as some have already done, should adopt this system of nomenclature.

Chapter III. is devoted to the discussion of the ontogenetic stages of the nautiloidea and ammonoidea. From direct observations Professor Hyatt has determined "*that the substages of development in ontogeny are the bearers of distal ancestral characters in inverse proportion and of proximal ancestral characters in direct proportion to their removal in time and position from the protocouch or last embryonic substage.*"

As a general rule the nepionic stage of nautiloidea draws to a close and the neanic characteristics begin to appear, at or near the completion of the first volution, which growth brings the whorl in contact with the apex or dorsal side of the couch. The ananeanic substage is marked by the first appearance of the impressed zone. This is the name given to the area on the dorsum affected by the contact of the dorsum of the growing whorl with the venter of the already formed whorl of the next inner volution.

This impressed zone can be readily seen to be at first due entirely to a mechanical cause, the resistance of the inner volution to the growing shell of the outer. It is the acquired character the phylogeny of which the author discusses in detail. It can be shown that the impressed zone is invariably consequent upon close coiling, as it is never found in adults of any ancient and normally uncoiled shells.

However as one ascends in the same genetic series to the more specialized nautilian involute shells, this purely acquired character through the action of the law of acceleration or tachygenesis becomes forced back, appearing as a rule in the nepionic stage before the whorls come in contact.

Chapter IV. is devoted to descriptive terms used in the following chapter, in which a large number of genera and species are described, some of which are new, with special reference to the history of the impressed zone.

The last chapter is a summary, and from it may be quoted the following conclusions which seem to be justified by the facts and arguments brought forward:

"1. The impressed zone is primitively a contact furrow, an acquired characteristic of the dorsum of the whorls of nautilian shells having large umbilical perforations, which appear either in the ananeanic or metaneanic substages, and rarely later in their ontogeny. There is abundant positive evidence that in these primitive forms this furrow is purely a mechanical result of the nautilian mode of growth, not appearing in the ontogeny before contact and either partially or entirely disappearing on the free gerontic volution.

"2. The impressed zone does occur independently of contact on the free dorsum of the paranepionic substage as a dorsal furrow in some close-coiled, highly tachygenic, nautilian shells in the Quebec group and in the Devonian.

"3. While there is no positive proof that the dorsal furrow originated through heredity in the paranepionic substages of these nautiloids of pre-Carboniferous age, there is also no satisfactory evidence that it originated in the young of such species as have this character through purely mechanical agencies.

"4. There is no positive evidence that the similar dorsal furrow which also appears at the same age in the young shells of *Coloceras globatum* and perhaps *Coelogasteroceras canaliculatum* among Carboniferous nautiloids can be explained only when it is considered as a transmitted, tachygenetic characteristic.

"5. This fourth conclusion is supported by the presence of a similar dorsal furrow in the paranepionic substage of the young shells of all the nautiloids of the Jura so far as observed.

"6. The fourth and fifth conclusions are rendered still more probable by the presence of the dorsal furrow at an earlier age, the metanepionic substage, in all the nautiloids so far as observed, from the beginning of the Cretaceous, through the Tertiaries to and including the living species of the genus Nautilus. Its presence on the cystoceran volution in Cretacic shells can be explained only when it is considered as a transmitted, tachygenetic characteristic derived from the ancestral, nautilian shells of the Jura, which have the same characteristic at a later age, *i. e.*, in the paranepionic substage.

"7. The first conclusion is also sustained by the parallel phylogeny of the impressed zone in the ancestral forms of the Ammonoidea, the Nautilinidæ and especially in Mimoceras, the radical genus of this family.

"8. The fourth, fifth and sixth conclusions are also supported by the presence of a contact furrow on the dorsum of the earliest age of the conch in the specialized and highly tachygenic forms of the Goniatitinæ of the Devonian and of all the remaining Ammonoids to the end of the Cretaceous.

"9. These cumulative results favor the theory of tachygenesis and diplogenesis, and are opposed to the Weissmannian hypothesis of the subdivision of the body into two essentially distinct kinds of plasm, the germplasm, which receives and transmits acquired characteristics, and the somatoplasm, which, while it is capable of acquiring modifications, either does not or cannot transmit them to descendants."

S. W.

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*The Protolenus Fauna.* By G. F. MATTHEW. Trans. N. Y. Acad. Sci., Vol. XIV., pp. 101–153. Plates I.–XI.

In a paper entitled *The Protolenus Fauna,* Mr. G. F. Matthew has added an important contribution to our knowledge of the Cambrian faunas of New Brunswick.

The Etcheminian Series, considered as pre-Cambrian by Mr. Matthew, and the overlying St. John Group, present similar stratigraphic features in New Brunswick and Newfoundland. In Newfoundland the Olenellus fauna is found in the same position as observed elsewhere, viz., preceding the Paradoxides fauna, but in New Brunswick the fauna characterized by Olenellus is absent, and the Protolenus fauna takes its place stratigraphically.

The author publishes a list, with notes and descriptions, of seventy-four species and varieties belonging to the Protolenus fauna, twenty-eight of which are new, with two new genera, *Pelagiella*, a new genus of Gasteropoda, and *Micmacca*, a new genus of Trilobites.

The fauna is of extreme interest, being a pre-Paradoxides fauna in which Olenellus is absent. The author says: "Though the Protolenus Fauna holds the place where we might naturally look for Olenellus, the genus is absent, and as so many of the genera associated with it are also absent, *we cannot regard this fauna as the Fauna of Olenellus.*" The author points out that in many respects the fauna is more primitive than the Olenellus fauna. He suggests that the two are contemporaneous, the Protolenus being prelagic, while the Olenellus is a shore fauna. Forms present in the Olenellus fauna differentiated for shore conditions, are absent in this fauna, calcareous corals and sponges are rare, and no Lamellibranch has been observed. Foraminifera belonging to genera which are today deposited most generally in one thousand to two thousand fathoms are abundant in some beds, and the Gasteropoda are of types adapted for deep water.

Heretofore the only pre-Paradoxides fauna described has been that one characterized by Olenellus, and Mr. Matthew's paper is of importance to geologists in pointing out a new facies of the pre-Paradoxides fauna.

S. W.

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*Republication of Descriptions of Fossils from the Hall Collection in the American Museum of Natural History, from the Report of Progress for 1861 of the Geological Survey of Wisconsin, by James Hall, with Illustrations from the Original Type Specimens not hitherto Figured.* By R. P. WHITFIELD. Mem. Am. Mus. Nat. Hist., Vol. I., Part II., August 1895.

The republication, with illustrations of the type specimens, of descriptions of fossils which were originally published without figures, is a most commendable undertaking. It is a work of this kind that Professor Whitfield has done.

In the paper descriptions of forty-three species are republished, which are distributed among the fellowing genera: *Buthograptus* (1 sp.), *Callithamnopsis* (1 sp.), *Receptaculites* (5 sp.), *Graptolithus* (1 sp.), *Dictyonema* (1 sp.), *Melocrinus* (1 sp.), *Tellinomya* (4 sp.), *Cypricardites* (3 sp.), *Modiolopsis* (2 sp.), *Ambonychia* (4 sp.), *Pleurotomaria* (3 sp), *Maclurea* (1 sp.), *Ecculiomphalus* (1 sp.), *Lituites* (2 sp.), *Cyrtoceras* (4 sp.), *Oncoceras* (5 sp.), *Orthoceras* (2 sp.), *Gonioceras* (1 sp.), *Illaenus* (1 sp.).

Thirty-three of the enumerated species are from the Trenton horizon, four from the Hudson River, three from the Galena Limestone two from the Niagara, and one, found in the drift, is supposed to be from the Devonian.

The paper is a real contribution to our knowledge of the faunas of Wisconsin and the Northwest.

S. W.

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*The Mineral Industry. Its Statistics, Technology and Trade in the United States and Other Countries to the end of 1894.* Vol. III., pp. 770 + xxviii + 111 (adv.). The Scientific Publishing Co., New York and London, 1895.

The third volume of *The Mineral Industry* is a worthy successor to the two preceding volumes. The general form and make-up is the same as volume two, yet there are several new subjects and new contributors while some of the former ones do not appear. Each volume of this publication is complete in itself and at the same time a supplement to the preceding volumes and in no sense a duplication of them.

As the name indicates, it is not simply a compilation of statistics, but contains up-to-date scientific articles on the different subjects, written by able specialists. They are all treated, for the most part, from the standpoint of the tradesman. The volumes form a valuable text-book in economic geology, serviceable alike to teacher, student and tradesman. Besides the figures of production there are given the localities, the markets, their geologic relations, and the most improved methods of mining and manufacturing.

The following subjects are treated in the present volume: Abrasives Aluminum, Alum, Antimony, Asbestos, Asphaltum, Barytes, Bauxite, Borax, Bromine Cement, The Chemical Industry, Chrome Ore, Clay, Coal, Copper, Cryolite, Fertilizers, Fluor spar, Gold and Silver, Graphite, Gypsum, Iron and Steel, Lead, Magnesite, Manganese, Mica Mineral Paints, Monazite, Nickel, Petroleum, Pyrites, Precious Stones, Quicksilver, Rare Elements, Salt, Slate, Stone, Sulphur, Tin and Zinc.

The condition of the mineral industry in the different foreign countries is given in separate chapters. There are also articles on Mining Stocks, Electrical Transmission of Power in Mining, Progress in Ore Dressing, Electro Plating, Metallic Oxides, Mining Law and Mineral Development.

As far as possible everything is arranged alphabetically, with numerous valuable tables and summaries, and a complete index both to the text and to the advertisements, all of which greatly increase its value as a reference book.

The aim of the editor is shown in the following extract from the preface:

> The intention in preparing this work has been to collect and put in convenient form all the reliable statistics of the world; to collect more promptly and more accurately than had hitherto been done the mineral statistics of the United States; and to photograph, as it were, the condition of the industry from year to year, bringing out into boldest relief that information which has the greatest practical value in the development of the industry and which is not easily accessible. . . . This work is above all things designed to be of actual value to the practitioner, to afford those engaged in mining, metallurgy, and industrial chemistry, a safe and authoritative guide which will keep them informed as to what is being done, and how it is done, in each department of the industry throughout the world.

T. C. H.

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*Honeycombed Limestones in Lake Huron.* By ROBERT BELL.

In the Bulletin of the Geological Society of America, Dr. Robert Bell describes the honeycombed limestone of Lake Huron. It is found chiefly about Manitoulin Island, Indian Peninsula, and the area between these and Georgian Bay. The formation progresses faster in water fifty or sixty feet deep, but takes place in shallow water. It is found on the under side of overhanging rocks as well as on other surfaces. There are two principal forms of this erosion. In the first the cavities are elliptical, and neighboring ones tend to meet, giving a very spongy appearance. In the second the pits are finger like and crowded close together at the surface. They are usually shallow, but may be some inches in depth. The rocks in the vicinity of Manitoulin Island run from the Chazy to the Guelph. Dr. Bell finds the pits largest and most numerous in the dolomite of the Guelph formation. As to the immediate causes of the solution to which they are due, Dr. Bell cites an obscure concretionary structure in the rock, and an unusual amount of $H_2SO_4$ and sulphates in the water. He attributes the source of the sulphur compounds to the Huronian rocks that lie on the north of the lake. These are in part volcanics and rich in sulphides. He thinks solution is aided by hydrostatic pressure, free action of water and shifting currents.

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*Critical Periods in the History of the Earth.* By JOSEPH L. LE CONTE.

The thesis laid down by the author is that "There must have been some greatest revolutions which have in some way directly or indirectly affected the whole earth, and which may therefore be used to form the basis of the primary divisions of time." These he calls "Critical Periods" in the earth's history. The marks of such periods are readjustments of the crust of the earth, causing widespread changes in physical geography, affecting profoundly the climate of the whole earth, and causing marked changes in organic forms. These are indicated in the rocks by (1) widespread unconformities; (2) great, general, and rather sudden changes in organic forms; (3) the introduction of new and higher dominant classes; (4) the birth of great mountain ranges. Of these periods, beginning with the last, he enumerates the following—the Glacial revolution, the post-Cretaceous or Rocky Mountain revolution, the post-Palæozoic or Appalachian revolution and the pre-Cambrian revolution.

Of these it may be said—(1) they become shorter and shorter as we progress in the earth's history; (2) the effect of the introduction of new dominant types in producing changes in the whole organic kingdom steadily increases; (3) the oscillations of temperature have gradually increased. These periods hasten the steps of evolution and increase organic diversity, but diminish geographical diversity. These revolutions seem to be contrary to uniformity in the forces and laws of nature, but they are not so in reality. We may conceive of phenomena as being under the influence of two opposite forces, one progressive, the other conservative. Such will be more or less paroxysmal. Resistance at first prevails, and there is little change, but forces of change are accumulating, and finally resistance gives way and conspicuous changes take place rapidly.

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*Teepee Buttes.* By G. K. Gilbert and F. P. Gulliver.

In the Bulletin of the Geological Society of America, Gilbert and Gulliver have some interesting things to say of the Teepee Buttes of Colorado. They are found in a belt about ten miles wide and fifty to sixty miles long, at least, beginning at Little Butte Station on the Denver & Rio Grande Railroad, and extending to the south and east along that railroad. They are not continuous but gravel areas separate areas dotted with them. They are twenty to thirty-five feet in height, rudely circular, and diameter is usually less than height. The structure is peculiar, viz., a core of coarse, light-gray limestone, bedded and full of marine fossils, surrounded by a shale which has few fossils and is rather easily eroded. There is no transition layer between the two, yet they interpenetrate somewhat. Processes of limestone surround portions of the shale, and lumps of limestone are found in the shale, moreover the limestone is roughly separated into beds by shale partings. They find that the steepness of the butte is a function of the rate of degradation of the surrounding surfaces, and that the height depends on the rate of degradation and the size of the cross section.

As to cause, the facts do not seem to be sufficient as yet. They favor the idea that the limestone cores are due to colonies of Lucina, more especially which dying on these sites left their shells to form the limestone while fine silts were forming the shales around. Why the molluscs congregated at these places and what caused the apparent mortality we are left to conjecture. They are interesting topographically and unique in some of their relations.

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THE

# JOURNAL OF GEOLOGY

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## THE GREENLAND EXPEDITION OF 1895.

After an unfortunate delay, the Greenland expedition of 1895, which was to bring Lieutenant Peary back to America, left St. Johns on July 11 in the steamship *Kite*. Instead of heading for Cape Desolation, a more northerly route was chosen, which, had it been held, would have brought us to the coast of Greenland in the vicinity of Frederickshaab. The first stop was to have been at the Frederickshaab glacier, but as the land was approached the fog was so dense and so persistent that it was deemed inadvisable to attempt a landing, and the coast was first seen at a point somewhat further north, in latitude 64° 30′ as nearly as was determined. This was on July 17.

*Coastal topography and its interpretation.*—The first glimpse of the coast was hardly more than momentary, but it was quite sufficient to reveal the essential features of the coastal topography. Fog shrouded and effectually concealed the lower half of the bold land front, but the upper half consisted of a succession of distinctly serrate peaks, many of them with slopes so steep that it would have been difficult or impossible to scale them. The serration was so pronounced as to be most significant, and seemed clearly to substantiate the general conclusion at which Professor Chamberlin arrived last year, namely, that there were portions of the Greenland coast which have not been glaciated in recent time.

The stretch of coast seen in this latitude was no more than ten or fifteen miles in extent. North of this point the coast was completely concealed by fog for some miles. When it again appeared, in latitude 65°, as nearly as was determined in passing, it presented a very different aspect. As before, the lower portion of the land, perhaps the lowermost 500 feet, was not seen. The contours of the southernmost portion of this stretch were in striking contrast with those of the region but a few miles further south. Instead of being markedly serrate, the topography was thoroughly subdued, and suggested as strongly as topography can suggest, that the surface had been heavily and recently glaciated. But this was true of the southernmost portion only. In latitude 65° 20′, as nearly as was determined, there was a sudden change in the appearance of the coast. North of this parallel, and extending thence to latitude about 66° 45′ or thereabouts, there succeeded a stretch of territory with serrate front similar to that which characterized the region in latitude 64° 30′. At 66° 45′, or thereabouts, this second stretch of serrate topography gave place to a topography of smooth and flowing contours, indicative of recent glaciation, and corresponding, in all essential features with the topography of the coast just above the 65th parallel. From this point to latitude 69° the coast was seen at intervals only; but wherever seen, it presented the contours which denote vigorous ice-action. The same sort of topography characterizes the coast continuously from latitude 69° to latitude 70°, as was seen in our further progress, so that with the possible exception of short stretches not seen, glaciation would seem to have been continuous along the coast from 66° 45′ to 70.

North of this latitude, the coastal topography, while not so markedly serrated as that at 64° 30′, or between 65° 20′ and 66° 45′, was still of such a character as to suggest that if it had been glaciated at all in recent times, the glaciation was not severe. On the whole, judging from topography alone, it seemed more probable that the coast from about latitude 70° north to the end of the Nugsuak peninsula, had not been recently smothered in ice, though it is well possible that the ice-cap may have once extended beyond its present limits, and that isolated glaciers occupied the valleys leading down to the sea. The northwest end of the peninsula bears the marks of the passage of ice over a considerable part of the coastal front. North of Nugsuak peninsula, and from that point to the south side of Melville Bay, the topography of the coast, so far as seen, indicated general though not universal glaciation. Thus the southwestern end of Svarten Huk peninsula (71° 30′) has a topography denoting the absence of glaciation.

North of the Nugsuak peninsula it was often difficult to distinguish between the topography of the mainland and that of the islands. Ubekyendt Island (lat. 71° 15′), or at any rate much of its west front, has a serrate skyline. North of 72° 30′ also, the topography is not such as to denote continuous glaciation over the outlying islands, even if the mainland was covered down to the water level. It would appear that the comparative phenomena of islands and mainland north and south do not agree—for south of latitude 70° the islands lying near the coast correspond in topography with the mainland opposite.

Except for thirty miles or so east of Cape York, the coast of Melville Bay was not seen. Along that part of the coast which was seen, the ice reaches the sea so generally, that something like three-fourths of the coast line is composed of it. This ice is not the edge of the ice-cap, strictly speaking, but consists rather of a succession of broad glaciers separated from each other by short distances only. In spite of the iciness of the coast it is doubtful if all its islands, even but a few miles from the coast, were ever overtopped by glacier ice.

North of Cape York, the ice-cap is nowhere distant from the coastal margin of the upland; yet there are many considerable stretches where there is no evidence, either in the topography or in the surface formations, that the ice ever reached the sea as a continuous sheet. In many places there is evidence that the edge of the ice-cap approached the coast more closely than now, in relatively recent times, and that its excess of material was discharged in the form of glaciers, some of which occupied valleys now free from them. But even where the ice has been recently extended, there is evidence of no more than a very moderate increase beyond its present limits, and between the valley glaciers which existed at the time of the greatest extension of which there is record, there often remained peaks or even considerable areas altogether free from moving ice. But there are other areas where the surface affords no evidence that the ice-cap was ever extended much beyond its present limit. Professor Chamberlin has called attention to the existence of a small driftless area[1] on the east side of Bowdoin Bay, reaching almost to the edge of the present ice-cap, basing his determination, not on topography alone, but on the absence of drift, and on the presence of a great body of earthy matter resulting from the decomposition of the underlying rock.

The conclusions reached by Professor Chamberlin last year during his voyage in the *Falcon*, viz: (1) that there are considerable stretches of the west coast of Greenland which have never been glaciated, or at any rate not glaciated within any time so recent as the later epochs of our own glacial period; and (2) that the ice-cap of Greenland—in the vicinity of Inglefield Gulf—was never greatly more extended than at present, or at least that it has not been notably extended within recent times, seem to me to be the only conclusions to which such study as is possible in such a voyage can lead.

This condition of things on the Greenland coast is not without its parallel on the east coast of America (Ellsmere Land, North Devon, Baffin Land, etc.). This coast was seen at intervals from latitude 78° 45′ to latitude 71° 30′. Within this distance there are places where the topography is such as to suggest that the coast has not been glaciated or at least not in recent times. This is true, for example, of some parts of Bylot Island, latitude 73°, and perhaps more conspicuously of a considerable stretch of the mainland coast in the vicinity of Dexterity Harbor, the latitude of which was not exactly determined, but which is not far from 72°. It cannot be asserted, on the basis of present evidence, that there are extensive areas in either of these positions which have altogether escaped the ice,

[1] Bulletin of the Geological Society of America, Vol. VI, p. 818.

but if reliance may be placed on topographic form, it seems clear that in both these places there are considerable stretches of coast over which no ice, except perhaps isolated glaciers, has descended in any recent time. This is the more noteworthy from the fact that the same regions now harbor very considerable glaciers, while the ice-caps which feed them approach very close to the outer edge of the upland. Fully a dozen glaciers, and the ice-cap above which nourishes them, were visible on the northeast side of Bylot Island, while about Dexterity Harbor there are very considerable glaciers, some of them descending nearly to the water level, separated from each other by serrate peaks which do not appear ever to have been over-ridden by ice, though the ice-cap today is no more than two or three miles distant.

In view of the facts already mentioned concerning the topography of the Greenland coast, it seems to be impossible to avoid the conclusion[1] that the Pleistocene ice-sheet of our continent did not have its starting point in Greenland. If reliance may be placed upon coastal topography, the phenomena observed on the American coast would seem to indicate further, that the great center of ice accumulation during the Pleistocene period was not on the most northerly lands on the west side of Baffin Bay. Had this been the case, Bylot Island, and the coast of the mainland in the vicinity of Dexterity Harbor, would hardly have escaped glaciation at the same time that the Labrador coast and its outlying islands were subjected to the action of ice on an extensive scale; and had latitude (at least present latitude) been the determining factor in glaciation, the west coast of Greenland north of latitude 76° would hardly have suffered so slight an extension of its ice as its condition seems to indicate, while more southerly regions were less favored.

It is to be borne in mind that the foregoing conclusion concerning the meager extension of ice-caps of the west coast of North Greenland and the east coast of America, in recent time, is based on general, rather than on detailed observation, and that

[1] Chamberlin, loc. cit., p. 219.

it is possible that the importance of topography in its bearing on this question, has been overrated. But if the conclusion be correct, it will be seen that it is not without bearing on the question of the cause of the glacial period. Of related import is the fact that the conditions for glaciation on the Greenland coast seem to be much better today in latitude 74° to 76°, than in latitude 76° to 79°. It is not merely that there are more and larger glaciers in the former region, descending to lower levels—for all this might be the result of topography—but the snow line itself is 1000 to 1200 feet lower in latitude 76° than in latitude 78°.

*Evidence concerning past glaciations, drawn from nature of rock surfaces.*—The first stop on the coast of Greenland was at Holstensborg, latitude 67°. The rock in this region is gneiss, which is much more distinctly and regularly bedded than gneissic formations usually are. From a distance, the rock has the appearance of being distinctly stratified, the dip being tolerably constant. So strong was this impression that it was difficult at a distance to avoid the conclusion that the rock was sedimentary. The general dip is to the northward, at an angle of 60° to 75°. On the land, the gneiss is seen to be affected to some extent by dikes of granite, but they are not sufficiently numerous to obscure the general regularity of structure. Its surface has undergone a notable degree of decomposition since glaciation. Striæ were not seen, nor did the rock surface show the polishing which glacial action produces. All these details were gone, although hills having the form of *roches moutonnées* were of common occurrence, and glacial drift was not wanting. This condition of things suggested that the lapse of time since the departure of the ice has been considerable. This is the more significant since it is in striking contrast with the condition of things along some other parts of the coast. It is clear that the cursory examination of the surface of a small area does not afford a safe basis for generalization. Nevertheless it is worthy of note that the amount of change undergone by the surface of the gneiss about Holstensborg since the ice abandoned it, appears to be greater than the average amount undergone by similar formations in the United States, since the departure of the last ice sheet.

The amount of drift in the vicinity of Holstensborg is slight. From the vessel it appeared as if the larger part of the surface was bare rock, but on the land the proportion of the surface covered by loose material was seen to be somewhat greater. The topography about Holstensborg is such as to suggest that the ice was never very effective in reducing it. It seemed to me probable that some of the higher peaks were nunataks at the time of maximum ice extension, while others of intermediate height were not covered by a great thickness of ice, and did not suffer any considerable modification of form.

The next stop on the coast of the mainland was at Jakobshavn, about 120 miles further north. Here as at Holstensborg, the rock is gneiss, though much less distinctly and regularly bedded. Occasionally it is closely foliated, and the foliations are locally much contorted.

The little peninsula lying north of Jakobshavn was crossed along two lines, and its general features well seen. Its surface everywhere bears the marks of glaciation, and the action of the ice here seems to have been much more intense—so far as topography affords a basis for judgment. Rarely is there better opportunity for observing the topographic effects of glaciation. The relief of the region is about 1400 feet. The surface before glaciation seems to have been affected by an erosion topography, in the early maturity stage of development. In its general westerly movement, the ice smoothed the eastern sides of the hills and ridges, at the same time that it plucked their western sides. The structure of the rock is such as to favor both processes, with ice moving in the direction which it here took, and both processes were therefore carried to an unusual degree. The result was that, standing in almost any valley and looking westward, smooth and relatively even slopes were seen, so characteristic as to leave no doubt as to the agency which produced them, or the intensity of its action, while looking in the opposite direction bold, rough walls of rock, with huge piles of angular bowlders at their bases, greeted the view. Rarely is the contrast between the lee and stoss sides of hills so clearly marked.

Apart from its topography, the surface of the rock near Jakobshavn was found to be in striking contrast with that at Holstensborg. Instead of being decayed, it was remarkable for its freshness, especially at elevations of a few hundred feet and a few miles inland. For the first few miles from the coast striæ were often seen, but they were also often wanting. Four or five miles inland, and from that point eastward to the limit of the land seen, it was the exception not to find the rock polished, and still retaining the grooves and fine lines due to the graving of the ice in all their pristine freshness, even where its surface has been continuously exposed since the departure of the ice. The surface was such as to give the impression that it had but just been freed from the ice which had polished it.

The bareness of the rock was one of the most striking characteristics of the peninsular surface. It is probably safe to say that half the surface seen in a jaunt of fifty miles is absolutely without soil or loose material of any sort whatsoever; that half of the remainder has a mantle of loose material, averaging less than two feet in depth ; while the remaining fourth has sufficient drift to effectually conceal the rock.

The contrast presented by the rock at Holstensborg and Jakobshavn, both in the matter of topography and freshness of surface, was repeated at other points further north, seeming to indicate that the glaciated surfaces now free from ice along the west shore of Greenland have been free for very unequal periods of time. In some places the surface seems to have been but just abandoned, while in other cases, even where the evidence of severe glaciation is equally conclusive, the surface seems to have been exposed to the influence of weathering for a much longer period of time. This leads to the conclusion that the ice-cap of Greenland did not suffer its greatest extension at all points at the same time. It is quite harmonious with the theory, though in itself does not prove it, that there have been distinct epochs of ice extension (perhaps distinct glacial epochs) during which the ice-cap moved forward unequally, advancing farther from its present position at one point in one epoch, and at another point in another. Opportunity was wanting to carry observations sufficiently far to place this suggestion on a firm basis of fact.

*General disposition of snow and ice.* Nowhere on the west coast of Greenland between the latitude where land was first sighted (64° 27′) and 69° was the main ice-cap seen from the Kite, along a course five to fifteen miles off shore. At a few points only, what appeared to be local ice-caps or local snow fields came into view. In one or two places between 66° and 67° there depended from these local snow fields what appeared in the distance to be incipient glaciers. In other places local snow fields were seen of such size that they can hardly fail to give rise to small glaciers, though from our position they were not seen.

At many points along this coast, as seen in July, there were considerable patches of snow, generally occupying ravines, which seemed to be the unmelted remnants of considerable drifts. These occurred at all altitudes, even down to the level of the sea. Many of the patches of snow were of such size and thickness that it was quite certain that they would hold over until the succeeding winter. They were in all cases apparently due to excessive local accumulation by the wind, and do not in any way indicate the altitude of the snowline in these latitudes. The height of the snow line was not determined here, but it is probably not less than 2000 feet, and may be somewhat higher.

North of latitude 68° 30′ the ice-cap appears to approach the coast much more closely than farther south, but even here its edge is so distant and so related to ice-free lands (often islands) in front of it, as not to be generally seen from the open sea. From a point a few miles back of Jakobshavn (lat. 69°), the glacier which bears that name, and the ice-cap beyond, were distinctly seen. Between latitudes 69° and 70° the main ice-cap to the east was now and then seen, either at the head of fjords, or where the coastal topography permitted an unusually unobstructed view to the eastward. North of Prince Island, the end of the glacier entering the head of Torsukatak fjord was seen—as well as the ice-cap behind it. Further north, during the passage of the Waigat, the local ice-cap of the Nugsuak peninsula was now and then sighted, though it sends no glaciers of importance to the southwest.

With the west coast of the Nugsuak peninsula the east coast of Disco is in striking contrast. On the latter the ice-cap very commonly reaches the edge of the upland, and nourishes numerous small glaciers which descend the slope some hundreds of feet.

Between the north end of the Nugsuak peninsula (lat. 70° 45′) and 74° 30′ the main ice-cap was rarely, if ever, seen. If the published charts be correct, this must have been due to the very considerable number of ice-free islands which lie off the coast, and hide the front of the mainland. That the ice-cap or at least huge glaciers from it reach the coast in very considerable numbers in this region, is demonstrated by the fact that large numbers of bergs take their origin from the coast in these latitudes. The local ice-cap of the Svartenhuk peninsula (lat. 71° 30′) was seen at several points.

The glaciers seen on Disco Island, and on the west coast of Greenland south of Melville Bay, do not depart from the usual type of alpine glacier, so far as general form and relations are concerned. Some of them—as the Jakobshavn glacier—are much larger than the usual alpine type, but they lack the peculiar characteristics which seem to mark the glaciers of the higher latitudes of west Greenland.

The north shore of Melville Bay was not seen except for twenty-five or thirty miles east of Cape York, where the coast line is very largely made up of ice. This ice is mainly in the form of glaciers—as distinct from ice-cap—but they are wide, often confluent, and, where distinct, are frequently separated by no more than trivial areas of land.

It was characteristic of all the glaciers seen along Melville Bay that their gradients were low; that their surfaces were relatively smooth and free from débris; that their centers were but slightly higher than their sides, that is, that they were but slightly arched in the cross-section; that their vertical fronts were very slight; and that their lateral margins rarely presented vertical sections.

One or two peculiar phenomena of this region merit special mention. In two of the minor indentations on the coast of Melville Bay, the ends of glaciers were seen to be floating. These little bays had not freed themselves from the ice of the preceding winter,—probably not from the ice of many preceding winters. The topographic relations are such as to indicate that the water deepens from the head of the bay outward, and from the lateral margins inward, very gradually. In their advance, the glaciers entering these bays at their heads encounter the bay ice, crowd it, break it more or less, and heap it up in front of themselves. But in the cases referred to, they had not forced it out, and it still constituted a barrier to their advance. The result was that the ends of the glacier were not broken off, or at least not floated away in the form of bergs, as would have been the case in open water. Since the water was shallower near the margins of the bay and deeper in the middle, the lateral margins of the protruding glacier continued to rest on the bottom, while its central portion got beyond its depth and was floated. The deepening of the water from the margins of the bay toward the center appeared to be so gradual, that in neither of the two cases seen did the floating center of the glacier appear to be greatly fractured where it joined the marginal portion which was still resting on the bottom. Similarly the deepening of the waters from the head of the bay out was so gradual that the floating portion of the end was not separated by any notable fault from the ice above which still rested on the bottom. That the central portion was actually floating, however, was shown by the approximate flatness of its surface, by the fact that it was somewhat lower than the marginal parts, in one case as much as thirty feet lower, and by the occasional gaping fissures which exposed the salt water beneath. In both cases the lateral margins of these glaciers, the central portions of which were floating, carried lateral moraines containing shells worked up from the bay bottom. In one case they were fully thirty feet above sea level. Phenomena of similar import, so far as glacier motion is concerned, were seen at many points, but never in any position except at the immediate edges or ends of glaciers.

In the same general locality there was another interesting phenomenon on some of the islands, and occasionally on the coast of the mainland. Even where the summits of islands were wholly free from snow, several places were seen where their lower slopes had perennial ice-caps reaching down to the water, and even appearing to be thickest at that level. This appeared to be the result primarily of the excessive local accumulation of snow, under the influence of the wind. Lodging against lee slopes, it had reached such thicknesses as to defy the sun. In several places, some of them on islands and some of them on the mainland, the accumulation had gone so far as to give rise to glaciers. That the ice was actually in motion was evinced by its structure, and by the débris which it carried.

Under these circumstances, it was difficult at many points to determine the altitude of the snow line, but on the narrow promontory just back of Cape York a satisfactory determination was made, giving the snow line an elevation of about 1000 feet (aneroid measurement). The ice-cap yielding this result is an isolated one, having an area of no more than five or six square miles. It would seem that the lowness of the snow line here must be the result of local meteorological conditions. There can be little doubt that the snowfall at Cape York is exceedingly heavy, since the small ice-cap referred to has a glacial discharge altogether out of keeping with its area. It feeds two active glaciers, one of which is considerably more than a mile in width, and both of which descend to the level of the sea, discharging small bergs.

North of Melville Bay the snow line is much higher. In the vicinity of Inglefield Gulf it averages fully 2000 feet, and in many places it rises as high as 2200 or 2300 feet. Accompanying the rise in the snow line, though the association may be no more than accidental, the glaciers take on a somewhat different aspect. In general they are narrower, thicker, more arched in cross section, more extensively fractured, and, most striking of all, have, as a rule, vertical sides and ends. Furthermore, their surfaces are much more likely to carry débris along their lateral margins and across their ends, wherever the ends are not more than 150 feet or so thick. These features characterize most of the glaciers seen on the Greenland coast north of latitude 76°. It is true that there are occasional glaciers within this distance which fail to show these characteristics, but they are so rare as to be conspicuous. Thus on the south side of Whale Sound there is a single glacier which has neither vertical sides nor end, although these features are possessed by all the other ice streams on this shore of the Sound. An adequate explanation of this very striking difference in the behavior of the Greenland glaciers north of Cape York and those east and south of that point has not yet been suggested. Such opportunity as was afforded for the detailed study of glaciers was principally within the region where vertical slopes abound.

North of Cape York there is a type of glacier so common as to deserve especial mention. On its seaward margin the upland often terminates abruptly, and from its edge a steep slope descends to the water. The uppermost part of this cliff face, just below the outer edge of the upland is often nearly vertical for a short distance. The junction of the vertical, or nearly vertical, face with the less steep talus slope below, is often the site of great accumulations of snow, drifted thither by the wind blowing from the plateau. These accumulations are not usually continuous for any considerable distance horizontally, but rather are gathered in patches wherever the topography favors lodgment. The patches of snow in these situations have in many cases become so considerable as to give rise to little glaciers. They do not usually descend more than a hundred feet below the snow fields which support them, but their glacier character is unmistakable.

This type of glacier seem to deserve a special name. Since both they and their feeding grounds are on the faces of cliffs, it is proposed to designate them *cliff glaciers.* It sometimes happens that the snow fields which support these tiny glaciers

FIG. 1. A cliff glacier on the north side of Herbert Island, a northerly dependence of Murchison Sound. The upper part of the glacier is covered by snow, which also borders it and fills the ravine below. The lack of connection with the ice-cap is shown by the line of rock out-crop above the glacier, the ice-cap lying some distance back.

coalesce laterally along their upper edges. Cliff glaciers were seen at other points, but nowhere else so strikingly developed as north of Cape York. Especially good examples are seen on the north side of Herbert Island and on the east side of McCormick Bay. These glaciers are really one in origin with the low lying glaciers already referred to as originating in huge drifts of snow banked against the lower slopes of islands and mainland east of Cape York, but they take on a distinctly different form, and the glaciers are much better defined.

The coast west of Baffin Bay has, where seen, a much more wintry aspect than the coast of Greenland in correspond-

FIG. 2. A series of cliff glaciers on the northeast side of McCormick Bay. The line of rock out-crop at the upper limits of the glaciers is but indistinctly shown in the figure, but is suggested by the dark line.

ing latitudes, Melville Bay alone expected. Where the coast is low, the ice-cap descends to lower levels on the American side of the water than on the Greenland side, leaving a narrower margin of land free from ice. This is in harmony with the fact already noted that the ice-cap comes nearer the coast on the east side of the Island of Disco than on the west side of Nugsuak peninsula opposite. It is also in harmony with the further fact that the ice-cap of Disco approaches its eastern shore much more closely than its western. In other words the generalization seems to be warranted that the ice is better developed along the eastern borders of land, than along the western.

Not only is the snow line lower on the east coast of America than on the west coast of Greenland, Melville Bay excepted, but the glaciers of the regions present certain contrasts. In and about latitude 78°, the glaciers of the Ellesmere coast were seen at a distance only, but they seemed to possess the general characteristics of those east of Cape York, rather than those of the Greenland coast further north. So far as seen, they are relatively broad, flat and clean, without notable vertical sides and without vertical ends except where they reach the sea. It is not to be understood that this is true of every glacier within the region specified, but it seemed to be the rule rather than the exception. It is to be noted that this is the latitude in which the glaciers opposite, on the coast of Greenland, are notable for their abrupt sides and ends. It is to be noted also that these are the characteristics of the glaciers east of Melville Bay, where the general aspect of the coast, so far as concerns snow and ice, is very similar to that of the American coast.

Similar characteristics mark many of the glaciers about Jones Sound, especially on the south side. Further south, the ends and margins of the glaciers are less abrupt than on the Greenland coast north of Cape York, but distinctly more so than east of Cape York, on the north coast of Melville Bay. In latitude 71° to 73°, there are many glaciers which have vertical sides and ends such as characterize the glaciers of the higher latitudes on the Greenland coast. It is clear, therefore, that the vertical faces of the glaciers are not the result of high latitudes simply. Whatever may prove to be their explanation, it seems to be true that thick glaciers of high gradients are much more likely to possess vertical sides and ends, than thin glaciers of low gradients.

*Bergs.*—Soon after leaving the harbor of St. Johns occasional icebergs began to show themselves. These proved to be of somewhat common occurrence, for at the end of the third day thirty-six had been sighted. Since the atmosphere was almost continuously clear, this number may be taken to represent essentially all that were within range of vision from the vessel during the hours of daylight. Although our course was continually bringing us nearer the source of the bergs, only two were seen on the fourth, fifth and sixth days. Their scarcity in this latitude (55° to 62°) was taken to mean that we had passed the eastern limit of the Arctic current, which was bearing them southward. As the coast of Greenland was approached they became again somewhat more common, and by the time Holstensborg was reached not less than 125 had been sighted.

As the coast of Disco was approached from the south, bergs became much more abundant. From the time the coast was sighted until the harbor of Godhavn was reached there was rarely, if ever, a time when as many as fifty could not be seen. Seventy-five were counted in the immediate vicinity of the harbor, and from the land above the settlement, a few hours later, 160 were seen in the little bay to the northeast.

Most of the bergs seen to this point were relatively small, the largest being perhaps not more than 100 feet in height and 200 to 400 feet in length. In most cases they showed that they had been long afloat, and that they had been subjected to considerable changes of position since the beginning of their history, for incisions made by the waves girdled them at all angles. In some cases they were affected by caves and archways, often of remarkable regularity; in other cases their tops were marked by high pinnacles and towers, sometimes having a regularity approaching that of an elaborate architectural design. Without exception they were altogether free from débris, and their colors were the colors of pure ice, varying from white to blue on the one hand, and from white to green on the other. A more perfect or more beautiful gradation of colors could hardly be imagined. More massive bergs were seen at other points, but none more beautiful.

East of Godhavn bergs were abundant continuously to Jakobshavn.. During the voyage between these points, a distance of about sixty miles, there was hardly a time when less than 100 were in sight, and it is probably quite within the limits of truth to say that 500 were seen between these settlements. So abundant were they that from many points the half of the horizon was concealed by them.

In the Jacobshavn fjord, the upper part of which at the time of our visit (July 23) had not freed itself from the winter's ice,[1] bergs were literally packed. In the outer part of the fjord they were free to move, and were sailing in and out, under the influence of wind and current. But further up the fjord they were imprisoned in the surface ice in such numbers as to suggest that the fjord had not been freed from ice for several years, and that the entire discharge of the huge glacier at the head of the fjord for those years was still fast in the ice.

The bergs in the fjord and near it presented two very distinct types: (1) Those whose surfaces were notably irregular, often a series of ice needles, and (2) those whose surfaces were relatively smooth. The surfaces of the former corresponded with the surface of the glacier above. They were the bergs which had moved out in upright positions. The bergs with smooth surfaces, on the other hand, were those which had capsized at some stage or other of their history, and since they were still imprisoned in the fjord ice, the turning doubtless took place when the bergs separated from the glacier.

The difference in the shape of the upper surfaces was uniformly accompanied by another significant difference. Those with smooth surfaces were always clean, while the upper surfaces of those with irregular tops were always discolored by a thin, discontinuous layer of mud. In this, as well as in their form, the surfaces of the irregular-topped bergs corresponded exactly with the surface of the glacier which gave them birth. It was here apparent that the bergs with clean upper surfaces had shifted their positions in the course of their history, while

[1] Governor Müller, of Jakobshavn, is authority for the statement that the fjord is not usually freed from ice oftener than once in four or five years.

those with dirty surfaces were still right side up. The conclusion that bergs with clean surfaces have been tilted or capsized in the course of their history was first reached at Jakobshavn, but it proved to be of general application. The ends of all glaciers seen had their surfaces covered with a sufficient amount of débris, mainly wind-blown dust, to give them a distinctly grayish appearance. In consequence, every berg originating from them, if it set sail without capsizing, must have a discolored surface. That many bergs do begin their history right side up — that is, with the parent glacier surface up — is shown by the fact that in the immediate vicinity of the calving glaciers the upper surfaces of many of the bergs are discolored.

In no case did the vertical faces or upper surfaces of the bergs about Jacobshavn show bowlders or detritus of any sort. This was in perfect harmony with the phenomena exhibited by the end of the glacier which had given origin to them, for neither its vertical front nor its upper surface showed a single stone, large or small, nor any trace of finer material. This in itself seems to be sufficient proof that the small amount of fine débris upon the upper surface had reached its position at the hands of the wind.

The bergs calved by the Jakobshavn glacier were 100 to 200 feet above water, and the vertical end-face of the glacier was of corresponding height. It is clear, therefore, that the thickness of the glacier at its end is very great. That its lower layers, and consequently the bottoms of the bergs at the beginning of their history were charged with débris, can hardly be doubted.

Above Jakobshavn, bergs continued to be plentiful through the north part of Disco Bay, though perhaps less abundant than opposite the Jakobshavn fjord. To the south entrance of the Waigat there was rarely a position where as many as fifty might not be sighted, and their average size was greater than at any point further south. While they did not often exceed eighty or one hundred feet in height, they were often 1000 feet or so in horizontal extent. Here for the first time occasional bergs were seen in which certain well-defined layers of ice, containing more or less earthy débris, stood out distinctly between the layers of cleaner ice on either hand. This was seen only in bergs which had been tilted, so that the originally horizontal layers had become highly inclined. The débris-laden layers were apparently layers which were near the bottom of the parent glacier and near the bottom of the berg at the beginning of its history.

A considerable procession of bergs was seen coming out of the fjord north of Prince Island, some of them being very massive. In this region an occasional berg was seen so completely covered with débris as to be essentially black. Such bergs were all very low, none of them being more than ten or fifteen feet in height. As subsequent observations indicated, they must have come from glaciers, the ends of which, as they reached the sea, were very thin; that is, glaciers, the upper surfaces of which were very near the lower. They therefore do not violate the general rule that the débris of the glaciers is not far above their bases. Glaciers with thin ends and edges, and such only, have abundant débris, apart from occasional medial moraines, on their upper surfaces.

In the Waigat, and for a considerable distance north of it, the bergs were, on the whole, considerably flatter than those further south, rarely standing more than fifty feet out of water. From thirty to fifty were generally in sight until the entrance to Umanak fjord was approached. Here a noble fleet of them, more than 100 by actual count, was seen sailing out from the narrow bay. Some of them were so large areally that the water produced by the melting of their surfaces gathered into streams of considerable proportions. From the upper edge of a single berg in this locality, three such streams were seen to be falling, each of which carried a very considerable body of water. The bergs were remarkably regular, such serration as characterized the bergs coming from the Jakobshavn glacier being wholly wanting. Most of them had never been overturned or even tilted; yet they were measurably clean, nothing more than a little dust being in any case visible upon their surfaces. Considerable processions of bergs seemed to be coming out of the waters north of Ubekyendt Island, and until the Svartenhuk Peninsula was reached, they were constantly in sight in great numbers.

Through Melville Bay, bergs were rarely seen. This may have been due partly to the fact that much of this stretch was passed in a foggy atmosphere, and vision was correspondingly limited. About Cape York, bergs were found in extraordinary numbers a little later, as also for a considerable distance east of this point. So abundant were they at Cape York toward the end of August that from a single position 1200 feet above the settlement just east of the Cape, about 700 were counted. Many of these were of great height, and of great areal extent as well. On the whole, this was much the noblest assemblage of bergs seen. They were not more remarkable for their size than for their freedom from débris, and for the extent to which they had been sculptured by the waves. Though without the marked serration of the bergs at some other points, their forms were often exceedingly fantastic. Here was seen the most unique berg observed at any point. From the bluff above Cape York its surface was seen to be marked by a huge, steep-sided depression, circular in outline. Its depth was considerable, its bottom appearing to be at least as low as the level of the sea. It was filled with water, the level of which appeared to correspond with that of the water in which the berg floated. The color of the water was such as to suggest that it was salt, and therefore that the depression extended quite through the berg from top to bottom. This was not, however, demonstrated. The origin of such a depression is not altogether clear, but it was probably developed while the berg was in another position. Other bergs about the Cape were notable for their huge amphitheatral reëntrants, sometimes 200 or 300 feet deep.

The bergs at Cape York were in process of rapid dissolution. At the time of our visit, the weather chanced to be sunny and warm, and the bergs appeared to have been afloat long enough for the ice to have become rotten. There was no period of more than a few minutes duration at any time during the fifty odd hours spent in this vicinity when reports due to their disruption were not heard. These reports resembled thunder much more closely than any other familiar sound, and, awakened by them in the night, the resident of lower latitudes could hardly fail to think, at the first moment, that it was a sharp clap of thunder that had roused him, and that a violent thunderstorm was raging.

Bergs occurred in considerable numbers in Wolstensholme Sound, in the upper part of Whale Sound, in Murchison Sound, and in Inglefield Gulf and its dependencies. North of Murchison Sound and between that point and Cape Sabine, latitude 78° 45′, bergs were nowhere abundant. There was probably no time during our passage through these waters when as many as two or three were not in sight, nor were there often times when more than a dozen could be seen. They were of even less frequent occurrence between Cape York and Coburg Island. In Jones Sound they were present in moderate numbers, while along the American coast south of that point to latitude 71° 30′ they were rare. There were frequently considerable intervals where not one was in sight, while at other points considerable clusters of them came into view.

Between Disco and the Labrador coast, on the return voyage, bergs were never abundant as compared with those in many other stituations, but they were almost never wanting. An approximate idea of their abundance in these waters may be obtained by the general statement that there was rarely a time when less than half a dozen or more than forty could be seen. Their numbers diminished with increasing distance to the south, and they practically disappeared before the coast of Newfoundland was reached. On the whole, the impression gained was that a very large amount of ice is discharged from the land in the form of bergs.

The highest berg seen was probably not more than 200 feet in height. The greatest areal extent of any berg seen was probably not more than one-third of a square mile, the maximum length being, perhaps, about a mile. These figures, it is to be understood, are the results of estimate, not measurement.

The almost uniform freedom of the bergs from débris is in itself a sufficient refutation of the idea that glacier ice is in general charged with débris. Extensive observation makes it certain that so far as west Greenland is concerned, only the lower portion of the ice of a thick glacier contains débris. There is little débris above the lowermost 100 or 150 feet of ice. As bergs are calved from massive glaciers, their lower portions doubtless carry a considerable quantity of material, but this appears to be dropped before they have proceeded great distances, for the bergs which are overturned or upturned rarely show any trace of it. On the other hand where a thin glacier reaches the sea, its bottom is not far from its top, the former being brought down nearly to the latter by melting, and the whole mass may be full of débris, without interfering with the general truth of the statement that débris does not rise any considerable distance above the bottom of the ice. From such glaciers only small bergs arise, and these may be well charged with rock rubbish from bottom to top. In spite of the possibilities in this line, and in spite of the fact that bergs from massive glaciers often capsize so as to bring their basal parts into view, rock débris on or in the Arctic bergs is yet so scarce that it would probably be within the limits of truth to say that not one berg in five hundred of those seen carried detritus of any sort, except dust which had been blown upon the glacier before the berg was detached.

Comparing the phenomena of 1895 with those of 1894, as seen by Professor Chamberlin, it appears that bergs were very much more abundant this year than last. This is in keeping with the fact that the warm season seems to have come on somewhat earlier than usual in 1895, at least in central Greenland, and that certain bays and fjords cleared themselves of ice somewhat earlier than is their wont, getting their bergs well to sea at an unusually early date, while other bays which often remain covered with ice for many years in succession, thereby holding all bergs discharged into them, this year cleared themselves, sending all their many bergs to sea.

*Floe ice.*—It is worthy of especial note that no trace of floe ice was seen along the coast of south Greenland. Approaching the land further north than expeditions have commonly done, it would not have been strange had we encountered less than the accustomed amount of ice, but we neared the coast sufficiently far to the south to have encountered at least the northern portion of the stream of ice which, coming down the east coast, usually rounds the point of Greenland, and passes northward along the west coast as far as Holstensborg. The fact that no ice was seen, where a wide belt of it usually occurs in corresponding seasons, seems to mean either that it disappeared much earlier in 1895 than usual, or that it was much less abundant, or both. From various facts which came to our knowledge, it seems that the former was certainly true, perhaps also the latter.

The first floe ice was encountered in the latitude of Upernivik, a little below 73°. The small pack of ice here seen, made up in considerable part of disrupted bergs, extended out a considerable distance from the coast. The floe ice of the pack was thin, and the pans were considerably tilted. A considerable number of small bergs were held in it.

In passing Melville Bay during the last days of July, but a small amount of ice was seen. Occasional pans a few yards, or in some cases a few hundred yards in diameter, were encountered, but they were rarely so abundant as to occasion any considerable deviation from a direct course. The pans were low, usually standing no more than a foot or two out of water, and were much perforated, indicating that they were near the last stage of dissolution. East of Cape York, toward the end of August, a considerable amount of floating ice was found, but it was nowhere sufficiently close to prevent navigation. In Whale and Murchison Sounds, and in the outer portion of Inglefield Gulf, ice was so abundant as to seriously interfere with navigation during all the first half of August. North of Murchison Sound, in the northern part of Baffin Bay, there was little ice, and Smith Sound was relatively free from it, except its northern end. Here, at the entrance to Kane Basin, the ice was plentiful.

On the American coast, floe ice was somewhat abundant in

Jones Sound, increasingly so with increasing distance to the west. Forty miles or so from the entrance, navigation became difficult. South of Jones Sound, little ice was encountered until latitude 72° 30′ was reached. Here it became more plentiful, and further south, in latitude 71° or thereabouts, a very extensive pack was encountered, the east-west extent of which could have been little less than 200 miles. Its extension southward was not determined, but southwest of Disco, in latitude 66° 30′, the east edge of a considerable pack was touched, which may have been continuous northward with that which had been encountered in latitude 71°. If so, the north-south diameter of the pack must have been as much as 300 miles.

*Evidences concerning recent changes of level.* On the whole, the evidence gathered concerning recent changes of level along the northern coasts is rather meager. This is not to be interpreted as meaning that such evidence is necessarily wanting, but merely that it is not usually so obtrusive as to be detected upon cursory inspection. Even the absence of topographic evidences of changes of level would not necessarily mean that such changes have not taken place. The study of the coastal lands here, as elsewhere, led to the conviction that a region may be submerged and reëlevated, without preserving very distinct topographic evidence of the change.

The topography of most of the land front seen, both on Greenland and on the continent, is without any notable horizontal element; that is, terraces, beaches, etc., if present at all, are generally, though not always, so inconspicuous that they were not detected in passing, even when the course was so close to the coast as to afford excellent opportunity for studying the details of its topography.

At Jakobshavn striæ were seen on the gneiss down virtually to the level of the water. Their presence at this low level is perhaps not especially significant so far as changes of level are concerned. If the land has risen since they were formed, the shore line probably did not remain long at the level at which they occur. Their presence at the sea level, and at all higher altitudes, would seem to mean that if the land has risen since glaciation, it rose rapidly. Nothing was seen about Jakobshavn which was taken to mean, necessarily, a recent uplift of the land, though features were seen which would be consistent with such movement.

Between Jakobshavn and Cape York but a single stop was made, but the coast (perhaps only islands) was seen almost continuously from the former place to latitude 74°. Nothing was seen in the topography at any place between these points to indicate recent changes of level, if the fjords be not considered such evidence. It should be stated, however, that the course of the *Kite* was frequently so far from shore, that minor, or even reasonably distinct, topographic evidences of rise might have escaped notice. Further north, positive evidences of recent rise were seen at various points. Thus there are well defined terraces on the east side of Saunders Island in latitude about 76° 35′. The elevation of these terraces was not determined as no landing was made on the island, but the highest may have been something like 100 feet above the water. Again, in Olrik's Bay, a dependence of Whale Sound, just above the 77th parallel, there are considerable deposits of sand containing abundant marine shells of species still living along the shore, at elevations ranging up to 150 feet at least. These sands are conclusive proof of recent elevation of the coast in this region by an amount equal to the height of the sands themselves, yet topographic evidence of this change of level is nowhere conspicuous along any part of the bay seen, and at many places is altogether wanting. The end of a large glacier descending toward the bay from the elevated lands on the south, rests on and conceals the upper part of these shell-bearing sands.

Nowhere else in Whale Sound or Inglefield Gulf was anything seen which seemed to necessitate the conclusion that the land has recently risen or sunk. Near the west end of Herbert Island, on the south side of Murchison Sound, there is a terrace which very likely signifies recent elevation. It is less well defined than that of Saunders Island, and its altitude is comparable. Elsewhere about the island distinct terraces are wanting.

The most conspicuous terraces seen were in the vicinity of Littleton Island, in latitude about 78° 30′. Here on the mainland coast, there is a notable series of terraces, at least three in number, which seemed clearly to have been fashioned by the waves. Opportunity was not afforded for their measurement, but the highest could hardly have been less than 300 or 400 feet.

It will be seen that the points where positive evidence of recent rise was found are distributed in latitude between 76° 35′ and 78° 30′, a stretch of something like 120 miles; but within this distance there seemed to be complete absence of evidence of recent submergence at most points. If one may trust topographic evidence, and such evidence as interrupted study on the shores themselves furnished, it would be as rational to conclude that the coast through this region has risen at certain points, while others have remained stationary or have subsided, as to conclude that it has risen at all points because it has risen at some. It is not believed, however, that anything less than an uninterrupted study of the coast through long stretches will afford positive evidence concerning the point in question, and the absence of topographic evidence of recent elevation at many points is therefore not interpreted as necessarily meaning absence of recent elevation at those points.

On the American coast a somewhat similar condition of things exists. On Smith Island, in Jones Sound, there is positive evidence of recent elevation to the extent of fifty feet, and less satisfactory evidence of a much more considerable rise. South of Jones Sound a horizontal element in the coastal front is often wanting, though sometimes present. It was somewhat conspicuous on Philpot Island, latitude 75°, though no landing was made at this point, and the significance of the horizontal element was therefore not determined. Suggestions of terraces were also observed at some points on Bylot Island. At Dexterity Harbor, about 72°, opportunity was afforded for more careful examination of the evidence bearing on this question, and here there was positive evidence of recent elevation to the extent of something like 480 feet, aneroid measurement. Beaches and flats of limited extent succeeded each other at frequent intervals up to this level. Along the line of ascent, seven tolerably well defined beach lines were noted, while on the line of descent, but a short distance from the former, two more were counted. From a short distance off shore these successive stages were altogether unseen, although the whole of the considerable stretch of territory below 500 feet had the general aspect of a marine plain. It is probable that detailed examination of the coast at other points would give specific information, which was not detected from the *Kite*, concerning the stages of rise

In conclusion it may be stated that while recent changes of level have certainly taken place at some points, and that they locally amount to several hundred feet, observations were too disconnected and too meager to make out the general system according to which they took place, or the general principles governing them.

ROLLIN D. SALISBURY.

# A CIRCUM-INSULAR PALÆOZOIC FAUNA.

CONTENTS.



## INTRODUCTION.

Zoölogists who have turned their attention to the geographic distribution of animal life on the earth at the present time, have divided it into numerous zoölogical provinces. The marine zoölogical provinces are separated by three classes of barriers, (1) Climatic, (2) Land, (3) Abyssmal. Each one of these establishes a limit to the migrations of marine life. There is no reason to doubt the existence of zoölogical provinces in past time similar to those existing today, with the same sorts of barriers, but ever changing with the progress of time.

These zoölogical provinces of past time give rise to problems with which the palæontologic geologist has to deal. Unfortunately the ancient barriers are obscured or lost, being buried by later formations, or the sea, or carried away by erosion, and it falls to the investigator to reconstruct the barriers from a study of the faunas and of the stratigraphy.

*Zoölogical provinces of Devonian time.*—During Silurian time the faunas of eastern North America and northern Europe were intimately related. Many species were common to both regions, and there seems to have been freedom for intermigration between the two. With the beginning of Devonian time these two regions became isolated. The faunas in each continued their evolution, but each in accordance with the conditions of its own environment. At the period of deposition of the Hamilton beds in New York, a distinct fauna had to come to exist in each of these two areas.

The east American fauna of this time has been described and illustrated chiefly in the various reports of the New York state geologist. From studies of the South American Devonian fauna, chiefly those of Dr. A. Ulrich,[1] it has been shown that the east American Middle Devonian fauna is related to the South American fauna. The peculiar genera *Tropidoleptus* and *Vitulina* are characteristic of these two regions, being unknown in the European and west American Devonian faunas. Besides these genera, there are other bonds of relationship between the faunas. This east American fauna inhabited an area bounded on the north by the nucleus of the North American continent and on the east by the land area lying at that time to the east of the present Appalachian region. It did not extend westward beyond the Mississippi River. From its relationship to the South American faunas, we may conclude that it extended far to the south.

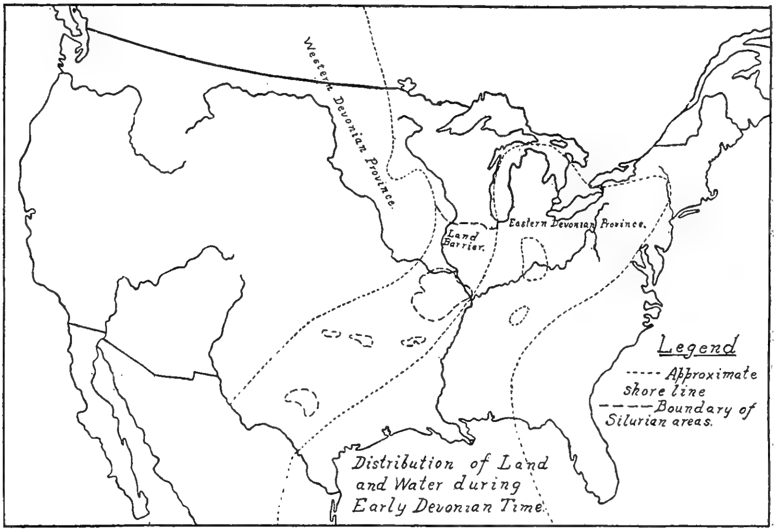
The contemporaneous European fauna was largely developed in central Europe, in the Ural Mountain region, and extended across Asia and into the western part of North America. In America its most typical development was in the far northwest. It was first described by Meek[2] from the Mackenzie River basin, and has lately been much more completely described by Whiteaves.[3] It extends southeastwardly, and, in the so-called Hamilton of Iowa, it reached the Mississippi River.

*Distribution of land and water during Devonian time.*— In seeking for the barrier, which must have existed during the greater part of Devonian time, near the present location of the Mississippi River, the presence of a land barrier seems to be necessarily presupposed. The stratigraphy of the region admits of this conclusion. Along the southern border of the Silurian peninsula, extending southward and including a large part of

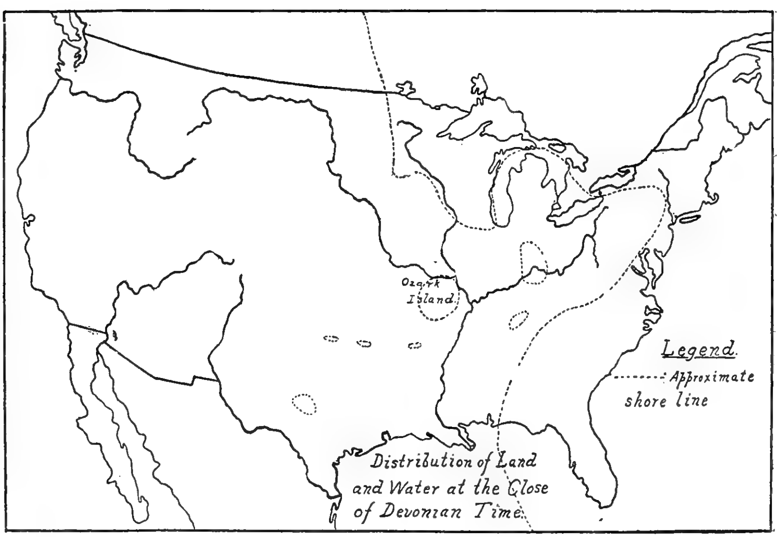
[1] Beiträge zur Geol. und Pal. von Südamerika, I, Paläozoische Versteinerungen aus Bolivien.

[2] Trans. Chic. Acad. Sci., Vol. I. (1868).

[3] Cont. to Canadian Pal., Vol. I., Part III. (1891).



Western Devonian Province.
Eastern Devonian Province.
Land Barrier.
Legend
----- Approximate shore line
— — — Boundary of Silurian areas.
Distribution of Land and Water during Early Devonian Time.

Ozark Island.
Legend.
........ Approximate shore line
Distribution of Land and Water at the Close of Devonian Time.

Wisconsin and the northern portion of Illinois, rocks of much younger age lie upon the Silurian beds, indicating that during a long period between Silurian and Carboniferous time this peninsula extended far to the south. The Ozark Silurian or Ordovician region has also lying upon its flanks rocks of much younger age, indicating that during the greater part of Devonian time it was a body of dry land of more than the present extent of the older rocks. There seems to be good reason, therefore, to suppose that during this period the Wisconsin peninsula and the Ozark Island were joined. This, however, would not alone form a sufficient barrier to separate the two faunas, as they could easily migrate around the southern end of this peninsula. There are, however, small patches of Silurian rocks exposed in Arkansas, Indian Territory and Texas, and all of these are surrounded in a similar way by rocks of much younger age, and this suggests the probable extension of this land barrier far to the southwest. Furthermore, the presence in the east American Devonian fauna of representatives from the South American province necessitates a shore line along which the migration could have taken place. This suggests the extension of this land into South America. With the existence of such a land tract the separation of the two Devonian faunas would be effectual.

If the conclusions of the last paragraph are correct, the Ozark region was not an island during earlier Devonian time, but was included in a long peninsular extension of the ancient northeastern land, or more probably in an isthmus joining it to some larger body lying to the southwest. By a partial submergence of this peninsula or isthmus the Ozark Island was formed. The depression of this land area was neither sudden nor continuous, but the movements were oscillatory in their nature.

*Union of eastern and western Devonian provinces.*—The earliest evidence of the union of the two seas on either side of this narrow strip of land is found in the appearance of an entirely foreign fauna in the midst of the Hamilton beds of New York. This is the Cuboides fauna of the Tully Limestone. From a study of this fauna Professor Williams[1] has shown that it was not the genetic successor of the fauna immediately preceding it, but that it was entirely foreign to the area, and that its relationships were with the Devonian faunas of western and northwestern America, which in turn were intimately related to the European middle Devonian faunas.

This earliest submergence of the Ozark Isthmus was not permanent. The two seas were not in communication for a sufficient period to admit of any extensive intermigration of the faunas. A colony from the west escaped into the east and found its way into the New York region, where it occurs in the Tully limestone. From the oscillatory natures of the movements of this region during its period of submergence, there is reason to expect that there will be found in the Devonian beds along the border line between the eastern and western provinces a mingling of the two faunas. This need not necessarily occur in the same beds at first; the faunas might appear in alternate layers. Much yet remains to be done, however, upon the details of the stratigraphy and palæontology of this region. None of the present records enter into sufficient detail to be available for a conclusive study of the subject.

On the final submergence of the connecting tracts and the formation of the Ozark Island—having approximately the area of the present exposure of the older rocks — the faunas of the two provinces had an unlimited opportunity to intermingle. It is this circum-insular fauna, found embedded in the strata of the Chouteau group,[2] which is the subject of chief consideration in this paper.

The study of island faunas has always possessed the greatest interest to evolutionists. In his observations upon island faunas during his trip around the world, Darwin found many of the facts which led to his proposal of the theory of natural selection.

[1] Bull. Geol. Soc. Am., Vol. I, pp. 481–500 (1890).

[2] The author may be criticised by some for using the name Chouteau, for these beds have of late come to be generally considered as contemporaneous with the Kinderhook, and designated by that name, which was applied at an earlier date. There is no doubt in the author's mind of the contemporaneity of the Kinderhook and Chouteau, but the latter term is used as a convenient discriminative formation name of a local nature to designate the beds deposited on the immediate shores of the Ozark

The studies of Wallace have elevated island life into a distinct field of investigation. In the study of an island fauna, whose records, and even the island itself, are buried in the rocks, the task of interpretation becomes especially difficult. The conclusions to which one may arrive, however, equal in importance those reached in the study of recent island faunas. The study of the littoral faunas has much the same nature and importance as that of the islands themselves. So far as the writer is aware, however, there never has been published the results of a special study of a circum-insular fauna of palæozoic time.

In the detailed study of any fossil fauna the palæontologist must ask himself of each individual genus and species, is this an evolution form, or is it a migration form? Every genus or species, in whatever geologic or geographic position it may be found, falls into one of these two categories. Either its ancestors have lived in the same geographic area where it exists, or they lived in some other part of the world, and the genus or species is in the particular position where it is found, through migration from the original center of evolution. This migration may have occupied a series of generations. Very often these questions cannot be answered, but in most cases an answer can be found for those forms which give character to the fauna.

From the nature of the case the fauna of the Chouteau group was composed necessarily of migration species. An area of land had become sea-bottom, having no preëxisting marine fauna, it had to be peopled, if peopled at all, by organisms which come in from without. This does not, however, make it necessary that the migration should have been a distant one. On a critical examination of the fauna it is found that the ancestry of the individual genera and species can be traced back to two different sources. These are the middle and lower Devonian faunas of the East and the Devonian fauna of Europe and the West.

*Generic evidence of the origin of the littoral fauna about the Ozark*

Island. The typical Kinderhook beds were deposited nearer the shore of the mainland of that time and under somewhat different conditions, and it might be misleading to use the term in this connection. It is only the circum-insular fauna as found in the Chouteau beds that is considered here.

*Island.*— In the following table all the genera occurring in the Chouteau group are tabulated with their geologic range[1] and geographic distribution, and from this table the generic evidence of the origin of the fauna may be seen.

| | Chouteau Group | East American Devonian Province | West American and European Devonian Province. | American Silurian | European Silurian |
|---|---|---|---|---|---|
| BRACHIOPODA. | | | | | |
| *Athyris* | x | x | x | x | x |
| *Camarophoria* | x | | x | | |
| *Chonetes* | x | x | x | x | x |
| *Cyrtina* | x | x | x | x | x |
| *Leptæna* | x | x | x | x | x |
| *Lingula* | x | x | x | x | x |
| *Orthothetes* | x | x | x | x | x |
| *Productella* | x | x | x | | |
| *Productus* | x | | | | |
| *Ptychospira* | x | | x | | |
| *Rhipidomella* | x | x | x | x | x |
| *Pugnax* | x | | x | | |
| *Rhynchonella* | x | x | x | x | x |
| *Schizophoria* | x | x | x | x | ? |
| *Spirifer* | x | x | x | x | x |
| LAMELLIBRANCHIATA. | | | | | |
| *Aviculopecten* | x | x | | | |
| *Cardiopsis* | x | x | | | |
| *Edmondia* | x | x | | | |
| *Entolium* | x | | | | |
| *Grammysia* | x | x | x | x | |
| *Pernopecten* | x | | | | |
| *Promacrus* | x | | | | |
| *Pterinea* | x | x | | x | |
| *Sphenotus* | x | x | | | |
| GASTEROPODA. | | | | | |
| *Bellerophon* | x | x | x | x | x |
| *Eccyliomphalus* | x | x | x | x | x |
| *Euomphalus* | x | x | x | x | x |
| *Loxonema* | x | x | x | x | x |
| *Platyceras* | x | x | x | x | x |
| *Porcellia* | x | x | x | | x |
| *Straparollus* | x | x | | | |
| CEPHALOPODA. | | | | | |
| *Goniatites* | x | x | x | | |
| *Nautilus* | x | x | x | x | x |
| *Orthoceras* | x | x | x | x | x |

[1] The range of the genera above the Chouteau group is not tabulated. In a future paper, now in preparation, the history of the faunas of the overlying Osage group will be considered.

| | Chouteau Group | East American Devonian Province | West American and European Devonian Province | American Silurian | European Silurian |
|---|---|---|---|---|---|
| PTEROPODA. | | | | | |
| *Conularia* | x | x | x | x | x |
| *Hyolithes* | x | x | x | x | x |
| CRINOIDEA. | | | | | |
| *Agaricocrinus* | x | | | | |
| *Amphoracrinus* | x | | | | |
| *Cyathocrinus* | x | x | x | x | x |
| *Dorycrinus* | x | | x | | |
| *Gennaeocrinus* | x | x | | | |
| *Platycrinus* | x | x | | | |
| *Scaphiocrinus* | x | x | | | |
| *Schizoblastus* | x | | | | |
| CORALS. | | | | | |
| *Amplexus* | x | x | x | x | ? |
| *Chonophyllum* | x | x | x | x | x |
| *Cyathophyllum* | x | x | x | x | x |
| *Leptopora* | x | | | | |
| *Lithostrotion* | x | | | | |
| *Michelinia* | x | x | | | |
| *Microcyclus* | x | x | x | | |
| *Palæacis* | x | | | | |
| *Syringopora* | x | x | x | x | x |
| *Zaphrentis* | x | x | x | x | x |
| TRILOBITA. | | | | | |
| *Brachymetopsis* | x | | | | |
| *Phillipsia* | x | | x | | |
| *Proetus* | x | x | x | x | x |

In the foregoing table it is seen that the genera, exclusive of those peculiar to the Chouteau, with but three exceptions, may be divided into three groups. (1) Those common to the Chouteau and the east American faunas. (2) Those common to the Chouteau and the west American or European faunas. (3) Those common to all these faunas. It is important to observe that the genera of the last class are all older than those peculiar to only one of the two Middle Devonian provinces. As shown in the table they extend back into the Silurian time when the two areas were united. After the isolation of the two regions as distinct Devonian provinces, new genera originated, and those thus originating in the separate provinces were different.

The exceptions to this rule are: *Productella*, *Goniatites* and *Microcyclus*. The fact of the recorded distribution of *Productella* points either to a dual origin of the genus, or to an imperfection in the record, or, possibly to an exceptional migration across or around the barrier in spite of the general effectiveness. The name *Goniatites* is applied to a heterogeneous assemblage of forms, which have been divided into numerous genera by Hyatt and other recent writers, and if the Chouteau species were referred to these more limited divisions, it is probable that they would not appear as exceptions. *Microcyclus* occurs in the Devonian fauna at Devil's Bake Oven in southern Illinois, where the eastern faunas approach nearest geographically to those of the west. It is possible that this fauna lived during the period of submergence of the land barrier, and that *Microcyclus* in this locality is really a representative of the western and not of the eastern fauna.

Taking the generic evidence as a whole, it points to the dual origin of the fauna.

*Specific evidence of the origin of the littoral fauna about the Ozark Island.*—In the consideration of the specific evidence of the origin of the Chouteau fauna each species has been studied with special reference to its evolution from preëxisting species. As might be expected, the evolution of the species can be traced in only a few instances comparatively, but this evidence also, so far as it is available, points to the dual origin of the fauna. Each of the species whose evolution can be traced will be briefly considered.

*Athyris hannibalenis*, Swallow. This species is not uncommon in the yellow Chouteau Limestone. It most closely resembles *A. lamellosa*, L'Eveille, of the succeeding beds. It is generally less transverse than that species, though this character is variable, and individual specimens may be found which are quite equal to *A. lamellosa* in this respect. The concentric lamellæ on the exterior of the shell are somewhat closer together than in *A. lamellosa* from the Burlington Limestone. It is intermediate in its characters between *A. spiriferoides*, Eaton, of the New

York Hamilton beds, and *A. lamellosa*, of the Burlington Limestone, though it approaches much closer to *A. lamellosa* than to *A. spiriferoides*. A well-preserved exfoliated specimen from the Chouteau limestone near Springfield, Mo., closely resembles a specimen of *A. spiriferoides*, which is in the same condition of preservation, from the black calcareous layers of the Hamilton series of New York.

*Athyris proutii*, Swallow. Though this species has never been figured, it is well characterized and easy of recognition. Specimens have been examined from the typical locality, and compared with those from the base of the Chouteau group, near Springfield, Mo., they cannot be separated. The species is not apt to be confused with any other American form, but it is similar to and possibly identical with *A. reticulata*, Gosselet,[1] of the Middle Devonian of Europe. American specimens agree closely with Tschernyschew's[2] figures of this species from the Ural Mountains, and the surface ornamentation of the American form is identical with the European.

*Leptæna rhomboidalis*, Wilckins. This cosmopolitan species is one of the most interesting in the whole fauna. It occurs in all the beds of the Chouteau group and extends up into the Burlington Limestone. In studying its geographic and geologic distribution, it is found not to be recorded in the Devonian fauna of the west, though it does occur in Europe. It occurs abundantly, however, in the Lower and Middle Devonian faunas east of the Mississippi River. Its origin in the Chouteau fauna may probably be traced to the eastern Hamilton fauna.

*Orthis* (*Rhipidomella*) *michelini*. L'Eveille. Although the subgenus *Rhipidomella* is present in the European Devonian faunas, it does not occur in those of northwestern America. The form from which *R. michelini* has its origin is *R. vanuxemi*, Hall, of the eastern Hamilton beds. Indeed, it is most doubtful

[1] *Spirigera* (*Athyris*) *reticulata*, GOSSELET, Ann. Soc. Geol. du Nord. Vol. IV., p. 312, Pl. III., Figs. 3 a–f (1887). *Spirigera reticulata*, GOSSELET Equisse Geol. du Nord de la France; Pl. VI., Fig. 6 (1880).

[2] *Athyris reticulata*, Tschernyschew, Die Fauna des Mitt. und Ober Devon am des W. Abhange des Urals., p. 57, Tab. X, Figs. 16 a–d (1887).

whether the two forms should be separated at all. Oftentimes individual specimens from the Chouteau beds cannot be distinguished from individual specimens from the New York Hamilton beds, except in color, the form being essentially the same. The presence of this form in the Iowa Devonian beds may be attributed to the nearness of that area to the border line between the two provinces during the period of submergence of the land barrier.

*Orthis* (*Schizophoria*) *resupinata*, Martin. American specimens of this species have been described as *O. swallovi*, Hall,[1] but it is impossible to separate the American specimens from European examples. The ancestor of this species is most certainly to be found in *O. striatula*, Schl. of the European Middle Devonian. In the beds of the Chouteau group many intermediate forms between the two species are found. The facts of the distribution of *O. striatula* are most interesting. It occurs in the Western American Devonian faunas under the name *O. iowensis*, Hall. In the eastern portion of America it appears first in the Tully Limestone under the name of *O. tulliensis*, Vanuxem. This represents its first eastward migration. Later, when the land barrier was more fully removed, it again migrated to the east, and is found in the Chemung faunas under the name *O. impressa*, Hall.

*Productella hallana*, Walcott (= *P. dissimilis*, Hall). This peculiar little species occurs abundantly in the Devonian fauna of the west and in Europe, and is also present in the very lowest beds of the Chouteau group near Springfield, Mo. It is also present in the very lowest beds of the Chemung group in New York.

*Productella pyxidata*, Hall. This species is closely related to *P. subaculeata*, Murch., of the European Devonian, and its ancestry may apparently be traced to that species.

*Rynchonella* (*Pugnax*) *acuminata*, Martin. This type of Rynchonella is wholly unknown in the east American province until after the period of immigration from the west, when it occurs with *Productella hallana*, in the very lowest beds of the Chemung

[1] Geol. Surv. Iowa, Vol. I., Pt. II., p. 579, Pl. XII., Figs. 5 a–b (1858).

group in New York. It also occurs, as does *P. hallana* in the lowest beds of the Chouteau group.

*Spirifer cf. compactus*, Meek. A common species in the Chouteau beds, is remarkably like Meek's illustrations of *S. compactus*[1] from the Mackenzie Valley. If not referable to that species it can most certainly be considered as its genetic successor.

*Spirifer marionensis*, Shumard. This is one of the most characteristic of Chouteau species. The form to which it is most closely related, through *S. Whitneyi*, Hall, of the Iowa Devonian, is *S. verneuili*, Murch. Some of the variations of this most variable species[2] are closely similar to individual specimens of the American *S. marionensis*.

*Eccyliomphalus paradoxus*, Winchell. The nearest ally and probable genetic predecessor is found in *E. laxus*, Hall, from the Devonian of the east.

*Loxonena cf. hamiltonae*, Hall. In beds of the Chouteau group near Springfield, Mo., is a little species of *Loxonema* which can scarcely be separated specifically from this species of the New York Hamilton beds.

*Conclusion*. From a consideration of all the evidence, the fauna of the Chouteau group is seen to be the resultant of the union of the two distinct faunas. Each of the original faunas is undoubtedly Devonian, but the resultant fauna as a whole has the strongest Carboniferous affinities. Before the removal of the barrier which kept them apart, these two faunas had lived under similar physical environments, and it is probable that either of them could have lived alone on the shores of the Ozark Island without undergoing any considerable change. But on the intermingling of two such distinct faunas, a fierce struggle for existence arose between them. In this struggle the most hardy elements of the two hardy faunas survived, and in their union resulted a most vigorous fauna which gave character to succeeding faunas for a long period of time, and whose influence was far

[1] Trans. Chicago Acad. Sci. Vol. I., p. 102 (1868).

[2] Etude sur les variations du *Spirifer vermeuili*, par J. Gosselett Mem. Soc. Geol. du Nord. (France) Tome IV., I., pp. 1–61, plates I.–VII. (1894).

reaching.[1] Many species became extinct and many new ones were initiated, while several genera appear here for the first time. The most important of these new genera is *Productus*, which attained at its period of initiation almost its complete range of primary differentiation. In the Chouteau Limestone occur species of this genus which represent the three subdivisions, including the greater number of all its known species, *i. e.*, the groups of *P. semireticulatus*, *P. cora* and *P. punctatus*. The genus *Productus* is one of the most characteristic of Carboniferous time.

It is of interest and value, for purposes of correlation to trace the further migrations of the fauna of the West Devonian province. When the land barrier was permanently removed, one detachment migrated eastward into New York and gave origin to the faunas of the Chemung epoch. In the Chemung fauna the same two elements exist as in the Chouteau fauna, but the western and European element is so much in the ascendancy, that the fauna has a very different aspect. It seems that the foreign fauna was much better adapted to the conditions of environment than the native one, and so, instead of a general mixture of the two, such as took place on the shores of the Ozark Island, the native fauna was driven out by the foreign one, only a small element of it being absorbed.

In the very base of the Chemung[2] are two extremely interesting species, *Rynchonella* (*Pugnax*) *acuminata*, Martin, and *Productella hallana*, Walcott. These same two species also occur

[1] It is not the intention of the author to convey the idea that the fauna of the Mississippian Series originated exclusively on the shores of the Ozark Island. On the shore of the mainland adjoining, the same opportunity for the intermingling of the two faunas existed. The Chouteau fauna is alone treated in the present paper because it is this fauna with which the author is familiar. The whole subject of the origin and evolution of the Mississippian faunas involves a detailed study, not only of the Chouteau and Kinderhook faunas and their successors, but also of the Waverly and Marshall faunas of Ohio and Michigan. It is believed that the key to the whole problem is to be found in the dual origin of the faunas as set forth in the present paper.

[2] On a remarkable Fauna at the base of the Chemung Group in New York. H. S. Williams. Am. Jour. Sci., Vol. XXV., p. 97 (1883). Fauna of the Chemung Beds at High Point. J. M. Clarke. Bull. U. S. G. S. No. 16., p. 72 (1885).

in the *base* of the Chouteau group. Both of them, or nearly related species, are abundant in the Devonian beds of the western province. In the eastern province they are unknown, and nothing like them occurs before the immigration of the western fauna. Appearing as they do for the first time after the removal of the land barrier between the east and west, in these two localities, southern Missouri and New York, they furnish good ground upon which to correlate the formations in which they occur in the two regions, making the base of the Chouteau group contemporaneous with the base of the Chemung group of New York.

In the early reports, the Chouteau beds were referred to the Chemung group, but at the present time they are generally considered as younger than the Chemung because the fauna as a whole is more nearly related to the succeeding Carboniferous than to any Devonian fauna. Continued investigation seems to substantiate the old view of the Devonian age of the Chouteau beds. While *the Chouteau fauna is not the Chemung fauna*, the two lived contemporaneously. The differences between them are geographic in their nature and origin, rather than chronologic.

The dividing lines between time periods such as are understood by the terms Devonian and Carboniferous must be taken arbitrarily in their closer application, whatever may be the distinctness of the periods from a general point of view. It is incompatible with modern doctrines to conceive of a sudden change through which the Devonian faunas of the world became extinct and the Carboniferous faunas simultaneously initiated. The Carboniferous fauna must have begun to take its origin in Devonian time, in the midst of Devonian faunas. A plane extended around the world between the formations having faunas most closely allied to those below, and the formations whose faunal alliance is upward, would not be a contemporaneous division. If time periods are arbitrarily separated by horizontal time lines, or time planes, of necessity it follows that cases will be observed where faunas with Carboniferous alliance will have lived before the arbitrary Carboniferous-Devonian time line, and faunas with

Devonian alliance will have lived after it.[1] The Chouteau fauna is a good illustration of a fauna with Carboniferous affinities living before the close of Devonian time, as divisions are usually shown.

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[1] An illustration of the persistence of a Devonian fauna is seen in the fauna of the Spring Creek Limestone near Batesville, Ark. See: The Recurrence of Devonian Fossils in Strata of Carboniferous Age. H. S. Williams, Am. Jour. Sci., Vol. XLIX., p. 94 (1895).

# EXPERIMENTS IN ICE MOTION.

In a previous study the author became convinced that a definite relation exists between certain deposits of glacial débris and the topography of the surface over which the ice from which they were deposited had just passed. It seemed that this relationship could only be explained by the existence of differential movements or currents in the ice bottom, and it was to determine the existence of these and, to as great an extent as possible, their nature, that the following experiments were undertaken.

Much discussion has taken place over the method of motion in glaciers and the condition of the basal portion of a thick bed of ice, such as a continental glacier. The upper parts of glaciers are known to be practically rigid, while the basal portions, as far as can be judged from the resultant topography, is possessed of differential movements, *such as might take place in a viscous body.* Whether the mobility of the bottom is caused by regelation, granulation or true viscosity, the currents would be the same and it was these alone that the author attempted to investigate.

Under the assumption that the currents were such as could take place in a viscous body, the substance chosen to experiment with was wax or paraffine in which was dissolved a quantity of refined petroleum to lower the melting point. The paraffine was melted and allowed to cool to a temperature such that it would just give under its own weight, great care being taken to keep it of an equal temperature and softness throughout The wax was than forced through long, narrow boxes, open at both ends, by means of closely fitting plungers, and caused to pass over obstructions of various kinds placed in its path. It was then allowed to cool in the box and sawn or sliced into sections. The boxes used were of varying lengths and generally about twice as high as broad, allowing for a vertical play of currents as the class of obstructions it was desired to study would produce only this kind. The face of the obstructions extended entirely across the box and was rounded but quite abrupt. The inside of the boxes was planed smooth and then rubbed with olive oil to reduce friction and consequent drag on the sides (which it was feared would influence the results of the experiment) to as great an extent as possible. In experiments upon the effect of drag it was found necessary to increase it artificially. The boxes were fastened together by screws to facilitate handling.

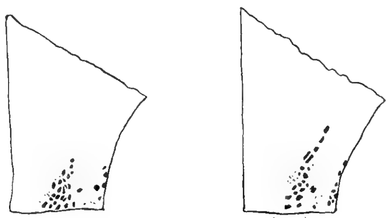


FIG. 1.

In forcing the paraffine through the boxes the strength of the operator was generally found sufficient to produce the necessary rate of motion which did not exceed a foot in fifteen or twenty minutes and was, when necessary, further reduced by pauses in the operation. In order to trace the currents thin lines of powdered coal or galena and layers of darkened wax were used. When the wax was being packed in the box the different layers were fused on the surface with a Bunsen burner and allowed to stand in contact for a few moments before being moved in order to form a perfect union and regain a temperature similar to the residue of the wax.

THE EXPERIMENTS.

*Experiment 1.*—A box 6 by 6 inches and 12 inches long was furnished with an escarpment 1 inch high which extended to the rear of the box. Coarsely powered galena was sprinkled upon the floor of the box and the wax packed upon it. The wax was then subjected to a shove of about 3 inches. The result is shown in Fig. 1.

*Experiment 2.*—A box 3 inches high by 3 inches wide was furnished with an escarpment 5/8 inch high. The wax was provided with a basal layer of darkened wax 1/2 inch thick. It was shoved 7 or 8 inches. Fig. 2.

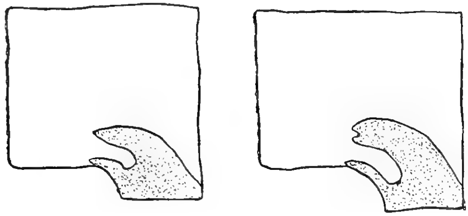


FIG. 2.

*Experiment 3.*—The same box as in Experiment 2 was provided with an escarpment 1 inch high and the wax provided with a thicker basal layer of darkened wax. The same length of shove was given. Fig. 3.

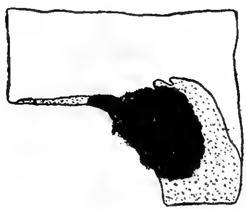
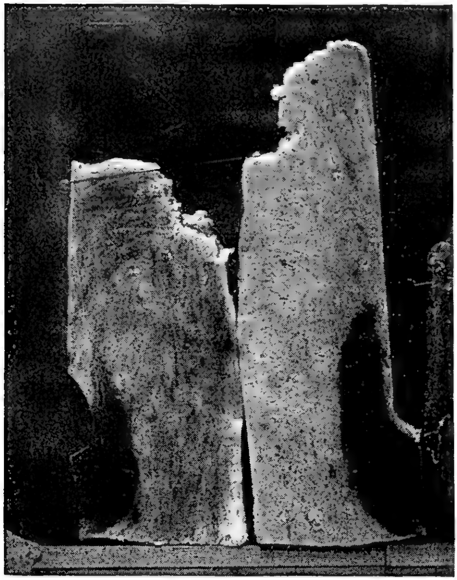


FIG. 3.

*Experiment 4.*—A box 3 1/2 inches wide and 6 inches high with an escarpment 7/8 inch high. The wax was provided with a basal layer of darkened wax and a little light wax, 3/4 inch, was packed between it and the escarpment. It was shoved about 13 inches. Fig. 4*a*.

*Experiment 5.*—The box used in Experiment 4 was provided with an obstruction 7/8 inch high and 2 1/4 long with an abrupt front and gently sloping rear. The wax was furnished with a basal layer of darkened wax and shoved about 10 inches. Fig. 4*b*.

*Experiment 6.*—A box 3 1/2 by 6 inches with an escarpment 1 1/2 inches high. The wax was provided with a basal layer of dark-



b FIG. 4. a

FIG. 5.

ened wax and a couple of dark lines at intervals of about ¾ inch above it. It was shoved about 12 inches, Fig. 5 (by transmitted light).

*Experiment 7.*—A box 4 feet long was furnished with two escarpments each ⅞ inch high. The first extended one-half the

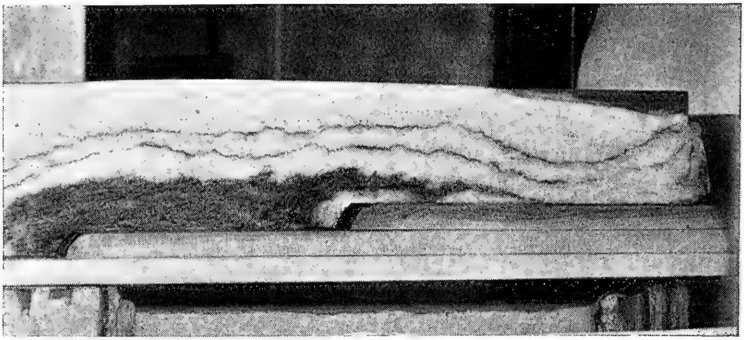


FIG. 6.

length of box and the second 14 inches from the back and lay upon the first. The wax was provided with a basal layer of dark wax and two dark lines. The shove was 18 inches. Fig. 6.

*Experiment 8.*—The arrangement in Experiment 7 was altered by taking 1½ inches from the upper escarpment and removing a piece 5 inches long from the lower, leaving a valley with an obstruction of 6¼ inches in front of it. The form of the base may be seen in the figure. The basal layer was substituted by a line at the level of its top. The shove was 18 inches. Fig. 7.

*Experiment 9.*—The last two escarpments in Experiment 8 were removed and one of the same height and 7½ inches long substituted, having a valley 10 inches long. The lines were as in Experiment 8. The shove was 18 inches. Fig. 8.

*Experiment 10.*—The same arrangement as in Experiment 9, but the wax was allowed to remain at rest five minutes with its front in the valley between the two escarpments. Fig. 9.

*Experiment 11.*—The valley was decreased to 7¾ inches by

FIG. 7.

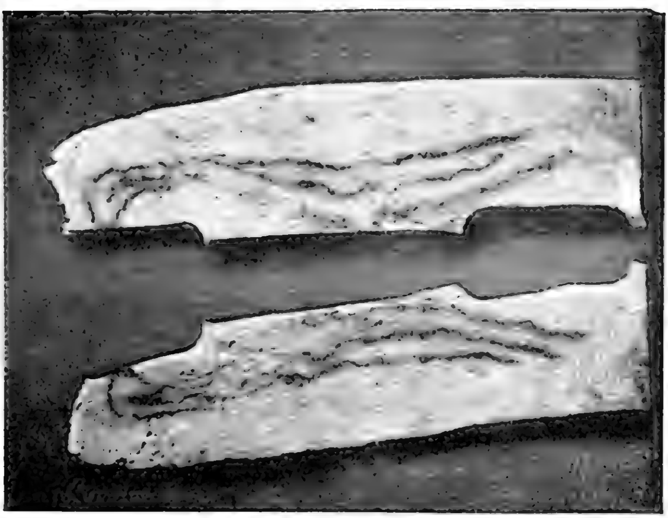


FIG. 8.

elongation of the rear escarpment and the number of lines in the wax reduced to two. Fig. 10.

RESULTS OF EXPERIMENTS.

An inspection of Figs. 1, 2, 3, 4 and 5 will show a very decided upward current produced in the basal portion of the

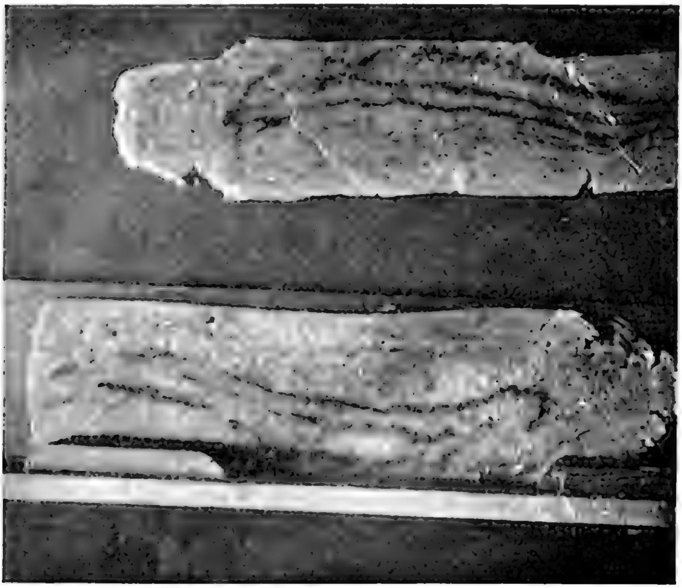


FIG. 9.

wax. The current starts somewhat back from the escarpment and travels up and over it in an arch, leaving between itself and the top and rear portions of the escarpment a layer of white wax seemingly unaffected by the movement.

A second current is shown in the same plates creeping up close to the face of the escarpment and reaching to its top, where, upon a flat surface it may spread out closely applied to the surface, as in Fig. 3, or rise a little above it as in Fig. 2. In every case it will be noticed that this current is a very minor portion of the wax movement. In case of a further movement of the wax the evidence of two currents, so clear in Fig. 2 is obscured, as shown in Fig. 6. A close examination, however, reveals their continued presence.

In the case of an escarpment or obstruction with a subsequent declivity the basal layer is continued out into the wax from the top of the escarpment or obstruction as a narrow line. Fig 4*b*.

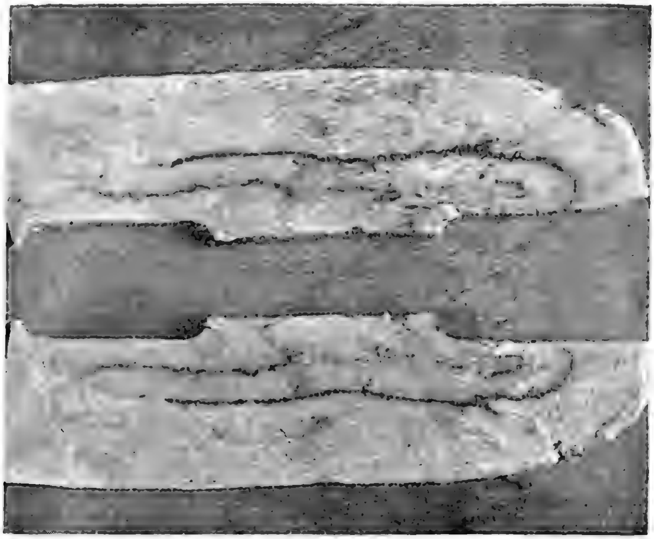


FIG. 10.

The part continued in the line is, possibly, the part noticed in Fig. 2, adhering to the face and top of the obstruction while its main current can be seen rising in an arch behind. The same feature is less prominently shown in the experiments where lines were used instead of the basal layer of darkened wax. Another point to be emphasized is the arch-like course taken by the upper and principal current. Rising abruptly a little way back from its front the currents extend to a considerable distance in its rear, where they descend in a much more gentle curve towards a point much farther from the escarpment than it originated. At all points it is free from contact with the escarpment. This is shown in Fig. 5, and in the simplest form in Fig. 4*a*, and in the upper lines at the second escarpment of Fig. 6.

In Fig. 5 the arch is shown complicated by a most important agency, namely, drag. This will be shown to be the source and explanation of some of the complicated phenomena observed in the wax. Experiment 6 was designed to determine the effects upon the moving wax of the drag from the bottom of the box. As noted above, it was necessary to induce drag. This was done by a pause in the shove allowing the wax to flatten slightly and adhere to the bottom. The currents marked by the lines in the wax descended upon the surface in the rear of the escarpment and where there retarded by friction, the upper part was carried forward by the general movement of the wax and the result is a curve reaching far to the rear of the escarpment, with a sharp curve passing back much closer to the escarpment and reaching the bottom of the box. Fig. 5 and the anterior portion of the wax in Figs. 7, 8 and 10 (in the latter it is to be noted that the curve is flattened by the unavoidable falling forward of the front of the wax as it cooled in its box).

It was now desired to ascertain what became of the recurved currents under conditions of recurring obstructions and of being carried forward over a plane surface. The first of these questions was answered incidentally in experimenting on the second, and its consideration may be retained till the last.

Experiments 7 to 11 were designed to answer the first question and the results are seen in Figs. 6, 7, 8, 9 and 10.

Experiment 7 was considered a failure because of the great reduction of the internal capacity of box and consequent acceleration of the motion of the wax and the inability of the currents to reach the bottom and become affected by drag. Fig. 6.

Experiment 8. The narrow valley and proximity of the escarpments produced a clogging of the wax and almost total disappearance of the characteristic curve, however enough remains to prove its existence. The lower layer and the second layer show drag respectively after the first and third escarpments, while the upper recurves only at the extremity.

The most important feature of the experiment is shown in the sharp angulation of the recurved portion of the upper line and of the folding upon themselves of the lower with consequent stretching out in a series of detached portions. Fig. 7.

Experiment 9 shows the same destruction of the lower line and a most remarkable elongated folding, also a recurving of the two upper ones as they arch over the last escarpment. Fig. 8. The advanced position of the rear of the upper lines is another evidence of the drag.

Experiment 10 shows identical phenomena with sharply angulated recurve just rising over an escarpment. Fig. 9.

Experiment 11 shows another form of the loops in passing an escarpment and the stretching with consequent approximation of the two ends of the loop caused by the horizontal progression of the wax. Fig. 10.

The effect produced on the loop by progression on a plane surface is clearly exemplified by the basal line in Figs. 7, 8 and 9, and in the loop at the extremity of Fig. 10. The action is to produce a stretching and close refolding of the loops, then a breaking up of the loop into sections. The result is the formation of laminæ, not of great extent themselves but in series of great extent.

It is necessary to again call attention at this point, to the phenomena shown in Experiment 5, Fig. 4*b*. The basal, dirty layer of the wax, upon reaching the summit of a rounded obstruction did not follow down the far side of the obstruction, but was carried forward in a straight line into the body of the wax leaving a portion of the rear of the obstruction untouched.

## RELATION OF THE EXPERIMENTS TO OBSERVED PHENOMENA IN ICE.

While the author was engaged upon these experiments Professor Chamberlin, in his annual address as president of the Geological Society of America (Recent Glacial Studies in Greenland, Bull. Geol. Soc. of Am., Vol. VI, p. 199) reported his observations of the previous summer on the glaciers of Greenland.

His observations tallied to such a remarkable extent with the results obtained in wax by the author that it has seemed important to consider the resemblance.

In comparing the two it must be recognized that the basal layer of dirty wax represents many débris layers and laminæ at the bottom of the ice and the lines above higher series of débris layers and laminæ. The seeming disparity in size of the wax experiments with the glaciers, need not be the cause of any hesitancy in comparing the results. Professor Chamberlin places the maximum limit of dirty ice at 150 feet of the basal part and thinks that it is "chiefly confined to the lower fifty or seventy-five feet." The experiments were supposed to represent only the basal portions of the ice and a ⅞ inch escarpment in a layer 6 inches thick is strictly comparable to an obstruction 10 to 20 feet high in 50 or 100 feet of the basal part of the ice.

In regard to the passage of the ice over low prominences, he says, p. 205, "In meeting obstacles in front, the basal beds have the habit of curving upward, carrying the débris with them." Again, p. 208, "*Behavior of Ice in passing over low Prominences:* Several excellent opportunities for observing the behavior of ice in passing over low embossments were offered. From the front of the embossment there originated laminæ which extended backwards with a graceful, arching curve, much like the profile of a drumlin. A portion of the ice remained between these curving laminations and the upper and rear portions of the embossment. After reaching a point in the rear of the embossment, the laminæ curved downward with increasing rapidity until well in the lee, when they turned about with a more or less sharp curve, or even angle, and ran backward to some point not far in the rear of the embossment, where they ended. The higher laminæ made the longest curves and had the sharpest angles in the lee of the embossment. It appears obvious that the ice in the lee of the embossment moved more slowly than that above; hence the doubling of the laminæ upon themselves. It appeared upon close inspection that some of the inthrust layers described above consisted in reality of very sharply reduplicated laminæ.

It seems, therefore, that this phenomenon grades insensibly into the preceding. A study of the laminæ not associated with embossments showed many signs of doubling upon themselves in a similar way. It appears, then, that there is a gradation from laminæ that simply suffered doubling up to layers that obviously sheared upon each other and produced manifest unconformity and overthrust." Compare the figures of this paper and Chamberlin's, Fig. 4, Pl. IV. Figs. 11 and 12, Pl. VIII.

The above might well serve as a description of the results of the experiments on the passage of wax over escarpments and the effect of drag. It might also serve as well to describe the formation of laminæ in wax, especially when supplemented by the following (p. 204): "The débris layers are not all uniform in their distribution. Often they have much regularity and persistence; often they thin out and disappear within a short distance; more often still they persist for a few rods and are replaced by adjoining layers which come in as these thin out. Thus a belt of layers has much persistence, while the constituent layers are freely entering and vanishing. Lenses of débris occasionally appear among the layers, and a doubling back of the layers upon themselves, giving a lenticular section is not uncommon." Compare this description with Figs. 7–10.

The action of the loops caused by drag in passing obstructions is not discussed by Professor Chamberlin, but Figs. 6, Pl. V, of his article is almost identical in its main features with the anterior part of Figs. 9–10 of the present experiments.

In discussing the origin of the stratification Professor Chamberlin brings forward the hypothesis of the shearing motion between superincumbent layers of ice, citing as proof, the observation of fluting in the interpolated laminæ of débris and the breaking of fallen blocks of ice along definite planes. "But," he says, p. 207, "the best evidence of the verity of shearing between ice-plates lies in the intrusion of the earthy material itself. I was fortunate enough unless I misinterpret, to observe the actual process of intrusion. The best illustration was found on the north side of a short lobe of the great ice-cap designated the

Gable glacier. Just back of the point of observation there was a large embossment of rock, which expressed itself at the surface of the ice by a beautiful half dome, like the Half Dome of the Yosemite. The other half of the dome was cut away, revealing the operations at the base within Here it was observed that the trains of débris, apparently rubbed from the surface of the embossment, were being carried out almost horizontally into the ice in its lee. Some of these were short, while others extended several rods into the ice. They were somewhat inclined downward, but the slope of the glacier being greater, they passed out into the body instead of following the base of the ice. At one point the overthrust reached such a degree as to carry the earthy layers obliquely almost across the thickness of the glacier, producing a pronounced unconformity. (Figs 9 and 10, Pl. VII., Chamberlin.) . . . The mode of operation seems to be this: When the ice is forced over a prominence it settles down a little in its lee, and is then protected somewhat from the thrust of the ice behind; the next ice that passes over, being prevented by the former portion from settling down at once, is thrust forward over it. To some extent this is accomplished by the bending and doubling of the layers, and to some extent by distinct shearing. At length, however, the first layer is compelled by the general friction to move somewhat forward, and in time to join the common moving mass, carrying the overthrust layer of débris between it and the ice layer above. The way is then open for a repetition of the process. This picture of the behavior of the ice is quite radically different from that entertained by the viscous hypothesis, in which the ice is supposed to flow down the lee side of a prominence, as if it were a liquid. The motive power here seems not so much gravitation pulling a fluent body forward as the thrust of a rigid body by a force in the rear."

The descriptive part of this would answer, especially in the first case cited, as a perfect description of the results of Experiment 5, Fig. 4*b*. But the explanation cannot be accepted as applying to the results produced in the experiments because they were obtained in warm wax, a viscous body, incapable of shear along definite planes, at least under the very slow movement to which it was subjected. The phenomena may be explained fully as well by recourse to the drag of the bottom. The lower layers of the ice were retarded while the upper flowed over the obstruction and onto its rear face. It was there protected from further push as well as retarded, and the lower layers having meanwhile backed up against the front of the escarpment, overflowed and passed out into the ice in a horizontal line resulting from a stretching of the viscous body as seen in all the experiments. It is to be noted that while the general depression of a viscous mass is caused by the pull of gravitation, the motion at any one point is due to the motion of the mass behind it and is largely a shove, rather than a pull.

The result arrived at by Professor Chamberlin from his observations was that the ice was rigid in great part and moved along planes of shear between well individualized layers. He says, p. 212: "My observations seems adverse to anything which can be properly termed viscous fluency." And again, p. 213: "Everywhere the aspect of the ice was that of rigidity rather than viscous fluency. The rigidity, to be sure, did not prevent contortions and foldings of the laminations, such as take place in the crystalline rocks, but faulting and vein structures also occur, and there seems no more occasion to assume viscosity in the one case than in the other. Even if a certain measure of viscosity be admitted, it does not follow that viscosity was an essential agent in motion."

From the peculiarly perfect manner in which the results of the experiments in wax and the observed phenomena in the ice parallel each other, it seems that the obvervations of Professor Chamberlin may be interpreted in a slightly different manner and that his "certain measure of viscosity" may have afforded a very considerable part in the mechanics of the ice bottom. At least some method of movement must be admitted which will produce currents such as would be produced in a viscous body under like conditions. And this motion, it seems to me, cannot be produced by shearing alone.

RELATION OF THE CURRENTS TO THE SUBGLACIAL TOPOGRAPHY.

It seems from the above to be fairly well proven that differential currents, vertical and horizontal, do exist in the bottom portion of the ice, and recognizing their existence it is possible to attempt the explanation of certain features of subglacial topography. It can be shown that great drumlin-covered drift deposits lie in the lee of escarpments, or other irregularities of the surface, composed of hard rocks, over which the ice has just passed.

The upward currents produced at the front of an escarpment and extending over it in an arch have already been pointed out. The active portion of the ice bottom is undoubtedly in the region of the descending currents and the portion below the arch must be one of very slight activity. In speaking of drumlins Professor Chamberlin mentions this curve and says, p. 216: "I suspect that this is the true drumlinoid curve and that it represents the balance or the accommodation between the force of the overthrust of the over-riding ice on the one side and the friction and resistance of the ice and débris against the embossment on the other. I suspect that the progressive tendency in such a case is toward the accumulation of débris below the drumlinoid line, which was apparently a line of shearing, and that the result of such an accumulation would be a drumlin."

This idea was also entertained by the author and applied to the formation not only of drumlins but to the larger deposits of drift. It will be easily seen that in passing large escarpments the base of the proportionally large arch currents would be thrown into minor arching currents by minor irregularities on the escarpment. The large arches would have under them regions of relatively smaller ice motion with consequent deposition of débris; the point of descent of the current would determine regions of erosion. This action will be clearly seen by reference to the diagram, Fig. 11. A line was taken from Sodus Bay on Lake Ontario to a few miles south of Ithaca, N. Y., taking in the deepest part of Cayuga Lake. Upon this line is projected the extremes of elevation in surface a few miles to each side of it.

It will be seen how currents might rise from the bottom of Lake Ontario passing in an arch over the drift-covered region south of the lake and then descend to aid in the excavation of the bed of Cayuga Lake.

The minor irregularities of the Medina conglomerate, bordering this portion of the shore of Lake Ontario, produced minor and differential currents in bottom of the great arch and formed the drumlins. This diagram would apply with slight modifications of detail to a large majority of the known drumlin regions.

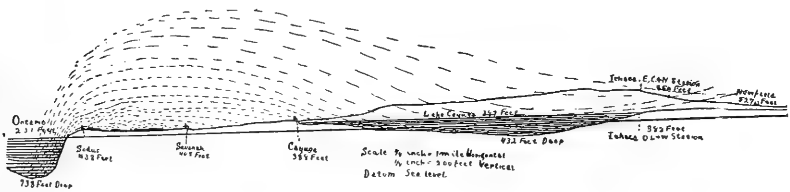



FIG. 11.

The formation of the elongated drumlins may find an explanation in the stretching out of the débris into the ice from the top of an obstruction. If toward the end of the glaciation the drift should become of sufficient thickness, it might in spots clog up under the ice and become sufficiently resistant to cause upward currents in the ice. Its face would be moulded to its steeper form by the minor currents which creep up the face of an escarpment or obstruction (Expt. 2, Fig. 2), and are perhaps responsible for the characteristic steeper slope of the face of all subglacial erosion forms. The currents of inthrust débris would arise from the heaps of débris and extend forward into the ice a short distance, while still under the arch of the currents they would gradually sink and build up the rear of the drumlin into the elongated form. The elongation and building up of the drumlin would tend to keep the currents from descending and would lengthen the arch till drumlins two miles long might be formed as noted in New York.

One other action must be noticed, namely, the moulding power of the ice currents upon a thick sheet of till. It has been claimed by various authors that the formation of drumlins was due to the erosion of a thick sheet of till by differential currents in the ice bottom. If this hypothesis is a true one, the source of the currents is readily found in the passage of ice over escarpments and other irregularities. It seems that the presence of the arched currents with regions of relatively inactive ice below over drumlin regions must give the weight of evidence largely to the theory of deposition, though the points of descent of the currents were points of erosion, in all probability, and these must have had some influence in determining the exact location and form of the drumlins.

E. C. Case.

Geological Laboratory, Cornell University,
May, 1895.

# ABSAROKITE–SHOSHONITE–BANAKITE SERIES.[1]

In the region of the Yellowstone National Park there are igneous rocks of a peculiar type which are associated with the normal andesites and basalts of the region, but which differ from them mineralogically and chemically, and deserves a special classification. The study of these rocks has been carried on in connection with that of all of the igneous rocks of this region, and the present paper is an abstract of a chapter prepared for the report of work done in the Yellowstone National Park by the division of the U. S. Geological Survey under the charge of Mr. Arnold Hague.

The rocks mentioned occur in a number of separate localities within this region, where it is apparent that their generic relations are with normal basalts and andesites, and in each locality the varieties having the peculiarities in question are genetically related to one another by differentiation. But all of these peculiar varieties in the region are not closely related to one another, for they are separate offshoots from distinct reservoirs of magma, and were probably produced by similar processes of differentiation. For purposes of systematic description they may be classified together in a series having certain chemical and mineralogical characteristics. They thus form classes of similar rocks (*i. e.*, like phases of differentiation), that belong to separate, but similar, families of rocks (*i. e.*, groups or series of genetically, hence generically, related differentiation products).

For the most part they are basaltic-looking rocks, occurring as lava flows and dikes, and less often as part of the basic volcanic breccia which constitutes the major portion of the volcanic mountains of the Absaroka Range. They are quite subordinate

[1] Published by permission of the Director of the U. S. Geological Survey.

in amount to the basalts and andesites. As surficial flows they are basaltic in character, being dark colored and heavy, with olivine among the phenocrysts in most cases. They are massive and compact or vesicular. They are porphyritic in some cases, but not noticeably so in others. They generally exhibit a semi-waxy luster that suggests the presence of nepheline, which however is not present. The luster is due to the alkali-feldspars in the groundmass. They are often dull greenish black owing to the serpentinization of olivine. As dikes they are basaltic in some cases, and phonolitic to trachytic in others, being gray in various shades, and having a somewhat waxy luster, due to alkali-feldspars. They are porphyritic or not in different cases, and range from aphanitic to phanerocrystalline.

They present quite a range of composition within limits, and form a series of varieties connected by gradual transitions. They could not be embraced by any one definition and must be divided into several classes.

The chief characteristics of the most basic class are the presence of abundant phenocrysts of olivine and augite, and the absence of phenocrysts of feldspar. The groundmass may be anything from a dark glass to an almost phanerocrystalline, light gray mass. It is oftener aphanitic and dark greenish gray. The phenocrysts are large and pronounced in many cases, but are quite small in others. Chemically they are low in silica, from 46 to 52 per cent.; low in alumina, from 9 to 12 per cent.; high in magnesia, from 8 to 13 per cent.; moderately high in alkalies, with potash higher than soda, except in one case. The molecular ratio of the alkalies to silica is .08 and .09. (See Table I). After the crystallization of abundant phenocrysts of olivine and augite the remainder of the magma, owing to low alumina and relatively high alkalies was so constituted that alkali-feldspathic minerals might crystallize out, which they did or not according to the conditions under which solidification took place.

The principal characteristics of the second class are the presence of phenocrysts of labradorite, augite and olivine, in a groundmass that is usually dark greenish gray, with a semi-waxy luster; but which is sometimes glassy, or phanerocrystalline. The varieties range from those rich in olivine and augite, which with decreasing labradorite grade into rocks of the first class, to varieties poor in olivine and augite. Chemically they range from 50 to 56 per cent. of silica. Alumina is moderate to high, from 17 to 19.7 per cent. Lime and magnesia are moderate to low, the former from 8 to 4.3 per cent., the latter from 4.4 to 2.5 per cent. Alkalies are moderately high with potash comparatively high for rocks of this region with like amounts of silica; potash from 3.4 to 4.4 per cent.; soda from 3 to 3.9 per cent. The molecular ratio of alkalies to silica is .10 and .11. After the crystallization of phenocrysts of labradorite, olivine and augite, the remainder of the magma was rich in alkali-feldspathic material, which shows itself in the groundmass according to the circumstances of solidification.

Rocks corresponding chemically to both of these classes occur without megascopic phenocrysts, and in various phases of crystallization, consequently they differ from them not only in microstructure but in the minerals developed. They occur as lava flows and as dikes, but no special characteristics can be connected with either mode of occurrence, except that the more highly crystallized forms are found as dikes. Not all the dikes, however, are more crystalline than all the lava flows.

Rocks of the third class have been found mostly in dikes. These rocks are highly feldspathic, with smaller amount of ferromagesian minerals, chiefly biotite with subordinate augite. The phenocrysts are labradorite in a groundmass of alkali-feldspars. Chemically they have from 51 to 61 per cent. of silica; 16.7 to 19.6 alumina; 3.5 to 6 per cent. of lime; 1 to 4 per cent. of magnesia; 3.8 to 4.5 per cent. of soda, and 4.4 to 5.7 per cent. of potash. The ratio of alkalies to silica is .13 and .14. Since much of the lime and soda go into the phenocrysts of labradorite, the feldspathic groundmass is rich in potash, and is largely orthoclase. The rocks stand at the end of the series, where labradorite becomes the prevailing phenocryst, and augite and olivine are more or less completely replaced by biotite.

The division of the series into three parts is for convenience. The classes will be described in the order just given under the names: *Absarokite*, *Shoshonite* and *Banakite*.

ABSAROKITE.

All of the rocks here classed as *absarokites* carry abundant phenocrysts of olivine and augite, except two that are included with them on grounds of chemical identity. They occur in the Absaroka range, and in other parts of the Yellowstone Park; at the north base of Sepulchre Mountain; upon Mirror Plateau; within the Crandall volcano; at Signal Point, Yellowstone Lake; at Two Ocean Pass, and in Ishawooa Canyon, and elsewhere. The chemical composition of five of these rocks is shown by the following analysis. Table I.[1]

TABLE I. CHEMICAL ANALYSES OF ABSAROKITES, YELLOWSTONE NATIONAL PARK AND VICINITY.

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $SiO_2$ | 47.28 | 48.95 | 48.36 | 51.76 | 49.71 |
| $TiO_2$ | .88 | .49 | 1.18 | .47 | 1.57 |
| $Al_2O_3$ | 11.56 | 12.98 | 12.42 | 12.36 | 13.30 |
| $Fe_2O_3$ | 3.52 | 3.63 | 5.25 | 4.88 | 4.41 |
| FeO | 5.71 | 4.68 | 2.48 | 4.60 | 3.37 |
| MnO | .13 | .13 | .13 | .11 | .17 |
| MgO | 13.17 | 11.73 | 9.36 | 9.57 | 7.96 |
| CaO | 9.20 | 7.66 | 8.65 | 7.14 | 8.03 |
| BaO | .... | .... | .29 | .... | .46 |
| $Na_2O$ | 2.89–2.73 | 2.31 | 1.46 | 1.99 | 1.49 |
| $K_2O$ | 2.22–2.17 | 3.96 | 3.97 | 3.83 | 4.81 |
| $P_2O_5$ | .59 | .67 | .84 | .56 | .66 |
| Cl | .18 | .... | .... | .... | .... |
| $H_2O$ | 2.96 | 3.16 | 5.54 | 3.05 | 4.07 |
| | 100.08 | 100.35 | 99.93 | 100.32 | 100.01 |
| Less O for Cl | .04 | | | | |
| | 100.04 | | | | |

[1] Most of the analyses cited in this paper have already been published in the paper by the present writer on the Origin of Igneous Rocks. Phil. Soc. Washington. Bull. Vol. XII. pp. 89–214. Washington, 1892.

1. Leucite-absarokite, Ishawooa Canyon, Wyoming—analyzed by J. E. Whitfield.
2. Absarokite, dike at head of Lamar River—analyzed by L. G. Eakins.
3. Absarokite, dike south of Clark's Fork River—analyzed by L. G. Eakins.
4. Absarokite, lava flow, head of Raven Creek—analyzed by L. G. Eakins.
5. Absarokite, dike, divide east of Cache Creek—analyzed by L. G. Eakins.

The five analyses are arranged according to decreasing percentage of magnesia, the range being a little more than 5 per cent. The alumina increases, the range being less than 2 per cent. Potash increases through a range of 2.6 per cent., while soda and lime have a still smaller range. The second, third and fourth analyses are closely alike. The first and fifth are not so much alike that they might not be considered separately; the chief differences being in magnesia and alkalies. But they are related in other respects. They all exhibit considerable loss upon ignition, corresponding to the amount of hydration due to alteration, or to the presence of zeolitic minerals.

As already remarked the rocks differ somewhat in the mineral composition of the groundmass, as well as in its microstructure. That with the coarsest grain is the one whose chemical composition is given by the first analysis. It was not found in place, so that its exact mode of occurrence is not known, but it is probably an intrusive mass or dike in Ishawooa Canyon, Wyoming. It has already been described by Mr. Hague.[1] It consists of abundant phenocrysts of olivine and augite, $3^{mm}$ in diameter, and of a subordinate amount of gray crystalline groundmass. In thin section the olivine is colorless and free from inclusions. The augite is pale green, with high extinction angle, reaching 42°. It encloses some olivine and magnetite. The form of these phenocrysts is only partially idiomorphic, the outline being jagged in some cases; the reëntrant angles being occupied by small crystals of orthoclase, whose formation must have been at least contemporaneous with the crystallization of the margins of the olivine and augite. The groundmass consists of crystals of orthoclase and leucite, which are in part idiomorphic, although the mass is holo-

[1] HAGUE, A. Notes on the occurrence of a leucite rock in the Absaroka Range, Wyoming Territory, Am. Jour. Sci., Vol. XXXVIII., July, 1889.

crystalline, except for occasional possible remnants of glass base. There are also small irregularly shaped crystals of augite and olivine, besides magnetite and much apatite in long, slender needles. Orthoclase and leucite are not uniformly mingled, but are clustered in groups. The orthoclase crystals are rectangular prisms, twinned according to the Carlsbad law. Very rarely they contain minute cores of lime-soda-feldspar, with symmetrical extinction angles of 30°, corresponding to labradorite. The leucites are partly idiomorphic, partly allotriomorphic. In places they are decomposed to a zeolitic mineral. The other constituents of the rock are very fresh. Owing to the small amount of material collected no separations or partial analyses were attempted.

The rock, whose chemical composition is given by analysis 2, occurs as a four-foot dike on the divide between Lamar River and Crandall Creek. It is dark colored and aphanitic, with abundant phenocrysts of augite, 5 to $10^{mm}$ in diameter, and smaller ones of olivine. On the sides of the dike the rock is glassy and black. The body of the dike is holocrystalline and very fine grained when seen in thin section. The groundmass consists of indistinctly outlined, lath-shaped feldspars with low extinction angles, there is also an indistinct feldspathic mineral as cement, which is clouded. The lath-shaped feldspars appear to be in part, at least, orthoclase with minute prismatic cores of lime-soda-feldspars. Nothing resembling leucite is present. The feldspathic matrix is crowded with microscopic crystals of augite, magnetite and brown biotite in thin tablets. The groundmass of the glassy margin of the dike is brown glass with microlites of augite and some of lime-soda-feldspar. The augite phenocrysts are light green in thin section and are filled with irregularly shaped inclusions of crystalline groundmass containing rods of ilmenite. There are also inclusions of small olivines and magnetite. The olivine phenocrysts are idiomorphic and quite fresh, with small inclusions of magnetite and glass, and occasionally bays of groundmass.

The glassy groundmass of the margin of the dike is unlike the groundmass of the central part in mineral composition. Biotite is not present, and the only feldspars are microlites of plagioclase, which may correspond to the prismatic cores in the small orthoclases of the central part of the dike.

When compared with the leucite-absarokite from Ishawooa Canyon it is found that the phenocrysts of olivine and augite are not so abundant as in that rock, while there is much more augite in the groundmass, besides abundant biotite. The microscopic feldspars are not so large and distinct, and leucite is wanting. Chemically the rock just described is richer in potash, with about the same soda. Alumina is slightly higher; and magnesia and lime slightly lower. Silica is a little higher. The high percentage of water indicates a hydrous silicate in the groundmass.

The rock, whose chemical composition is shown by analysis 3, forms a 3-foot dike on the high ridge south of Clark's Fork River, southeast of Index Peak. The rock corresponding to analysis 4 forms a surficial lava flow east of the head of Raven Creek on Mirror Plateau. Chemically they are almost identical, and nearly the same as the dike rock from the divide between Lamar River and Crandall Creek. They have slightly less magnesia, and the lava flow has 3.4 per cent. more silica than the dike rock. The dike rock is dark greenish gray, aphanitic, with small megascopic phenocrysts of augite, and occasional large crystals of quartz with augite shells. In thin section the few megascopic augites resemble those in the rock last described. All the other constituents may be considered as parts of the holocrystalline groundmass. They are abundant pale green augite, brown biotite and magnetite with a subordinate amount of feldspathic matrix. There are larger augites, colorless at the center and green at the margin, besides many small serpentinized olivines. The feldspar is partly lath-shaped orthoclase with prismatic cores of lime-soda-feldspars. They are often in radiating groups. There is also much cloudy microcryptocrystalline material with no definite form, except a frequent approach to the outline of an isometric mineral. These are often darker colored at the center, and suggest altered leucites. The large loss upon ignition and the presence of leucite in similar rocks in this region render this highly probable. Some parts of the rock contain what is undoubtedly analcite. The occasional large quartz crystals have the character of primary crystals. Their possible association with leucite is indicated, but no leucite has been actually observed in the rock.

This rock resembles the dike rock from the divide at the head of Lamar River in the general character of the groundmass, except that the phenocrysts of olivine and augite are almost microscopic, and may be considered as part of the groundmass. The ferromagnesian minerals are about the same in each, and the feldspathic components are obscure, with indications of alkaline character.

The rock of the lava flow at the head of Raven Creek is dark gray with abundant small megascopic phenocrysts of olivine and augite. In thin section these minerals resemble those in the rocks already described. The groundmass consists of small rectangular prisms of orthoclase, sometimes with minute cores of prismatic labradorite; besides abundant microscopic crystals of augite and magnetite, there is a little serpentine. The feldspars are distinctly crystallized and their character as orthoclase is unquestionable. They resemble the orthoclase in the leucite-absarokite from Ishawooa Canyon. No leucite, however, was observed in this rock. Only a very small part of the groundmass is lime-soda-feldspar. There is no biotite, and no analcite. Apatite occurs in delicate needles. The absence of biotite may be correlated with more pronounced orthoclase and abundant olivine; and the absence of leucite accords with the higher percentage of silica.

The rock, whose composition is shown by analysis 5, occurs as a narrow dike on the divide east of Cache Creek. It is brownish gray and aphanitic, without phenocrysts, but having minute brown pseudomorphs, presumably after olivine. There are occasional rounded grains of dark colored, crackled quartz, surrounded by a thin, green shell. In thin section the rock is fine grained and holocrystalline, consisting of thin prisms of feldspar, frequently grouped in fan-like clusters. They are not distinctly striated, and are probably orthoclase. Others are lime-soda-feldspars, with low extinction angles, and some are irregularly bounded and are obscure. This matrix is crowded with idiomorphic crystals of pale green augite, dark brown biotite and magnetite. Some of the biotite crystals are long, narrow plates, resembling prisms of hornblende, for which mineral they were at first mistaken. There is considerable serpentine scattered through the rock.

Mineralogically this rock is very similar to the dike rock south of Clarks Fork River. Chemically, it is slightly higher in alumina and potash and lower in magnesia and lime. The high loss on ignition is probably due in this case to the serpentinization of the olivine.

There are other rocks of this class in the region, but they will not be described here. Transitional varieties between absarokite and normal basalts occur, as well as transitions to shoshonite.

SHOSHONITE.

The rocks classed as shoshonites are more numerous than the absarokites, and embrace a somewhat wider range of composition. They occupy the middle ground, as it were, in the series and pass by transitional varieties into absarokite, banakite and into normal basalt. They occur associated with absarokite, and consequently at the same localities: on the Lamar River, Mirror Plateau, Crandall Basin, at various localities in the Absaroka Range, and at Two Ocean Pass, one of the divides at the head of Shoshone River. From this locality the rock was first collected and identified as an orthoclase-bearing basalt. Shoshonites also occur in the northwestern portion of the Yellowstone Park. Most of these rocks are characterized by prominent phenocrysts of labradorite, together with those of augite and olivine. But some are without megascopic phenocrysts and are correlated with the porphyritic forms on chemical as well as mineralogical grounds. A small number are leucite-bearing.

The chemical composition of five of these rocks is given in Table II. The analyses are arranged so as to bring those most alike by the side of one another. The range of silica is 6 per cent. Alumina is moderately high. Magnesia, with a range of less than 2 per cent., is rather low for basic rocks. Lime, with a range of less than 4 per cent. is moderate. Soda is almost constant; and potash is relatively high, with a range of only 1 per cent. The loss upon ignition is comparatively high for all the rocks analyzed. As already mentioned, the mineralogical variation is from an abundance of olivine and augite to a paucity of them, with inverse variation in the feldspars. This accords with the variations in the chemical composition.

TABLE II. CHEMICAL ANALYSES OF SHOSHONITES, YELLOWSTONE NATIONAL PARK AND VICINITY.

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $SiO_2$ | 50.06 | 53.49 | 52.49 | 54.86 | 56.05 |
| $TiO_2$ | .51 | .71 | .81 | .69 | .98 |
| $Al_2O_3$ | 17.00 | 17.19 | 17.89 | 17.28 | 19.70 |
| $Fe_2O_3$ | 2.96 | 4.73 | 5.76 | 4.08 | 3.74 |
| FeO | 5.42 | 3.25 | 2.08 | 2.28 | 2.32 |
| MnO | .14 | .14 | .09 | .19 | tr. |
| MgO | 3.61 | 4.42 | 3.49 | 4.19 | 2.51 |
| CaO | 8.14 | 6.34 | 7.01 | 5.42 | 4.34 |
| BaO | .. | .06 | .30 | .37 | .. |
| $Na_2O$ | 3.53 | 3.23 | 3.18 | 3.94 | 3.29 |
| $K_2O$ | 3.40 | 3.86 | 3.73 | 3.96 | 4.44 |
| $P_2O_5$ | .66 | .43 | .55 | .48 | .66 |
| $H_2O$ | 4.85 | 2.17 | 2.63 | 2.16 | 1.86 |
| | 100.28 | 10.002 | 100.01 | 99.90 | 100.14 |

1. Shoshonite, lava sheet, Lamar River, south of Bison Peak; analyzed by L. G. Eakins.
2. Shoshonite, lava sheet, S. E. fork of Beaverdam Creek; analyzed by L. G. Eakins.
3. Leucite (?) -shoshonite, lava sheet, mountain east of Pyramid Peak; analyzed by L. G. Eakins.
4. Olivine-free shoshonite, dike N. E. of Indian Peak; analyzed by L. G. Eakins.
5. Shoshonite, lava sheet, Two Ocean Pass; analyzed by J. E. Whitfield.

The rock of analysis 1 is a surficial lava on Lamar River, south of Bison Peak. It is dark gray, with a waxy luster, and has abundant phenocrysts of labradorite, augite and olivine; also some small amygdules of zeolite and calcite. In thin section it is holocrystalline, the groundmass consisting of lath-shaped lime-soda-feldspar and considerable orthoclase in zones surrounding the plagioclase microlites, and also in twinned prisms. There are besides augite, magnetite and a little serpentine. The phenocrysts of labradorite are twinned with very narrow lamellæ. Those of augite and olivine are like the phenocrysts of these minerals in absarokite.

The rock of analysis 2 forms a massive lava sheet on the southeast fork of Beaverdam Creek. It is dark purplish gray, with numerous phenocrysts of labradorite, augite and serpentinized olivine. A lighter colored variety carries porphyritical biotite and amygdules of zeolite. In thin section it is holocrystalline, and resembles the rock just described very closely, except that the olivine is serpentinized. The groundmass is similar to that of the former, and there is considerable orthoclase. In the variety with biotite there are cloudy patches of an isotropic mineral, which may be analcite. The lava sheet immediately overlying this one is similar to it in general appearance, but contains leucite, and is somewhat more alkaline (analysis 5, Table III), and will be described in connection with banakite.

The rock of analysis 3 is a surficial lava flow occurrring on the top of the table mountain east of Pyramid Peak. In general appearance it resembles the shoshonite from Lamar River south of Bison Peak (analysis 1), but the phenocrysts are fewer and smaller. The rock is holocrystalline and very fine-grained, with an abundance of microlites of augite and magnetite. The microscopic feldspars are lath-shaped crystals and allotriomorphic grains with low double-refraction. There are spots where minute grains of augite and magnetite are clustered together and are inclosed in a yellowish substance which is almost isotropic, and has the outline of leucite. These impure leucites are scattered through the rock and are not very numerous. They are very minute and cannot be more definitely identified. The groundmass carries irregular patches of light brown mica, small phenocrysts of augite and of serpentinized olivine, and still fewer larger crystals of augite and olivine, but none of labradorite. The rock is a leucite-bearing modification of shoshonite magma, without noticeable difference in the chemical composition.

The rock of analysis 4 forms a narrow dike on the ridge northeast of Indian Peak, Crandall Basin. It is gray and aphanitic, with abundant small phenocrysts of augite and lime-soda-feldspar with rather low extinction angles. It is very fine grained and holocrystalline, consisting of indistinctly outlined feldspar microlites, in part alkaline with low double-refraction and no polysynthetic twinning. There is a subordinate amount of biotite in idiomorphic microlites, besides prisms of augite and grains of magnetite. Olivine is absent, in which respect it differs from other varieties of these rocks. Chemically it is very similar to the shoshonite from Beaverdam Creek (analysis 2).

The rock of analysis 5 is the uppermost of five lava sheets that overlie one another at Two Ocean Pass. It is dark gray, with a waxy luster, and carries scattered phenocrysts of feldspar and serpentinized olivine. In thin section the rock is seen to be holocrystalline; the groundmass consisting of orthoclase in idiomorphic and also in allotriomorphic crystals, with much magnetite and augite, and some chlorite or serpentine, besides red-brown biotite, and hairlike needles of apatite. There are also comparatively large, but microscopic, dusted apatites among the phenocrysts, showing this mineral in two generations, or periods of crystallization. Some of these apatites are enclosed in olivine, which is completely serpentinized. The feldspar phenocrysts are labradorite, with highly developed polysynthetic twinning. In the rock of the second sheet at this place the feldspar phenocrysts are labradorite-bytownite, being decidedly basic with high extinction angles, and relatively strong double-refraction. The groundmass is like that of the overlying shoshonite, just described, except that the orthoclase crystals sometimes have a small nucleus of lime-soda-feldspar. Another one of these five sheets of lava is shoshonite like the last two mentioned.

BANAKITE.

The most feldspathic rocks of this series, which occur as dikes associated with dikes of shoshonite and absarokite, are not so numerous, although more of them have been analyzed. They occur in Crandall Basin, in Ishawooa Canyon and near the head of Stinkingwater River. A leucite-bearing variety forms a lava sheet near Beaverdam Creek. Their chemical composition is shown by the analyses in Table III.

TABLE III. CHEMICAL ANALYSES OF BANAKITES. YELLOWSTONE NATIONAL PARK AND VICINITY.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 51.82 | 52.63 | 51.46 | 52.33 | 52.93 | 57.29 | 60.89 |
| $TiO_2$ | .71 | .81 | .83 | .71 | .72 | .72 | .49 |
| $Al_2O_3$ | 16.75 | 16.87 | 18.32 | 18.70 | 19.67 | 18.45 | 17.14 |
| $Fe_2O_3$ | 4.56 | 4.52 | 4.61 | 4.95 | 3.07 | 4.38 | 3.32 |
| FeO | 3.36 | 3.11 | 2.71 | 1.83 | 3.50 | 1.20 | .95 |
| MnO | .23 | .10 | .17 | .03 | .15 | tr. | .09 |
| MgO | 4.03 | 3.69 | 2.91 | 2.69 | 2.88 | 2.08 | 1.16 |
| CaO | 4.94 | 4.77 | 6.03 | 4.71 | 4.69 | 3.57 | 3.58 |
| BaO | .26 | .29 | .... | .... | .21 | .... | .... |
| $Na_2O$ | 3.91 | 3.86 | 4.11 | 4.51 | 4.20 | 4.43 | 4.54 |
| $K_2O$ | 5.02 | 5.17 | 4.48 | 5.45 | 4.75 | 5.43 | 5.71 |
| $P_2O_5$ | .52 | .63 | .86 | .81 | .59 | .46 | .27 |
| NiO | .... | .... | .... | .14 | .... | .12 | .19 |
| $H_2O$ | 3.97 | 3.65 | 3.89 | 3.45 | 2.73 | 2.18 | 1.61 |
| | 100.08 | 100.10 | 100.38 | 100.31 | 100.09 | 100.31 | 99.94 |

1. Banakite, dike, head of Lamar River, analyzed by L. G. Eakins.
2. Banakite, dike, Hoodoo Mountain, analyzed by L. G. Eakins.
3. Banakite, dike, Ishawooa Canyon, analyzed by L. G. Eakins.
4. Banakite, dike, near head of Stinkingwater River, analyzed by W. H. Melville.
5. Leucite-banakite, lava sheet, southeast fork of Beaverdam Creek, analyzed by L. G. Eakins.
6. Quartz-banakite, dike, near head of Stinkingwater River, analyzed by W. H. Melville.
7. Quartz-banakite, dike, near head of Stinkingwater River, analyzed by W. H. Melville.

The rocks of analyses 1 and 2 form dikes; the first occurring on the divide between Lamar River and Crandall Creek, and the second on the south slope of Hoodoo Mountain. The two dikes trend in the same direction and are possibly one continuous body. The rocks are alike chemically and mineralogically and may be described together. They are light gray and aphanitic, with a waxy luster. There are prominent phenocrysts of augite and rusted spots of serpentinized olivine, but none of feldspar. In the rock from Hoodoo Mountain there are amygdules of white stellate zeolite. In thin section the rocks are seen to be holocrystalline with more feldspar than ferromagnesian minerals. The feldspars are in part lath-shaped, in part tabular. They are simple twins, and are orthoclase with kernels of plagioclase which is mostly altered, the centers of the crystals being decomposed in many cases. There is considerable serpentine scattered through the rock. The ferromagnesian minerals are augite, biotite, magnetite, with some ilmenite in rod-like shapes. Apatite occurs in needles. There is considerable analcite, which partly occupies former cavities or cracks, and partly has outlines suggesting former isometric minerals. The dike on the divide at the head of Lamar River is immediately alongside of the dike of absarokite whose chemical composition is given by analysis 2 of Table I.

The rock of analysis 3 is quite similar to those just described but is still more feldspathic. It forms a dike in the Ishawooa Canyon. It is dark gray and waxy looking with tabular phenocrysts of feldspar and many smaller ones. It is holocrystalline, and consists of abundant lath-shaped twins of orthoclase having a rectangular kernel of labradorite, whose symmetrical extinction angles correspond to a composition of $An_3\ Ab_2$. There is an isotropic cement between the feldspars which may be analcite or sodalite. Biotite and augite are abundant in small crystals, besides magnetite and a little serpentine, which appears to have been derived from small olivines. The phenocrysts are labrodorite ($An_2\ Ab_3$), some of which have borders of orthoclase. Sodalite is possibly present among the phenocrysts.

The rock of analysis 4 is closely related to the last. It forms a dike near the head of Stinkingwater River. It carries more phenocrysts of serpentinized olivine, and is coarser grained, though still microcrystalline. The feldspars are more altered and less distinct. The mineral composition is like the last rock described, but a few of the augites are bright green, indicating an approach to aegerite-augite.

The rock of analysis 5 is a leucite-bearing variety of banakite, already mentioned as forming a massive surficial lava flow immediately overlying the shoshonite whose chemical composition is given by analysis 2 of Table II., and which occurs on the southeast fork of Beaverdam Creek. Its chemical composition is but slightly different from that of the rock last described (analysis 4). The rock is dark gray with a somewhat waxy luster. It carries small phenocrysts of feldspar, serpentinized olivine and a few of augite. It is holocrystalline with a groundmass of microscopic leucites and unstriated feldspars which appear to be orthoclase, but may be plagioclase with low angle of extinction. There are also microscopic augites and magnetite, and some serpentine, besides a few patches of light brown mica. The phenocrysts are labradorite, serpentinized olivine and fewer augites, magnetites and stout apatites. The crystals of leucite have the characteristic form and inclusions, and in places are somewhat altered. This rock grades into denser, finer grained forms, and also into vesicular forms, which have the same mineral composition as the more crystalline part of the mass. Mineralogically the rock is more suggestive of shoshonite than of banakite, owing to the paucity of biotite and more numerous olivines. But the amount of ferromagnesian minerals is smaller than in shoshonite, and the proportion of alkaline-feldspathic minerals greater, which corresponds to the chemical composition.

The rocks of analyses 6 and 7 belong to this series both mineralogically and chemically, but are somewhat more siliceous, having 5 to 9 per cent. more silica. They might properly be given specific names, but at present we prefer to class them with banakite, under the name of *quartz-banakite*, the amount of quartz however being very small.

The two rocks analyzed are closely alike in alkalies and lime, but the first one is lower in silica and slightly higher in alumina, iron oxide and magnesia. They differ somewhat in mineral composition, though both are characterized by abundant feldspar and biotite.

The first one (analysis 6) is a gray rock, distinctly crystalline with a few megascopic crystals of feldspar and mica. It is holocrystalline, and is composed of lath-shaped, rectangular and allotriomorphic feldspars, with considerable brown biotite, besides magnetite and a little augite, partly decomposed. There is a very little quartz and calcite. The central portion of the crystals of feldspar is lime-soda-feldspar, in some cases labradorite. The marginal portion is orthoclase which forms a considerable part of the crystal, but is subordinate in amount to the plagioclase.

The second rock (analysis 7) is light-gray with numerous small tabular feldspars and some large ones, besides a few phenocrysts of biotite. The rock is holocrystalline and nearly panidiomorphic, the feldspars of the groundmass being in small, rectangular to lath-shaped crystals with fluidal arrangement. The groundmass also contains a small amount of biotite, very little magnetite and augite, and some colorless apatite. The feldspar phenocrysts are labradorite, while the feldspar of the groundmass is mainly orthoclase with kernels of fresh feldspar that has the optical characters of oligoclase. There is very little quartz and a little chlorite or serpentine.

The mineralogical analogy between banakite and shoshonite is chiefly in the association of phenocrysts of labradorite with microlites of orthoclase. Biotite and augite occur in some rocks of both classes, while olivine is present in one variety of banakite, and is common to most shoshonites. These banakites are not properly minettes on account of the prominence of labradorite, and they differ from kersantites by the presence of orthoclase in the groundmass. They bear the same relation to kersantite that shoshonite bears to normal basalt. They are the highly feldspathic modifications of shoshonite magma, and are complementary to absarokite, which represents the least feldspathic modification of the same magma.

A comparison of the chemical analyses of the rocks of this series, besides making evident the relationships already noted, also shows what mineralogical differences may obtain for rocks of nearly the same chemical composition. Some of these differences have already been described in the case of the leucite-bearing varieties. Other differences may be mentioned. Comparing the shoshonite lava flow from the south base of Bison Peak (analysis 1, Table II.) with the banakite dike rock from Ishawooa Canyon (analysis 3, Table III.), we find in the first, abundant phenocrysts of labradorite, augite, and olivine; while in the second, numerous phenocrysts of labradorite, but few and small ones of augite and olivine. The groundmass of the first shows much less orthoclase than that of the second, and no biotite, which abounds in the second. The latter contains what is probably analcite. The shoshonite lava flow from the southeast fork of Beaverdam Creek (analysis 2, Table II.), and the shoshonite dike rock from the ridge northeast of Indian Peak (analysis 4, Table II.), though nearly alike chemically, are quite unlike mineralogically. The first has abundant phenocrysts of labradorite, olivine and augite, while the second contains no olivine. The groundmass of the second contains some brown biotite, which may be secondary, while that of the second contains much biotite that is primary. In each pair of cases we find olivine more abundant in the surficial rock, and biotite more abundant in the dike rock, or these minerals may be entirely absent in one case or the other.

*Similar rocks in neighboring regions.*—Rocks almost identical with absarokite occur in the region of Bozeman, Montana, and have been described by Professor Merrill,[1] whose work was reviewed in the last number of this Journal.[2]

[1]MERRILL, G. P. Notes on some Eruptive Rocks from Gallatin, Jefferson and Madison counties, Montana. Proc. U. S. Nat. Mus., Vol. XVIII., pp. 637–673 (No. 1031), Washington, 1895.

[2]JOURNAL OF GEOLOGY, Vol. III., No. 7, p. 850, Chicago, 1895.

The chemical composition of these rocks is shown by the first four analyses in Table IV., taken from Professor Merrill s paper.

TABLE IV. CHEMICAL ANALYSES OF IGNEOUS ROCKS CORRESPONDING TO ABSAROKITE AND SHOSHONITE.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 46.90 | 49.13 | 50.82 | 51.65 | 50.03 | 52.33 | 54.15 |
| $TiO_2$ | .41 | .42 | .59 | .55 | .61 | .14 | .... |
| $Al_2O_3$ | 10.17 | 9.05 | 11.44 | 13.89 | 14.08 | 15.09 | 18.92 |
| $Fe_2O_3$ | 1.22 | 3.57 | .25 | 2.70 | 2.92 | 4.31 | 6.79 |
| FeO | 5.17 | 5.05 | 8.94 | 4.80 | 6.11 | 4.03 | |
| MnO | .10 | .15 | .19 | .15 | .08 | .09 | .... |
| MgO | 20.98 | 17.21 | 14.01 | 11.56 | 10.73 | 6.73 | 1.90 |
| CaO | 6.20 | 5.68 | 8.14 | 4.07 | 7.46 | 7.06 | 3.72 |
| BaO | .... | .05 | .06 | .19 | .04 | .07 | .... |
| $Na_2O$ | 1.16 | 2.01 | 1.79 | 2.99 | 1.46 | 3.14 | 5.47 |
| $K_2O$ | 2.04 | 2.24 | 3.45 | 4.15 | 2.64 | 3.76 | 8.44 |
| $P_2O_5$ | .44 | .38 | .20 | .21 | .42 | 1.02 | .... |
| $Cr_2O_3$ | .33 | .39 | .03 | .80 | tr. | .... | .... |
| $SO_3$ | .... | .... | .... | .19 | .... | .... | Cl .42 |
| $H_2O$ at 110° | 1.04 | .84 | .... | 1.30 | .... | 2.68 | .... |
| Ign. | 4.38 | 3.50 | .58 | 1.89 | 3.70 | .... | not det. |
| | 100,54 | 99.87 | 100.49 | 101.09 | 100.28 | 100.45 | 99.81 |

1. Fort Ellis, 2½ miles southeast of Bozeman, Montana—analyzed by T. M. Chatard
2. Bear Creek, Madison Valley, Montana—analyzed by T. M. Chatard.
3. South Boulder and Antelope Creek, Montana—analyzed by L. G. Eakins.
4. Cottonwood Creek, Montana—analyzed by T. M. Chatard.
5. Cottonwood Creek, " —analyzed by L. G. Eakins.
6. Cottonwood Creek, " —analyzed by L. G. Eakins.
7. Cottonwood Creek, " —analyzed by G. P. Merrill.

The variability of these rocks within certain limits is evident; the greatest range being in magnesia. As a class they are characterized by low silica and alumina, high magnesia, comparatively high alkalies, with much potash. The rock of the fifth analysis is a transitional variety, between absarokite and normal basalt. The sixth analysis is from a rock corresponding somewhat to shoshonite, in alkalies, but slightly lower in alumina, and higher in lime and magnesia. It is associated with the rocks of analyses 4 and 5. It has nearly the chemical composition of the rock called yogoite by Pirsson. Associated with the absarokites in several places are highly feldspathic rocks, richer in alkalies than the banakite of the Yellowstone Park. The chemical composition of one of them is shown by analysis 7, of Table IV. They are undoubtedly complementary products of differentiation.

In the Highwood and Little Belt Mountains of Montana there are rocks almost the same as absarokite in chemical composition, but coarsely crystalline. They have been described by Weed and Pirsson,[1] the account of the rocks of Yogo Peak having just been published. The chemical composition of the rocks of Yogo Peak and those of the two rocks of Square Butte, Highwood Mountains, is shown by the analyses in Table V. taken from the articles cited.

Pirsson states that the three rocks from Yogo Peak grade into one another, and are facies of one mass, whose variations are the result of differentation. They are granular crystalline, and consist essentially of orthoclase and augite in different proportions, and with subordinate amounts of plagioclase, biotite, magnetite; and in the syenite, hornblende; and in shonkinite, olivine, besides accessory minerals. In the syenite orthoclase exceeds augite, in yogoite orthoclase equals augite, and in shonkinite augite exceeds orthoclase. Chemically the series is characterized by comparatively low alumina, with relatively high potash, which is nearly constant. The sum of the alkalies decreases with decrease of silica and alumina. Magnesia and lime are fairly high. In the two rocks of Square Butte the shonkinite is like that of Yogo Peak, but alumina and alkalies are somewhat lower, and magnesia and lime higher. The syenite of Square Butte, the complementary rock with shonkinite, is high in alumina and alkalies, and very low in magnesia and lime,

[1] WEED, W. H. and PIRSSON, L.V., Highwood Mountains of Montana. Bull. Geol. Soc. America. Vol. VI., pp. 389-422. Rochester, 1895. Reviewed in this JOURNAL. Vol. III., No, 7, p. 851 ; also Igneous Rocks of Yogo Peak, Montana. Am. JOUR. Sci., Vol., L., No. 300. Dec. 1895. pp. 467–479.

with very high potash. In these two cases we find shonkinites as extreme forms of differentations in connection with syenitic rocks quite different from one another in chemical composition, one being comparatively low in alumina and the other high, the sum of the alkalies in one case being 8.85 per cent., and in the other 12.74 per cent. In each instance the associated rocks are facies of one igneous mass.

TABLE V. CHEMICAL ANALYSES OF IGNEOUS ROCKS FROM YOGO PEAK AND SQUARE BUTTE, MONTANA.

| | Yogo Peak. | | | Square Butte. | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| $SiO_2$ | 61.65 | 54.42 | 48.98 | 46.73 | 56.45 |
| $TiO_2$ | .56 | .80 | 1.44 | .78 | .29 |
| $Al_2O_3$ | 15.07 | 14.28 | 12.29 | 10.05 | 20.08 |
| $Fe_2O_3$ | 2.03 | 3.32 | 2.88 | 3.53 | 1.31 |
| FeO | 2.25 | 4.13 | 5.77 | 8.20 | 4.39 |
| MnO | .09 | .10 | .08 | .28 | .09 |
| MgO | 3.67 | 6.12 | 9.19 | 9.68 | .63 |
| CaO | 4.61 | 7.72 | 9.65 | 13.22 | 2.14 |
| BaO | .27 | .32 | .43 | .... | .... |
| $Na_2O$ | 4.35 | 3.44 | 2.22 | 1.81 | 5.61 |
| $K_2O$ | 4.50 | 4.22 | 4.96 | 3.76 | 7.13 |
| $P_2O_5$ | .33 | .59 | .98 | 1.51 | .13 |
| $Cr_2O_3$ | tr. | tr. | tr. | .... | .... |
| SrO | .10 | .13 | .08 | .... | .... |
| $Li_2O$ | tr. | tr. | tr. | tr. | .... |
| Fl | .... | .... | .22 | Cl .18 | .43 |
| $H_2O$ at 110° | .26 | .22 | .26 | 1.24 | 1.77 |
| $H_2O$ above 110° | .41 | .38 | .56 | | |
| | 100.15 | 100.19 | 99.99 | 100.97 | 100.45 |
| | | | O=Fl .08 | O=Cl .04 | .10 |
| | | | 99.91 | 100.93 | 100.35 |

1. Syenite, Yogo Peak, analyzed by W. F. Hillebrand.
2. Yogoite, Yogo Peak, analyzed by W. F. Hillebrand.
3. Shonkinite, Yogo Peak, analyzed by W. F. Hillebrand.
4. Shonkinite, Square Butte, analyzed by L. V. Pirsson.
5. Sodalite-syenite, Square Butte, analyzed by W. H. Melville.

In his account of the rocks of the grorudite-tinguaite series,[1] Professor Brögger describes a series of igneous rocks occurring as dikes that are characterized by mineralogical and chemical peculiarities, which distinguish them from all other rocks in the Christiania region, and which warrant their being separated into distinct classes. These have been named grorudite and sölvsbergite, the third member of the series being tinguaite. Between these classes are transitional varieties. The rocks of this series grade through mineralogical and chemical transitions into other rocks belonging to different series, such as laurvikite, laurdalite, nordmarkite and soda-granite. They represent a series of particular phases of differentiation of genetically related magmas, as in the case of the series described from the Yellowstone Park.

The chemical composition of the rocks in the grorudite-tinguaite series, as given by Brögger, is shown in Table VI. The whole series is more siliceous than those we have been considering, the range of silica being from 56.58 to 74.35 per cent. Some of the marked characteristics of this series are the strong decrease in alumina with increase of silica; also the corresponding increase in ferric oxide; the relatively high percentage of alkalies which increase with alumina, soda being greater than potash. Magnesia and lime are very low. The mineral characteristics are equally marked.

The consistent minerals are potash-feldspar and soda-feldspar, with ægerite (or alkaline hornblende) with quartz in some cases, without it in others, and with nepheline in others. Plagioclase is entirely wanting, and mica and hornblende are generally scarce. The chemical character of the series is distinctly different from that of the series of rocks just described from Yellowstone Park and Montana. A comparison of these series shows to what extent the products of differentiation in various regions may differ from one another, the laws of variation being quite opposite sometimes. Hence natural series of rocks, which may be genetically related, may traverse any scheme of sys-

[1] Brögger, W. C. Die Eruptivgesteine des Kristianiagebietes. 1. Die Gesteine der Grorudit-Tinguaite-Serie. Kristiania, 1894.

TABLE VI. CHEMICAL ANALYSES OF GRORUDITE, SÖLVSBERGITE, TINGUAITE.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 74.35 | 70.15 | 71.35 | 68.95 | 64.92 | 62.70 | 58.90 | 56.58 |
| $TiO_2(+ZrO_2)$.... | | .65 | .50 | .35 | tr. | .92 | .40 | .... |
| $Al_2O_3$ | 8.37 | 10.60 | 12.21 | 14.00 | 16.30 | 16.40 | 17.70 | 19.89 |
| $Fe_2O_3$ | 5.84 | 5.77 | 4.53 | 2.12 | 3.62 | 3.34 | 3.94 | 3.18 |
| FeO | 1.00 | 1.74 | 1.14 | 3.56 | .84 | 2.35 | 2.37 | .56 |
| MnO | .22 | .52 | .78 | .55 | .40 | tr. | .55 | .47 |
| MgO | .07 | .35 | tr. | .07 | .22 | .79 | .54 | .13 |
| CaO | .45 | .72 | .22 | .23 | 1.20 | .95 | 1.05 | 1.10 |
| $Na_2O$ | 4.51 | 5.30 | 6.51 | 5.45 | 6.62 | 7.13 | 7.39 | 10.72 |
| $K_2O$ | 3.96 | 4.09 | 3.22 | 5.29 | 4.98 | 5.25 | 5.59 | 5.43 |
| $H_2O$ | .25 | tr. | 0.33 | .05 | .50 | .70 | 1.90 | 1.77 |
| | 99.38 | 99.89 | 100.89 | 100.62 | 99.60 | 100.10 | 100.33 | 99.83 |

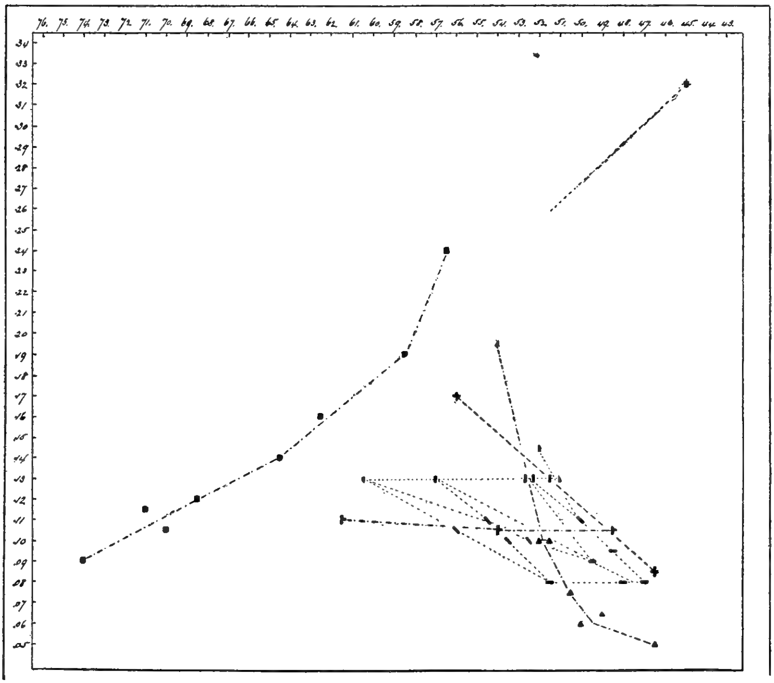
1. Grorudite, Varingskollen, Norway.
2. Grorudite, Grorud, "
3. Grorudite, Kallerud, "
4. Grorudite, Frön, "
5. Quartz-bearing Sölvsbergite, "
6. Nearly quartz-free Sölvsbergite, Lougenthal, Norway.
7. Nephelin-bearing Sölvsbergite, Tjose-Aklungen, Norway.
8. Tinguaite, Hedrum, Norway.

tematic classification of igneous rocks in various directions. This may be shown graphically as in the accompanying diagram, where the series of analyses are plotted so as to bring out the relation between the total alkalies and the silica in each case. The grounds for this method of comparison will not be gone into at this time, owing to lack of space, only the results can be given. The molecular proportion between the sum of the alkalies and silica in each case is expressed in parts of a hundred, which are used as ordinates. The silica percentages are used as abscissas, the highest being placed at the left. Hence the most silicious rocks are at the left hand end of the diagram, and those with the smallest ratio of alkalies to silica at the bottom. The rocks with least alkalies are at the lower right hand corner of the diagram. The location of the various rocks in such a scheme is indicated by different symbols.

DIAGRAM SHOWING THE RANGE IN ALKALI-SILICA RATIOS

$$\left(\frac{Na_2O + K_2O}{SiO_2}\right)$$

IN CERTAIN GENETICALLY RELATED SERIES OF IGNEOUS ROCKS.




- ▪ Grorudite-Tinguaite Series, Christiania region.
- ✦ Nepheline-Porphyry, Beemersville, N. J.
- ✚ Shonkinite-Sodalite-Syenite Series, Square Butte, Montana.
- Shonkinite-Yogoite-Syenite Series, Yogo Peak, Montana.
- ▲ Absarokite-Sodalite-Syenite Series, Bozeman District, Montana.
- Banakite, Shoshonite, Absarokite } Series, Yellowstone National Park.

The grorudite-tinguaite series traverses the diagram in an almost straight line, which rises steeply from the most siliceous end to the least siliceous, the alkali-silica ratio ranging from .09 to .24. The location of the so-called Sussexite, from Beemersville, Sussex county, N. J., which Brögger considers equivalent to a possible extreme form of differentiation belonging to this series, occurs in the diagram in direct line with the trend of the grorudite-tinguaite analyses. The alkali-silica ratio being .32.

The few analyses of the differentiation facies of the igneous cores at Square Butte and Yogo Peak are merely indications of the trend of these series. In fact at Square Butte, there are simply the two end results of highly advanced differentiation. The trend of the line connecting these extremes is almost at right angles to that of the grorudite-tinguaite series. The trend of the line connecting the three parts of the Yogo Peak mass is almost horizontal. The two analyses of shonkinite lie close together, but those of the complementary syenitic rocks are separated from one another by considerable space. Assuming that the sodalite-syenite and absarokites described by Professor Merrill are complementary rocks, as their association in the field and their analogy with the rocks of Square Butte indicate, we find a line connecting their possible series would be nearly vertical, as in the diagram. The analysis of the rocks of the absorakite-shoshonite-banakite series occupy a rather broad belt in the diagram, which lies between the extreme of the Yogo Peak and Square Butte series. The least siliceous absarokites lying very near shonkinite and the quartz-banakites lying between the syenites of these series. From the position of the analyses in the diagram it is evident that the absarokite-banakite series as here constituted is more comprehensive than either of the two above mentioned, which are in fact distinct series, since each is confined to a particular rock mass. But in the case of the dikes and lavas in the Yellowstone Park no such subdivision of these orthoclase-bearing, basic rocks could be established. Occurring as they do as a group of related lavas, having like geological relations, and analogous chemical and mineral compositions, they must naturally be considered as a series variable in two principal directions chemically: in the ratio of alkalies to silica, and also in the silica percentages. The variations of the other chemical constituents are to some extent functions of these variables. In a region where highly differentiated igneous rocks occur as disconnected geological bodies in great numbers, it might always be possible to select some particular series of isolated rocks as a genetic series, from which a law of differentiation might be derived. But it would seem that the several instances of "laccolithic differentiation" described by Pirsson must be the surest basis upon which definite laws may be established. And on the other hand, anything like the frequent occurrence of differentiated lavas in a region must involve a multiplicity of lines of differentiation which cannot be disentangled, and which must of necessity be treated collectively. As Professor Brögger observes in the work already quoted the various members of the grorudite-tinguaite series in the Christiania region are mostly disconnected rock masses, and are probably related genetically with rocks differing slightly from them in chemical composi tion, so that members of a parallel series, differing in its general character from the one described, may be genetically more closely related to certain members of the first series, than to some members of the chemical series in which they may have been placed.

The question how far the genetic relationships between igneous rocks can be made to serve as a basis of classification is an open one. They certainly constitute the foundation of a genealogy of igneous rocks, but it may be doubted whether they can properly mark the lines along which a systematic classification can be established.

JOSEPH P. IDDINGS.

## DISTRIBUTION OF GOLD DEPOSITS IN ALASKA.[1]

THE deposits hitherto worked on the Yukon River are stream avels, and the region in which most work has been done thus far lies on the great river and its tributaries near the point at which it crosses the eastern boundary of the territory. Along the southern coast of Alaska there are several localities at which quartz mining is carried on, and some at which placers are in operation. A number of deposits exist along the coast in the region of Juneau. Of these much the most important and famous is the Treadwell mine. The Treadwell, on Douglass Island,[2] produces over half a million a year, from ore which averages only $2.50 to $3.00 per ton. Thanks to the enormous scale of the workings, more than half of the gross yield is net profit. The main country rock is a slate of sedimentary origin, and probably of Triassic age. It has been penetrated by a heavy dike of granite and two other intrusive masses. The last of these is a rock of basaltic character, and its eruption seems to have accompanied the mineralization. Both the granite and the slate were ruptured along a zone which is at some points several hundred feet in width, and the interstitial spaces have been filled with ore. In the granite the mass was in great part reduced to irregular fragments, and these have been decomposed and impregnated. In the slate the fractures mostly followed the cleavage, and the deposit there assumes the form of what I call a "stringer lead." The claims to the southward of the Treadwell are controlled by the same company, and are profitable, but the next claim to the northward is said to be too poor to pay.

Silver Bow Basin lies about three miles north of east from

[1]Note read before the Washington Geological Society, by Mr. George F. Becker.

[2]Dr. GEO. M. DAWSON wrote a paper on this mine in Amer. Geologist, Aug., 1889.

Juneau. A considerable number of small veins of rather rich ore occur on the southern side of this basin. Although the basin was formerly occupied by a large glacier, the diminished upper end of which is still visible from the locality, parts of the side are covered with rotten rock in place, carrying gold quartz seams and forming what I call a "saprolitic placer." After the retreat of the glacier the basin was occupied by a lake, and the lake beds are successfully worked for gold by the hydraulic process, a very unusual case. Sheep Creek basin is separated from Silver Bow basin by a divide, and the same series of quartz veins extends into it. Some fifty-five miles to the southeast of Juneau lies Sumdum, at which there is a very promising vein already yielding some bullion, although the property is only being developed. At Seward City, near Berner's Bay, about fifty miles northwest of Juneau, there are also veins which are extremely rich at some points, and are yielding gold. On Admiralty Island, at Funters Bay, about thirty miles from Juneau, there are promising veins on which it is expected that mining will be commenced next year. Near Sitka, especially along Silver Bay and in the country to the southeast of it, there are numerous veins some of which have yielded a little gold. Most of them seem rather low grade, and the development is insufficient to justify an opinion as to their future.

At Yakutat Bay, just to the eastward of Mt. St. Elias, there has been some beach mining, as there has also been along the west shore of Kadiak Island. The ease of working and the unlimited supply of sand make beach mining on the western coast of North America very attractive, but the capriciousness of the distribution of pay streaks, and the difficulty of saving the gold, commonly rob such undertakings of success. I am not aware that any notable profit has been made in a single case from beach mines, either in Alaska or to the southward. Nevertheless the amount of gold which occurs in this way is enormous. On Kadiak Island, in Uyak Bay, there are several promising looking gold quartz veins of a couple of feet in thickness. Prospecting is going on there, and should be more actively prosecuted. On Turn-again arm at the head of Cook's Inlet, where Cook was turned back from his effort to find a "northwest passage," stream gravels are being worked. The only success was on Bear Creek, for some two miles, and I could not ascertain that the average results there were more than about $5.00 a man a day. I learn from Captain Hansen, of the mail steamer Dora, that richer gravel was discovered after I had left Cook's Inlet, near the head of Turn-again arm.

The island of Unga is in the Shumagin archipelago, about 1000 miles a little south of West from Sitka. Near Delaroff Bay, on this island, is the Apollo Consolidated mine, a highly interesting and an important deposit, which is now yielding at the rate of over $300,000 a year. The country rock is andesite, and the deposit occupies interstitial spaces in a crushed zone of this rock. The ore averages between $8.00 and $9.00 per ton, and a very large part of the gold is free, though heavy bunches of sulphurets are of frequent occurrence in it. This district, in which ore has been found at many points, bears a striking resemblance to Bodie, Cal.

On the island of Oonalaska auriferous quartz has been found, but thus far nothing like a mine has been discovered.

I was accompanied to the Alaskan coast, during the past summer, by Messrs. Wm. H. Dall and C. W. Purington. Mr. Dall took charge of the coal deposits and I of the gold. Our report is naturally not ready, but is expected to appear in the spring.

GEO. F. BECKER.

THE very unfortunate report of the death of Dr. Geo. M. Dawson, we are most happy to state, proves to be entirely unfounded. It seems that it arose from the error of a cable operator in substituting "D" for "L" in transmitting a notice of the death of Dr. George Lawson, of Halifax. The erroneous report received considerable currency in the English press and appeared in a part of an issue of *Nature*, but was corrected by a second cablegram before the edition was completed. The false report returned to this country, but the correction, as usually happens in such cases, did not keep equal pace with it. The erroneous announcement appeared in *Science*, accompanied by a biographical notice, and thence received currency in this country. This was duly corrected in a later issue of *Science*, but the happy information again fell far behind the sad news, in our case and in some others, and so we find ourselves among the latest and most unfortunate victims of a mistake, very slight in a phonic sense, but very grave in its import. It is an inexpressible pleasure, however, to know that it is a mistake. We offer to Dr. Dawson and his friends our profound apologies.

# *EDITORIAL.*

FOR the second time in the brief history of the JOURNAL OF GEOLOGY, we are called upon to record the loss of a member of its editorial staff. And now, as before, it is one in the prime of life, in the midst of a brilliant career, and in the enjoyment of rare prospects, Dr. George M. Dawson. Less than a year ago, he was elevated to the directorship of the Geological Survey of Canada, a position which he had amply earned by a score or more years of markedly successful work on the geology of the Dominion. His "Geology and Resources of the 49th Parallel," prepared when he was yet a very young man, gave him a recognized place in the scientific world. It has been followed by a long list of papers of unusual merit. It is to Dr. Dawson especially that we are indebted for the geology of the northern cordilleras and the great northwestern plains beyond the national boundary. His studies lay along many lines, and the wide range of his abilities peculiarly fitted him for the multitude of questions that were presented in the exploration of his vast and varied field. We hope to present a more adequate notice of his work in a succeeding number. T. C. C.

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IN the very interesting experiments on ice motion, described by Mr. Case on previous pages of this number of the Journal, it may be worthy of note, that the force employed was localized and horizontal. In a glacier, if it be assumed to act as a viscous liquid, the force is distributive and primarily vertical. In so far as there is a horizontal component it is derived from the vertical. It is therefore never in excess of the vertical (momentum and the lag in local adjustment aside). In a perfect liquid it is precisely equal. In a viscous liquid receiving additions above, the horizontal is necessarily less than the vertical force (except locally). A horizontal force greatly in excess of the vertical does not therefore closely imitate the agencies of glacial motion, if it be true that a glacier acts as a viscous liquid.

If a glacier be presumed to move by means of granular changes, the ratio of vertical and horizontal forces may still be essentially the same, for the granular action may be merely a mode of motion under gravity. If, however, the growth of the granules brings into play the forces of crystallization, it is conceivable that the ratio of vertical and horizontal forces may not remain the same. It may be conceived that the amount of crystalline force brought into action along any given line is somewhat correspondent to the number of granules lying in that line, or to the length of the line. If this be true, the axis of the glacier would represent the line of greatest force. Gravity would of course interpose its influence and the combined result would be merely a greater or less departure from the mode of action under gravity alone. Probably no one will doubt that gravity dominates the phenomenon.

The experiments of Mr. Case more nearly reproduce the conditions of this phase of the granulation hypothesis than those of the viscosity hypothesis.

It is obvious that the nature and mode of application of the forces employed are critically important in dealing with a substance on the border line between the solid and liquid states. It is quite possible to manipulate a liquid so that it shall deport itself like a solid, and conversely, to handle a solid so that it shall deport itself like a liquid. A solid may be made to flow, or seem to flow like a liquid, and a liquid may be made to shear or to seem rigid like a solid. In these cases it is the manipulation rather than the nature of the substance that gives expression to the result. A semi-solid is peculiarly sensitive to the mode of manipulation, and in experiments with bodies of this class the interpretation of results is quite as much to be guided by the mode of manipulation as by the nature of the substance manipulated. The experiments of Mr. Case, therefore, only whet our interest to a keener edge. Is it the viscidity of the wax and the mode of thrust that gives the similitude to the phenomena of the Greenland glaciers? T. C. C.

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THE beautiful investigations of Dr. O. Mügge, which have come to hand since the above was put in type, go straight to the heart of one phase of the subject, viz., the method of internal movement of ice crystals when deformed by an external force.[1] Prisms were cut from carefully formed ice in various directions to the principal crystallographic axis, *i. e.*, the optic axis of the crystal, particularly in directions parallel and transverse to it. These were tested by placing their ends on supports and weighting them in the center. In testing the transverse prisms the optic axis was first placed in a vertical position. The prisms sagged and their ends were drawn inward. Optical examination showed that the optic axis remained normal to the bent surface. Subsequent observations on surfaces fractured for the purpose showed striation and other indications that plates of the crystal parallel to the basal plane had *sheared* upon one another.

When similar prisms were placed so that these gliding planes stood on edge, *no appreciable result followed*, even though greater weights and longer times were employed.

When prisms cut parallel to the principal axis were tested, the gliding planes being transverse to the prism, the weight sunk sharply into the upper face of the prism, and a *corresponding protrusion appeared below*. As the process continued, the protrusion below kept closely parallel to the indentation above, both widening somewhat, until a section of the prism had been pushed entirely out. Optical examination showed that the optic axis remained parallel to itself throughout. The block remained transparent and free from fracture. The weight appeared to

[1] Uber die Plasticität der Eiskrystalle. Separat-Abdruck aus dem Neuen Jahrbuch fur Mineralogie, etc., 1895. Bd. II.

have simply slipped the plates over their neighbors, carrying the adjacent ones forward with them to some extent by dragging, but not visibly affecting the more remote ones.

If a prism be made up of square cards and placed on its side and a transverse force be applied, the result will illustrate the apparent method of movement within the ice crystal in this last case. If such a prism be pressed at right angles to the cards, it will illustrate the bending of the first case, and if the cards be placed on edge, they will illustrate the effectual resistance to deformation of the second case. Variations of temperature through 10°, were not found to produce notable differences of result.

Not to mention other significant points, the investigation seemed to warrant the important conclusion that ice crystals yield to deforming forces by the sliding or shearing of the crystalline layers at right angles to the principal axis. No analogy to the motion of a viscous fluid appeared. Dr Mügge had previously found a similar method of deformation in other minerals, including gypsum, stilbite and vivianite. In respect to its mode of internal motion, ice is therefore to be classed with these minerals rather than bodies properly called viscous.

From these trenchant experiments it would appear that there is a suggestive analogy between the shearing movement of the crystalline plates within the ice crystal and the shearing motion of the individualized layers of the Greenland (and presumably other) glaciers. The ulterior question of the source of motion in glaciers is not reached by these investigations, though they offer suggestions of the first importance. They seem, however, to cut at the roots of the viscosity hypothesis by showing that ice-deformation is not even analogous to the internal movement of a viscous body. The word *plasticity*, as a very general term indicating the yielding of solid bodies, may still be applied to ice, but is not the term viscosity already sufficiently burdened with duplicity to entitle it to relief from further service in this much battled field?

T. C. C.

BEGINNING with the first number of Vol. IV, the JOURNAL will present a series of four articles under the head of "Studies for Students," by Professor Van Hise, on (1) Movements of Rocks Under Deformation; (2) Analysis of Folds; (3) Cleavage and Fissility; (4) Joints and Faults. Dr. Van Hise has recently given these subjects very careful study, and his synopses will undoubtedly possess rare merit. C.

# *Reviews.*

*Mollusca and Crustacea of the Miocene Formations of New Jersey.* By R. P. Whitfield. Monog. U. S. Geol. Surv. Vol. XXIV. (1894).

Previous to the publication of this monograph by Professor Whitfield, the fossils of the Miocene beds of New Jersey have never been systematically studied and recorded. A few of the most prominent species have been described here and there by different authors. Mr. F. B. Meek mentions only seventeen species from New Jersey in his list of Miocene fossils published in "Smithsonian Miscellaneous Contributions." In his "Tertiary Geology of the Eastern and Southern United States," Professor Heilprin enumerates twenty-seven species, seventeen of which he gives as peculiar to New Jersey. The same author, in an article on "The Miocene Mollusca of the State of New Jersey," enumerates thirty species, but later adds to this list from collections obtained from the marl pits at Shilo, giving fifty species from this one locality. The total number of species known up to 1887 was eighty-two.

In the present work one hundred and four species are recognized, thirty-six of them, so far as known, being peculiar to New Jersey. The author states, however, that there is no doubt that many more might be obtained were the beds more thoroughly examined and more localities visited.

A list of fourteen species of foraminifera are recorded, determined by Mr. Anthony Woodward of the American Museum of Natural History, obtained from a few ounces of marl from the interior of some of the shells.

The geological horizon of these New Jersey beds is considered by Professor Whitfield not to differ from that of the beds in Maryland, Virginia and the Carolinas, whether they be strictly Miocene or Mio-Pliocene as some are disposed to call them.

The fossils described are illustrated by twenty-four plates and are distributed as follows: *Brachiopoda*, 1 sp., *Lamellibranchiata*, 61 sp., *Gasteropoda*, 41 sp., and *Crustacea*, 1 sp. S. W.

# *Authors' Abstracts.*

*U. S. Geologic Atlas. Folio 11, Jackson, California, 1894.*

This folio consists of two pages of text descriptive of the Gold Belt, concluding with a generalized section of the formations of the Gold Belt, four pages of text descriptive of the Jackson area, signed by H. W. Turner, geologist, and G. F. Becker, geologist in charge; a topographic map of the Jackson tract (scale 1:125000), a sheet showing the areal geology, and a third of structure sections.

The area covered by the folio embraces a portion of the foothills of the Sierra Nevada, chiefly in the counties of Amador and Calaveras, California. The area is drained by the Mokelumne and Calaveras rivers. The region is one of great economic importance, and comprises a portion of the rich belt of gold-quartz mines known as the Mother Lode. One of these mines, the Utica, at Angel's Camp, is said to be paying one million dollars yearly at the present time.

There are two distinct series of formations represented in this area. The Calaveras and Mariposa formation, of sedimentary origin, and the associated igneous rocks form an older, highly disturbed series, on which a later series rests with a marked unconformity. This later series represents the Tertiary and Pleistocene periods.

The Calaveras formation, of Carboniferous age, is composed of slates, quartzite, mica-schists, and limestone lenses, and contains frequent gold-quartz veins. The Mariposa formation, of Jurassic age, is largely made up of clay-slate. There are two main belts of this formation, and in the eastern one occur many of the gold-quartz mines of the Mother Lode.

The igneous rocks associated with the Calaveras and Mariposa formations are of considerable variety, but only three form considerable areas. These are serpentine, granite, and the porphyrites (old andesites) and their tuffs. The serpentine is undoubtedly an altered form of basic igneous rocks (pyroxenite and pridotite), and is intrusive. The granite is likewise intrusive, cutting through all the older rocks, except the Mariposa formation, and there is little doubt that it is later than this formation also, and in adjoining districts it invades the Mariposa slates as well. The porphyrites are largely altered forms of surface lavas and tuffs, resembling andesite and in part basalt, and these rocks have been folded and compressed along with the sediments of the Calaveras and Mariposa formations. The areas called amphibolite-schist on the geological map are chiefly metamorphic forms of these porphyrite-tuffs.

The formation of the later series, resting on these older rocks, that deserves most attention is called Auriferous gravel formation. These gravels which are found chiefly on the ridge-tops, were deposited in Neocene time by rivers. These old streams, as may be seen by inspecting the map, united into one trunk a little to the north of the Bear Mountains, and there found an outlet into the gulf that then filled the San Joaquin Valley. At many localities these old-river gravels have been profitably mined for gold. Forming a capping to the gravels are usually beds of volcanic material, chiefly andesite and rhyolite.

The Calaveras formation is of economic importance as containing frequent gold-quartz veins and lenses of limestone. Most of the latter are noted on the geological map.

The Mariposa formation affords a good roofing slate, but is chiefly remarkable as containing, in Amador county and in the north portion of Calaveras county, the quartz veins of the Mother Lode.

The amphibolite-schist belts contain copper deposits and gold-quartz veins. In the southern part of Calaveras county, at Angel's Camp, the Mother Lode lies to the east of the Mariposa slates and intersects a belt of amphibolite-schist.

In the granite of the West Point area are numerous gold-quartz veins, the ores of which contain a larger per cent. of sulphurets than the ores of the Mother Lode mines, and such ores are called base.

The serpentine areas contain chrome-iron deposits at numerous points.

The tuffs overlying the gravels at Mokelumne Hill, Valley Springs, and other points, have been found to make good building stone. Sandstone quarries are worked in the foothills in beds of Tertiary age, and the deposits of the same age near Ione afford large quantities of clay for pottery, and of coal.

*U. S. Geologic Atlas, Folio 12, Estillville, Kentucky; Virginia; Tennessee, 1894.*

This folio consists of five pages of text by M. R. Campbell, geologist, a topographic map of the district (scale 1:125,000), a sheet showing the areal geology, another showing the economic geology, a third of structure sections, and a fourth giving a columnar section north of Clinch River and another south of that river.

The territory represented by the folio is located principally in southwestern Virginia, though the southern portion extends into Tennessee and the northwestern portion into Kentucky. Its area is 957 square miles, four-fifths of which is in the Appalachian Valley and one-fifth in the Cumberland coal basin.

The surface features are quite varied. In the Appalachian valley they consist of a succession of narrow ridges separated by equally narrow valleys, trending in a northeast and southwest direction. In the coal basin the ridges are less regular, but higher, reaching in two cases an elevation of over 4100 feet above the sea level.

The region is almost entirely within the drainage basin of the Tennessee River. The principal tributaries of this stream are Holston, Clinch, and Powell Rivers, each of which is a stream of considerable importance. The Kentucky portion of the territory is drained by the headwaters of the Cumberland River.

The geologic structure of the region is complicated. In the Appalachian Valley the rocks have been squeezed, in a northwest and southeast direction, until they have been forced into great folds. These are generally overturned toward the northwest, and have in many cases been compressed to such an extent that they have broken, allowing one limb of the fold to be thrust over the other. These faults are of frequent occurrence in this region. Sixteen or seventeen can be counted on the geologic map. In the coal basin the folding is less severe, and the result is a broad basin in which dips are prevailingly light, and in many places the rocks are horizontal.

The intense folding of the strata has brought to the surface all of the geologic formations from the Carboniferous to the Cambrian. On lithologic grounds these are divided into twenty-two separate and distinct formations. As a result of the original folding and subsequent erosion, these formations show at the surface in long, narrow outcrops of limestone, shale, or sandstone, which, in the various folds, are repeated over and over again. It is this repetition of the hard beds that gives rise to the numerous ridges which are such conspicuous features of Appalachian topography. In the coal basin the rocks are nearly horizontal, and hence they show in outcrop around the flanks of the mountains, or irregularly over the less rugged portions.

The mineral resources of this region are important, though at present but slightly developed. A belt of marble, varying considerably in composition and appearance, outcrops along the northern side of Clinch Mountain. Iron ore occurs in many parts of this territory, both in the form of limonite and in that of hematite. Red fossil ore is found in the Rockwood formation in the northern part of the region, and it is mined on Wallen Ridge south of Big Stone Gap. Coal is the principal mineral resource of this territory. It occurs in the structural basin north of Stone Mountain, and sparingly in the great arch of Powell Mountain east of High Knob. The coal-bearing rocks are approximately 5000 feet in thickness, and include many seams of workable coal. In the vicinity of Big Stone Gap the Imboden seam is the most important. It has been traced over a large area on the Virginia side of the basin, where it varies from 3 to 16 feet in thickness. On this side there are a number of other seams of good quality, ranging from 3 to 7 feet in thickness, which could be easily worked. The Kentucky portion has also many workable seams, but at present, owing to lack of transportation, no mining has been done on a commercial scale.

*U. S. Geologic Atlas, Folio 13, Fredericksburg, Virginia; Maryland, 1894.*

This folio consists of five and one-fourth pages of text, signed by N. H. Darton, geologist, and M. J. McGee, geologist in charge; a topographic map of the district (scale 1 : 125,000), and a sheet showing the areal geology.

The map represents an area of approximately 1000 square miles of the Coastal Plain region of northeastern Virginia and the southwestern corner of Charles county, Maryland. It includes, in Virginia, King George and the greater part of Caroline and Stafford counties, and adjoining portions of Spottsylvania, Essex, and Westmoreland counties. The city of Fredericksburg is near the center of the western margin of the area. The Potomac River crosses the northeastern corner of the area, and the Rappahannock River extends diagonally across its center on a northwest and southeast line. The headwaters of the Mattapony River are in its southwestern corner. Along these river valleys there are wide, low terraces capped by the Columbia formation, of Pleistocene age. The intervening areas are plateau remnants capped by Lafayette deposits, of supposed Pliocene age. The underlying formations are the Potomac, Pamunkey, and Chesapeake, which lie on an east-sloping floor of crystalline rocks. This floor rises to the surface and constitutes hills of considerable height in the northwestern corner of the tract; eastward it is deeply buried under the Mesozoic and Tertiary sediments. The Potomac formation, which is the basal member of these sediments, consists of a heterogeneous series of sands and sandstones with intercalated clays. Much of the sand is arkosic, and consists of detritus of crystalline rocks. The Pamunkey formation, which overlies the Potomac unconformably, is the representative of the Eocene in this region. It consists in greater part of glauconitic marls. These marls are important fertilizers, and in some portions of the region have been used with excellent results. They are overlain unconformably by the Chesapeake formation, which is of Miocene age. It is characterized by fine sands, marls, and clays, portions of which consist largely of diatom remains. It is the same series that extends to Richmond, where its diatomaceous character was discovered many years ago, and to the northward through Maryland. It thickens rapidly eastward, and is nearly 1000 feet thick in the lower Chesapeake Bay district.

The crystalline rocks consist mainly of granites and gneiss and an infolded bed of slates, to which the name Quantico slates has been given. They are not of value for roofing slates, so far as is now known. They appear to be a continuation of the slates in the belts west of Richmond, in which lower Silurian fossils were discovered some time ago, but no fossils have been found in the area of the Fredericksburg sheet.

*U. S. Geologic Atlas, Folio 14, Staunton, Virginia; West Virginia, 1894.*

This folio consists of four pages of text, signed by N. H. Darton, geologist, and closing with a columnar section of the area; a topographic map (scale 1 : 125,000), a sheet showing the areal geology of the district, another showing the economic geology, and a third exhibiting structure sections.

The area represented is about 1000 square miles of central Appalachian Virginia. It comprises central and western Augusta county and portions of several adjacent counties. Staunton lies near the center of the eastern margin of the tract. About a third of the area is in the Great Valley of Virginia, and the remainder stretches halfway across to the Allegheny.

The geologic formations comprise members from the Shenandoah limestones of the Great Valley to the Pocono sandstones of Lower Carboniferous age. There are also some small dikes of diabase in the northwestern corner of the area. The region is one in which relatively gentle folds predominate. There is an overthrust fault which extends along the western side of the Great Valley for some distance, and several other faults traverse the Shenandoah limestone.

The geologic classification does not differ materially from that outlined by W. B. Rogers, but geographic names have been applied to the formations. The name Shenandoah limestone has been selected for the great series of limestones of the valley. This series comprises several subdivisions, but they merge so gradually in the Staunton region that no attempt has been made to differentiate them on the map. The upper member contains a Trenton fauna, and it is thought that the basal beds of the series extends into the Cambrian, although no fossils have been discovered in them. Next, there is the representantive of the Utica and Hudson shales, which has been designated the Martinsburg shale. It is overlain by the Massanutten sandstones, which comprise the Oneida and Medina, in terms of the New York series. Next, there are the Rockwood formation and the Lewistown limestone, which include the formations between the Clinton and Lower Helderberg. The Oriskany and associated sediments are here represented by a stratigraphic unit to which the name Monterey sandstone has been given. The great series of Devonian strata lying above the Monterey has been divided into the Romney shale, Jennings formation, and Hampshire formation. As they are not sharply separated from each other the patterns by which they are represented on the map are merged over a narrow zone along their boundaries. Only a portion of the Pocono formation is included in the stratigraphic column in the region.

The principal economic resources are iron ores, which lie on a local unconformity between the Monterey sandstone and the Romney shale, and limestone for flux. Some of the limestones are suitable for marbles, and at many points lime is burned for local use. There are several thin, irregular beds of coal in the Pocono sandstone, but they are not of economic importance. Brick and pottery clays in the Great Valley complete the list of economic resources.

*U. S. Geologic Atlas, Folio 15, Lassen Peak, California, 1895.*

This folio consists of two pages of text by J. S. Diller, geologist, descriptive of the Lassen Peak district, supplemented by two pages, with illustrations (nine figures), devoted to recent volcanic activity; a topographic map of the district, a sheet showing the areal geology, and another showing the economic geology.

The Lassen Peak district is situated in northern California, between the Sacramento Valley and the Great Basin, and adjoins the northern end of the Sierra Nevada. It is bounded by the 121st and 122d meridians and the 40th and 41st parallels, and contains an area of 3634.4 square miles.

Within the district there are three distinct topographic features. Beginning at the west, it includes (1) a small portion of the eastern border of the Sacramento Valley; (2) the Lassen Peak volcanic ridge; and (3) upon the east a portion of the Great Basin platform.

Twenty-two geological formations are shown upon the map. Thirteen of these were deposited by water as sedimentary rocks. The remaining nine are of igneous origin, and were erupted from the interior of the earth in a molten condition. Some of the sedimentary rocks, especially the younger ones, have not been materially changed since they were deposited; but others, such as the auriferous slates, have been greatly altered or metamorphosed, and contain veins of quartz and metalliferous deposits.

By far the most abundant rocks of the Lassen Peak district are those of igneous origin. The numerous volcanoes of the district have furnished a great variety of such rocks.

Beds of unaltered stratified rocks, none of which are older than the Cretaceous, are still nearly horizontal; although uplifted, they have not been compressed enough to produce folds. On the other hand, the auriferous slates have been thrown into a series of anticlines and synclines, and so greatly compressed as not only to close the folds, leaving the strata in many cases approximately vertical, but also to break and displace them along a series of thrust faults during the earth movements by which the mountains were produced.

Upon the economic map special attention is called to the distribution of auriferous slates, in which alone there is any probability of discovering valuable deposits of precious metals. These rocks are exposed in the southeastern and northwestern portions of the area mapped, and extend through under the lavas of the Lassen Peak district, from the Sierra Nevada to the Klamath Mountains of the Coast Range. The broad stretch of unaltered lavas about Lassen Peak does not contain any appreciable amount of precious metals, and may be wholly neglected by the prospector.

Among the auriferous slates seven formations have been distinguished, ranging in age from the Silurian to the Jurassic, inclusive. Of these the Cedar formation, of Triassic age, has been the most productive. By its disintegration it has furnished the gold for the placer mines of Indian Creek below Shoo Fly, of Soda Creek, Rush Creek, the north fork of Feather River, and Dutch Hill. The Savercool mine, by the north fork of Feather River, is on this belt, and active prospecting is going on at a number of points. Numerous copper deposits have been discovered in the Pit River region.

Intermingled with the auriferous slates there are eruptive rocks, such as diabase, porphyrite, peridotite, and diorite, which have much to do in determining the distribution of certain classes of ore bodies. The areas of eruptive rocks have been outlined, and it has been found that the most promising prospects of that region are located near the borders of these eruptive masses. The ore deposits may be in the auriferous slates or the eruptive rock, but in either case they are not far from the contact.

Traces of coal have been discovered in the Chico and Ione formations, but no deposits of considerable value are yet known in the region of Lassen Peak. The Tuscan tuff has furnished some excellent material for chimneys, hearths, and water coolers. The large deposit of diatom earth on Pit River, having a thickness of over one hundred feet and a length of several miles, is of economic importance for polishing, packing, making explosives, and other purposes.

*U. S. Geologic Atlas, Folio 17, Marysville, California, 1895.*

This folio consists of two pages of text descriptive of the Marysville tract, signed by Waldemar Lindgren and H. W. Turner, geologists, and G. F. Becker, geologist in charge; a topographic map (scale 1 : 125,000) of the tract, a sheet showing the areal geology, another showing the economic geology, and a third exhibiting structure sections.

*Topography.*—The Marysville tract includes the territory between the meridians 121° 20′ and 122° and the parallels 39° and 39° 30′, and contains 925 square miles. The tract is located near the center of the Sacramento Valley. The larger part of it is occupied by the alluvial plains of the Sacramento and Feather Rivers. The extreme northeastern corner includes the first rolling foothills of the Sierra Nevada. In the center of the tract rises the isolated mountain group of the Marysville Buttes.

*General geology.*—The alluvial lands consist of sands, clays, and gravels, deposited by the shifting currents of the streams. The foothill region of the northeastern corner is principally occupied by the gravels of Pleistocene and Neocene age. The area composed of the bedrock series of the Sierra Nevada is small and consists of diabase and porphyrite. The mountain group of the Marysville Buttes is an extinct volcano of probably late Neocene age, the internal structure of which is to a certain extent laid bare by erosion. The eruptive rocks of the buttes are andesites and rhyolites. In describing the structure of the group three parts may be distinguished: First, the central core of massive andesite and rhyolite; second, the upturned sedimentary rocks surrounding the massive core, evidently brought into their present position by the force of the ascending lavas; the sediments are of Eocene and Neocene age; third, the external ring of tuffs and breccias. The feature of greatest interest in connection with the Marysville Buttes is doubtless the presence of upturned sediments around the central core.

*Economic geology.*—The shore gravels in the northeastern corner contain some gold and have been washed superficially. Somewhat auriferous gravels are also found in the upturned sediments of the Marysville Buttes. Coal and natural gas have been found in small amounts in the Marysville Buttes.

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*Iowa Geological Survey.* Vol. IV., Third Annual Report, 1894, with accompanying papers. SAMUEL CALVIN, State Geologist, Des Moines, 1895.

The fourth volume of the reports of the Iowa Geological Survey has been issued and distributed. So far as size and general make-up are concerned this volume is uniform with those previously issued. About fifteen pages are devoted to Administrative Reports and the remainder of the volume, which contains 467 pages altogether, is devoted to county geology. The geologists of Iowa have adopted the county as the areal unit for final geologic mapping and report. "The boundaries of counties are definitely located and generally known. The county is one of the organic units of civil government. Its inhabitants are bound together by common purposes, and have a common pride in its resources and in whatever promotes its welfare. Definite information regarding the resources of his county as such has more interest to the ordinary intelligent citizen, . . . . than a report on an area embracing probably parts of several counties, though that area lend itself more naturally to scientific investigation, because limited by natural geographic features or distinguished by some peculiarities of geologic structure."

The first work of the Iowa geologists was necessarily in the nature of a general reconnoissance of the entire field. That work done, the energies of the Survey will hereafter be chiefly devoted to areal geology, the county in each case being the areal unit. The present volume contains reports on six counties: Allamakee, Linn, Van Buren, Keokuk, Mahaska and Montgomery. Reports on two counties, Lee and Des Moines, were included in Volume III. Geological maps of the several counties are published on a scale of one-half inch to the mile.

*Geology of Allamakee County.*—The volume proper begins with the geology of Allamakee county, by Samuel Calvin. This county is somewhat unique among the counties of Iowa in that it lies almost wholly within the *Driftless Area.* Its topography therefore is such as would be produced by the chemical and mechanical effects of destructive agents acting, for a somewhat limited period, on beds of limestones, sandstones and shales in a region standing from 600 to 700 feet above base level. The main streams have cut their channels to base level, and the dividing ridges have their sides deeply scarred and gashed by multitude of divaricating erosion channels indicative of greater or less progress in the work of bringing down the ridges to the same level. The tops of the ridges are regarded as co-incident with an old peneplain, and the difference in altitude between this peneplain and the base level of the present streams measures the amount of elevation that the region has suffered since the original peneplain was completed.

The geological formations of Allamakee county include the Saint Croix sandstones of Cambrian age, and the Oneota limestone, Saint Peter sandstone and Trenton and Galena limestones of the Lower Silurian. Overlying the indurated rocks are beds of residual clays and sands, while over nearly the whole county there is in addition a thin mantle of loess. A few erratic bowlders, probably overwash from the margin of the drift, are scattered over the southwestern part of the county. The report is embellished with a number of engravings that are chiefly illustrative of the topographic features of the county. The economic products of the county justly receive a fair share of attention.

*Geology of Linn County.*—By WILLIAM HARMON NORTON. This paper contains several paragraphs of general interest. The Devonian series in the county is divided into the Cedar Valley stage and the Wapsipinicon stage. The latter embraces the Upper Davenport beds, equivalent to the Gyroceras beds of Calvin, and to the Upper Helderberg of Hall, and the Carboniferous of Barris; the Lower Davenport beds not before delimited; the Independence Shales described for the first time in natural sections, and a new basal terrane termed the Otis beds, whose characteristic fossil is *Spirifer Subumbonus*, Hall. Above the Le Claire, the highest member of the Upper Silurian hitherto recognized, were found two new formations, transition beds to the Devonian and named the Bertram and Coggan.

Of special interest to glacialists are the sections and maps showing the form and structure of the unique glacial hills of this region, the Paha. They are treated as loess-capped drumloid accretions of till.

*Geology of Van Buren County.*—By C. H. GORDON. Van Buren county lies on the southern border of the state with one county (Lee) lying between it and the Mississippi River. The main drainage is effected by the Des Moines River which cuts it diagonally from the northwest to the southeast. The surface consisted originally of a broad level plain having a gradual slope toward the southeast.

The indurated rocks belong entirely to the Carboniferous formations, including the Burlington, Keokuk, Saint Louis and Lower Coal Measure stages. The Burlington is represented by the upper chert beds, to which the name Montrose cherts is here given. The stratigraphy of the region is described in considerable detail, and errors of previous writers corrected. Some of the points of interest brought out in the paper are the following: a revision of the classification of the Keokuk and Saint Louis formation, and the plane of separation between these more satisfactorily defined (See Journal of Geology, Vol. III, No. 3, 1895); the origin of the ox-bow bend of the Des Moines (a topographic map of the area is given showing terraces up to 145 feet above the river); the erosion unconformity between the Lower Carboniferous and the Coal Measures.

*Geology of Keokuk and Mahaska Counties.*—By H. FOSTER BAIN. These two adjoining counties lie in the southeast central portion of the state well to the eastern border of the coal field. In general geological features they are essentially similar. The indurated rocks include the Augusta and Saint Louis limestones and the Des Moines Coal Measures. The first two are, for this district, conformable. The erosion unconformity between the Saint Louis and the Des Moines is strikingly exemplified in Mahaska county at Corrier's Mill and Raven Cliff, and in Keokuk county at What Cheer. The Saint Louis in its full section shows from the top downwards (*a*) Pella beds, fossiliferous marls and bedded limestones, (*b*) Verdi beds irregularly alternating limestones and sandstones; and (*c*) Springvale beds, blue shales and earthy magnesian limestones. The Des Moines beds are made up largely of shales, with certain heavy sandstones and at least two coal horizons of which the lower is widespread and well opened up, and the upper is confined to a small portion of the Muchakinock Valley. The two counties are important coal producers, their aggregate tonnage for the year 1893 being 1,363,880 tons. The sandstones of the Coal Measures seem to mark local differences in sedimentation rather than a general horizon. There is evidence of some erosion during Coal Measure time. A series of slight parallel anticlinals cross the county from northeast to southwest.

The drift covers both counties in a sheet of very irregular thickness. It includes blue and yellow tills, local gravel and sand deposits, and an overlying silt or loess-like bed. The latter reaches no great thickness, but is an important source of material for clay-working industries, the total value of whose products for the year 1893 was $120,312. No distinct evidence of a well-marked forest bed is found and the correlation of the drift with that of other portions of the state is not attempted. Glacial striæ being S. 42° E., and a later set bearing S. 70° E. (magnetic), are found near Eddyville. The reports are illustrated by figures, half tones, cross sections and maps. On the map of Keokuk county a small area in Section 7 of Liberty Township, which the text shows to be Coal Measures, is by mistake colored as Saint Louis.

*Geology of Montgomery County.*—By E. H. LONSDALE. The exposed geological formations of Montgomery county represent three systems, the Pleistocene, the Cretaceous, and the Carboniferous. Alluvium, loess and till make up the Pleistocene, and the combined thickness of these three deposits amounts to nearly 100 feet. The Cretaceous, which consists for the most part of friable grits, constitutes the southern extremity of the formation in Iowa. Although present as outliers, the maximum thickness of the deposit is as much as 115 feet. It is possible to consider these soft sandstones, with the associated clay shales and conglomerates of the same age, as Dakota—the Nishnabotna of White.

The Carboniferous is represented by only the Upper Coal Measures which here has a thickness of approximately 1500 feet; while the entire Upper Carboniferous is found to be about 2000 feet thick. To a depth of several hundred feet the Upper Coal Measures is made up almost exclusively of argillaceous shales and hard limestones. Occasional bituminous seams are prevalent, but heavy veins of coal are certainly not present within accessible depths and deep borings indicate that none occur even to the base of the Upper Carboniferous.

The district is supplied with various materials of great economic value. The eighteen-inch seam of coal found near the drainage level in the northwestern quarter of the county is being quite extensively mined. The clays from two of the geological horizons are being used in the manufacture of various marketable products. The limestone ledges are being quarried at several points and utilized as building-stone, but the rock is also suitable for lime-making. There is also an abundance of less important yet useful substances. The fertility of the loess soil is probably not inferior to that of any other locality in the state.

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*How Old is the Mississippi?* By FRANCIS M. FULTZ. Proc. Iowa Acad. Sci., 1894. Vol. II., p. 39. Des Moines, 1895.

The evidence set forth goes to show that the present Mississippi drainage system existed as early as the beginning of the Upper Burlington epoch; and that, although interrupted by frequent and perhaps prolonged submergences, it nevertheless still remains practically the same.

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*Glacial Markings in Southeastern Iowa.* By FRANCIS M. FULTZ. Proc. Iowa Acad. Sci., 1894. Des Moines, 1895. Pp. 213–217.

Recent discoveries of glacial scorings in southeastern Iowa are reported as follows: Near Kingston, in the northern part of Des Moines county, two patches within about half a mile of each other. The first presents a perfectly level surface, over one hundred feet in length and from ten to twenty-five feet wide. The floor is covered with striations and grooves, all finely preserved. Four different sets can be easily determined. The grooves are straight and parallel; those from the latest series being fully an inch deep, while those from the earlier one are nearly obliterated. The trends given in the order of apparent age are as follows: 1. S. 30° 15′ E. 2. S. 64° E. 3. S. 60° 30′ E. 4. S. 72° 15′ E. Corrected for magnetic deviation. Aside from the direction of the striæ, all evidence points to a southeasterly flow of the ice sheet.

The second Kingston exposure lies on the brow of the bluff, facing the Mississippi flood plain, and extends for some distance down the face, descending at an angle of about 30°. There is but one set of markings, the trend being approximately 72° east of South. The bluff faces nearly due east.

In the Loftus quarry, four miles west of the city of Burlington, a large area was uncovered, showing both surface and lateral erosion. There was but one series of striæ, the direction being S. 75° E. The lateral erosion very strongly indicated the direction of ice flow to have been toward the Southeast.

Two other patches of scorings, about four miles northwest of Burlington, and located not more than forty rods apart, showed widely different trends. One was S. 33° E.; the other S. 73° E. Both surfaces were too badly weathered to furnish good corroborative evidence of direction of ice flow.

All the scorings above given are on the hard, compact limestone of the Upper Burlington formation, and are situated on or but a few miles back from the brow of the bluff that borders the old flood plain of the Mississippi.

Glacial markings previously reported from the vicinity of Burlington are as follows: By White, S. 15° E.; by Keyes, S. 63° E.; by Leverett, S. 65° E.

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*The Erosive Action of Ice.* By G. E. CULVER. Trans. Wis. Acad. Sci., Vol. X., 1895.

This paper reviews briefly much of the literature relating to ice action, from the time of Ramsay to the present, and records some personal field observations bearing on the subject.

The author concludes that the erosive power of ice has been exaggerated in the past; that its transporting power has not been clearly discriminated from its eroding power; that it probably did not make rock basins, much less valleys; that in general its effect was to cut down prominences and fill depressions, and thus to lessen rather than to strengthen relief. He regards the drift as largely composed of material furnished by preglacial decay of northern rock. With this was mingled such fresh material as the ice could break from projecting points, and tear or wear from its bed.

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*Crystalline Limestones, Ophicalcites and Associated Schists of the Eastern Adirondacks.* By J. F. KEMP. Bull. Geol. Soc. of Amer., VI., 241–262, 1895.

As study of the crystalline rocks in the eastern Adirondacks has progressed, it has become evident that in the gneissoid rocks on all sides of the Norian intrusions of anorthosites and gabbros, and extending well up between their ridges, crystalline, graphitic limestones, ophicalcites, and associated black hornblendic schists are met. Interlaminated with these are feldspathic gneisses, and occasionally graphitic quartz-schist, rich in sillimanite. The paper gives geological sections at Port Henry, and in western Moriah township, to show these relations. A most peculiar exposure in the Keene Valley, and well within the great anorthosite ridges, is also described, together with its intruded rocks—which are very similar to the Saxon granulites. In conclusion, the author briefly summarizes his conception of the rocks as a metamorphosed series of impure calcareous sediments.

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*The Stratigraphy of the Kansas Coal Measures; Division of Kansas Coal Measures; The Coal Fields of Kansas:* By ERASMUS HAWORTH. *Kan. Univ. Quart.*, Vol. III., April 1, 1895, pp. 271-309, with two plates.

The articles with the above titles are summaries gleaned from chapters already prepared for Volume I. of the University Geological Survey of Kansas, which it is hoped will be completed during the year. Under the first heading is given a general description of the principal limestones and shale beds from the base of the Coal Measures to the Cottonwood Falls limestone, a vertical distance of 2500 feet or more. At the base of the column lie the heavy Cherokee shales, which are the principal coal-bearing shales of the state. Above these are successive limestones and shales, the whole aggregating a total thickness of 2750 feet. But the author states (p. 272) that probably no one place could be found where the thickness would be quite so much.

Plate XX. represents this column. Plate XXI. is a semi-perspective map of the east end of the state, on which is shown outcroppings of the principal limestone formations.

The author divides the Kansas Coal Measures, in the second article, into two divisions, the Upper and the Lower, with the top of the Pleasanton shales serving for the division line. In the last article, the geologic and geographic position of each of the principal coal beds is given, with tables of analyses of the coals by Professor Bailey, and of the steam heating properties by Professor Blake.

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*Annual Report of the State Geologist of New Jersey, for 1894.* Part I. Surface Geology: 149 pp. and 4 plates. By ROLLIN D. SALISBURY.

The titles of the several sections of the report are as follows: Sec. I. General Outline Sketch of the Drift Deposits of New Jersey North of the Moraine; Sec. II. The Glacial Striæ of New Jersey (with map); Sec. III. Changes in Drainage Effected by the Drift; Sec. IV. Postglacial Changes in Drift Area; Sec. V. Beacon Hill Formation; Sec. VI. Pensauken Formation; Sec. VII. Jamesburg Formation; Sec. VIII. Post-Jamesburg Formations; Sec. IX. Road Material; Sec. X. Explanation of Map of Surface Formations of Sheet 6, New Jersey Atlas.

In Section I., in addition to the matters implied in the title, details and sections (Pl. I) are given, showing the conditions under which the stratified drift of the valleys was deposited, and many details concerning the effect of stagnant ice on drift accumulations. In Section III., it is represented that while the ice effected many minor changes in the drainage in New Jersey, there were few of great extent outside the basin of the Passaic, and possibly the Raritan. The lakes of the state are classified with reference to the origin of their basins. In Section IV., emphasis is laid upon the trivial amount of erosion suffered by the northern part of the state since the drift was deposited. In Section V., the conclusion is reached that the Beacon Hill formation is of Miocene age; in Section VI., that the Pensauken is the equivalent of the Lafayette; and in Section VII., that the

Jamesburg formation corresponds with the Columbia. A twofold division of the Jamesburg is recognized, corresponding, in all probability, with the "high level" and "low level" Columbia of the south, as described by McGee and Darton. Sections (Pl. III.) are given showing the topographic and stratigraphic relation of the formations referred to in Sections V.–VIII. The report is accompanied by a map of the surface formations of the area covered by Sheet 6 (Basin of the Passaic and surroundings) of the New Jersey atlas, and Section X. is a brief statement intended to assist in an understanding of the map.

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*The Stone Industry in 1894.* By WM. C. DAY. Sixteenth Ann. Report U. S. Geol. Survey, Part IV., 83 pp., 1895.

This report forms a part of the volume "Mineral Resources of the United States." It shows by numerous statistical tables the condition of the stone industry of the country in 1894 and compares this with former years. The various kinds of stone considered are included under the heads granite, marble, slate, sandstone, limestone and bluestone. The term granite is used in the broad commercial sense and includes rocks of igneous and crystalline siliceous character. The total value of the stone output in the United States in 1894 was a little more than $37,000,000 being a gain of about $3,500,000 over 1893.

The distribution of the active quarries is shown by states and counties. Many analyses and results of physical tests are recorded, and the present methods of quarrying, dressing and manufacturing the various kinds of stone are given in some detail. It is also shown that indications early in the present year point to 1895 as a period of increased activity in quarrying operations.

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*The Rocks of the Sierra Nevada.* By H. W. TURNER. Fourteenth Ann. Report, U. S. Geol. Survey, pp. 435–495, 12 plates and 3 figs. 1895.

The following sedimentary terranes are recognized: Grizzly formation (Silurian), Calaveras formation (Lower Carboniferous), Robinson formation, chiefly tuffs (Upper Carboniferous), and Juras-Trias beds. All of the above terranes together with the associated igneous rocks were upheaved and folded at the close of the Jurassic. On their upturned edges rests a series of late Cretaceous, Tertiary and Pleistocene sediments and lavas.

The igneous rocks are divided into an older series of Jura-Trias and Palæozoic age comprising diabase and porphyrite, gabbro, norite, peridotite and pyroxenite, granite, quartz-porphyrite, quartz-porphyry and diorite, and a later series comprising rhyolite, andesite and various basalts.

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*Results of Stream Measurements.* By F. H. NEWELL. Fourteenth Ann. Report of the U. S. Geol. Survey, 60 pp. and 2 maps, 1895.

This paper gives the results of operations of the Division of Hydrography up to 1893, showing in concise form the mean monthly, minimum and maximum discharge of rivers in various parts of the United States. Most of the streams measured are in the West, where data of this character have especial value in considering the question of irrigation, and to a less extent that of water power. There are also given facts concerning some of the eastern streams. The most important feature of the paper, however, is to be found in the last part, in a discussion of the depth of run-off for the United States and the relation between mean annual rainfall and mean annual run-off. To illustrate, this small diagrammatic maps of average annual precipitation and run-off are given, and a diagram showing the general relationship between these. This discussion is necessarily general and preliminary to the preparation of more detailed maps which can be made only after observations have been carried on through many years.

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*Report on the Coosa Coal Field with Sections.* By A. M. GIBSON, Assistant Geologist, Pp. 143, 1 plate. Geological Survey of Alabama. Montgomery, 1895.

This report deals with a coal field which, though long known, has not heretofore been adequately brought to public notice. This field is about sixty miles long by five to eight wide containing 345 square miles of productive area. It lies mainly in St. Clair and Shelby counties, the most southeastern division of the Alabama coal field. It lies in a synclinal fold of coal measures between the Cahaba and Coosa (Silurian) valleys. The reports shows that this field contains much undeveloped coal, embracing a large number of minable seams, some of which are of unusual thickness. The coal is generally very good, low in ash and sulphur, hence well adapted for raising steam and forge work. Its coking qualities are specially commended. It is claimed that the well-known fact that the best coking coals in Pennsylvania and West Virginia lie toward the eastern side of this coal field is equally true of Alabama. A comparison of the cokes produced in these three regions seems to prove that this claim is well founded.

At present peculiar economic conditions confine active mining to two points. It is confidently hoped, however, that these conditions will be overcome in the near future, and that extensive developments will result from the information disseminated by this report.

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*The Structure of Monument Mountain in Great Barrington, Massachusetts.* By T. Nelson Dale. Fourteenth Ann. Report of the U. S. Geol. Survey, pp. 557–65.

Following up some studies of the late Professor J. D. Dana, the author shows that this mountain is either of Cambrian age and separated from the Silurian schist mass of Lenox Mountain on the north by a zigzag fault, similar to that described in his other paper as occurring at Dorset Mountain, or else of Lower Silurian age with either a sharp fold or normal fault on its eastern side. The latter view involves a local change in the character of the Silurian sediments.

Since the publication of the paper the author has revisited the locality with Professors C. R. Van Hise and B. K. Emerson who regard the fault theory as the more probable one. The question then arises whether such a transverse fault would not necessitate a longitudinal fault on one or both sides of the mass.

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*On the Structure of the Ridge between the Taconic and Green Mountain Ranges in Vermont.* By T. Nelson Dale. Fourteenth Ann. Report of the U. S. Geol. Survey, 1895.

A topographic and geologic map of four square miles of the ridge, sections, sketches and illustrations of clearage phenomena, "torsional grooving," Pteropod oölite, etc., are given. The ridge is a complex anticline of Lower Cambrian quartzite, etc., overlain by the Cambro-Silurian "Stockbridge Limestone" followed by the Lower Silurian "Berkshire schist," measuring 2000–3200 feet. This anticline is faulted by a double fracture letting down a block several hundred feet wide into the anticline to a depth of 1500 feet and in other places by a reverse fault showing the Cambrian over the Silurian. The fault is twelve to eighteen miles long. In Danby the ridge is crossed by a zigzag E.-W. transverse reverse fault bringing the Cambrian to the level of the Silurian with a vertical displacement of 1450 feet, accounting for a large part of the height of Dorset Mountain.

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*Notes on the Stratigraphy of the Cambro-Silurian Rocks of Eastern Manitoba.* D. B. DOWLING, B.A.Sc. Ottawa Naturalist, Vol. IX., No. 3.

Below the Hudson River shales, the limestones are provisionally divided into a lower and upper Mottled, with a dividing band of fine grained limestone holding cherty nodules. The basal member of the series is a soft sandstone with shaly partings grading downwards to a friable sandstone which may be correlated with the St. Peter's sandstone. The distribution of these divisions is discussed and shown on a sketch map. The thickness of the formation is estimated from exposures on Lake Winnipeg at 580 feet. This is compared with sections obtained from borings within the district.

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*Tertiary Revolution in the Topography of the Pacific Coast.* By J. S. DILLER. U. S. Geol. Survey, 14th Ann. Report, pp. 397–434.

An ancient peneplain is traced about the northern portion of the Sacramento valley and the western slope of the Sierra Nevada. It was once covered with residual material that gave rise to the earlier auriferous gravels.

The topographic revolution consisted in the development out of such lowland conditions of the conspicuous mountain ranges of today. The northern end of the Sierra Nevada was raised at least 4000 feet, and a fault was formed along the eastern escarpment. As the uplift progressed the rejuvenated streams at first accumulated the auriferous gravels and finally, displaced by volcanic flows, cut deep canyons down the western slope of the range.

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*The Kame-Moraine at Rochester, New York.* By H. L. FAIRCHILD. Am. Geologist, Vol. XVI., July 1895.

The "Pinnacle" hills at Rochester, New York, with their complex and puzzling structure, are explained as a frontal moraine, with a preponderance of water-laid drift. The eastern half of the range is a ridge-like series of sand and gravel knolls, with considerable till, the latter partially as a capping. The western half of the range is a typical kame-area. The topography of the whole range is decidedly morainic. With a trend of about 15° south of west the whole range forms part of a curving moraine which beyond the Genesee River swings north of west toward Albion. A critical fact is the discovery of a late system of glacial striæ, over all the vicinity, at right angles to the range, or radial to the arc of the curving moraine. These features are shown by a sketch map.

Certain structural features, as the occurrence of extensive deposits of horizontal fine sands and silts, sometimes occupying the whole breadth of the range, are explained by deposition in the water of the glacal Lake Warren, which is believed to have laved the retreating ice-front throughout western New York.

The paper enumerates other kame-areas in the region, two of which are of much greater bulk and area than the Pinnacle hills.

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*Essential Properties of Building Stones.* By H. FOSTER BAIN. Reprint Monthly Review Iowa Weather and Crop Service, 22 pp., Des Moines, 1895.

This essay presents in convenient form a summary of information on the subject. It is intended for popular distribution so citations to original authorities are omitted. The essential properties of a stone in relation to its use for building purposes are considered to be (1) Strength, (2) Durability, (3) Color, (4) Workability, (5) Availability. The first two topics are treated more fully as being of the greater importance.

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*Recconnaisance of the Gold Fields of the Southern Appalachians.* By GEO. F. BECKER, Ann. Rep. U. S. Geol. Surv. 1894–5. Part III.

This report is based on field work done in 1894, but the work of previous observers in the same area is of course taken into consideration. It also includes a digest of the literature dealing with the gold deposits of Nova Scotia and other northerly auriferous districts, the purpose being to present in a single paper the most noteworthy facts of gold occurrence on the entire eastern side of the continent. The total production of the Southern Appalachians to the end of 1894 was over $45,000,000, which has come chiefly from the Carolinas and Georgia. The deposits are distributed along belts which are parallel to the general trend of the Appalachians. The primary deposits are real veins or secondary impregnations, not beds as has sometimes been maintained, and the ores are similar to those in most gold-bearing regions. They are quartzose masses with very subordinate admixtures of carbonates in which pyrite is always present while chalcopyrite is common and galena, mispickel and zincblende are not rare. The veins commonly follow the schistosity of the pre-Cambrian schists and include fragments of the wall rock. The impregnations occur chiefly in Algonkian fragmental volcanics similar to those of the South Mountain of Pennsylvania. The deposition of ore is associated with intrusions believed to belong to the same Algonkian epoch, but it is more recent than the mountain building era during which the schistose structure was developed. The veins were opened by normal faulting and no indications of the replacement of wall rock by quartz were detected. The term "stringer lead" is proposed for a group of small auriferous veinlets such as usually constitutes the basis of economical operations in the South and is very common in California and Australia. The impregnations, that of the Haile mine for example, are similar to the Norwegian Fahlbands. The ores of the Maritime Provinces appear to be of the same age as those of the South and to resemble them closely. The placers of the southern Appalachians are in part stream gravels and in part consist of quartz-bearing rock, which is in place but entirely decomposed. The term "saprolite" is used to denote such untransported but thoroughly rotten rock. In the South the saprolite forms a blanket which is generally from 30 to 100 feet in thickness. About half of the report deals with the deposits systematically and the remainder consists of descriptive notes on the different areas.

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