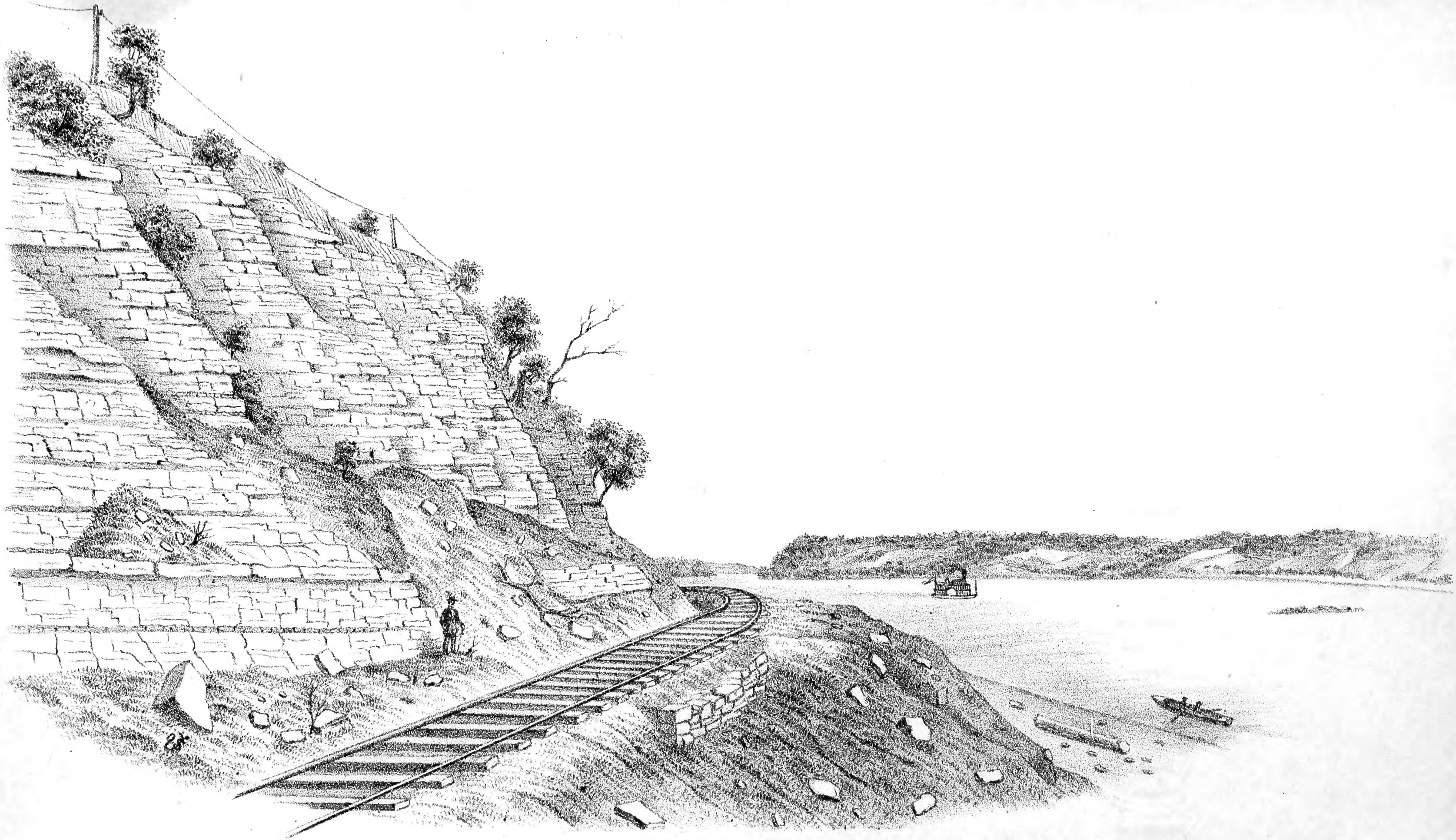
Prof. Theo. Gill
with regards of
C. A. White



Mills & Co. Lith. Des Moines.

VIEW ON THE MISSISSIPPI AT FOOT OF THE "KEOKUK RAPIDS", LOOKING UP THE RIVER, NORTHWARD.

Bluff exposure of the Keokuk Limestone above the city on the K. & St. Paul R.R. On right, Bluff on Ills. shore.

(Sketched from near the upper end of the coffer-dam 1868)

REPORT

ON THE

GEOLOGICAL SURVEY

OF THE

STATE OF IOWA,

TO THE THIRTEENTH GENERAL ASSEMBLY, JANUARY, 1870, CONTAINING RESULTS OF EXAMINATIONS AND OBSERVATIONS MADE WITHIN THE YEARS 1866, 1867, 1868, AND 1869.

By CHARLES A. WHITE, M. D.

GEOLOGICAL CORPS:

Charles A. White, -	*State Geologist.*
Orestes H. St. John,	*Assistant.*
Rush Emery, - - -	*Chemist.*

VOLUME I.

DES MOINES:
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PREFACE.

There is probably nothing an author regrets more than to be obliged to publish the results of his labors in an incomplete form. While all fall short of their wishes in this regard, it is not unfrequently the case, that the nature or magnitude of the subject treated renders a near approach to perfection impossible. This is especially true of geological subjects, and peculiar trials beset those who undertake the preparation of reports upon State Geological Surveys, as they are usually organized. Instead of adopting a definite policy for the work, and making suitable and reliable provision for maintaining it until it shall be completed upon a carefully devised plan, the State Legislatures usually authorize these surveys by special legislative acts, appropriating, at the same time, only sufficient funds to commence them. These acts are not only liable to be repealed by any subsequent legislature, and the work thereby arrested, but it is in constant danger of being suspended by the failure of those legislatures to provide funds for its support. Examples of such legislation may be seen in the copies of laws in the historical part of the introduction on pages eight to twelve.

Under such circumstances, the person appointed to conduct the work feels obliged to adopt, not such plans as he knows to be best in case it were sure to be completed, but such as will ensure the most creditable results for the short time he may have charge of it. Thus, the full realization of the objects for which the people, through their representatives, support these works, is seldom attained.

In gathering together the results of the past four year's labor to be embodied in this report, which is ordered to be published without further addition, it has been my aim to so arrange and present them that the subjects treated should be not only as complete in themselves, as the circumstances would permit, but that the report should also serve as a basis for future labor of the kind, if the legislature should ever order it.

Besides the mention in my letter to the Governor, on pages three and four, of persons who have conferred especial favor while the survey was in progress, I desire here to acknowledge the earnest efforts of the publishers, Messrs. Mills & Co., to present the work to the public in a creditable manner in all its parts.

C. A. WHITE.

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LETTER TO THE GOVERNOR.

To His Excellency, Samuel Merrill, *Governor of Iowa.*

Sir:—I have the honor of laying before you my report embracing the greater part of the results of the labors of the State Geological Survey performed by myself and under my direction during the years 1866 to 1869 inclusive. The work was undertaken and prosecuted during the first two years with a view to its full completion, but by the act of the Twelfth General Assembly, I was required to "complete the Geological Survey of the State on or before the first day of January, 1870, and to prepare a full and complete report of the said Survey, accompanied by such maps and drawings as may be necessary to illustrate the same, and transmit them to the Governor, who shall lay a copy of such report before the next General Assembly."

The work of only a general reconnoissance has been so great that it has been impossible to fulfill this requirement, and as that fact was anticipated and so stated in my report to your predecessor, Governor Stone, and by him laid before that General Assembly, I have felt obliged to regard the clause just quoted as a direction to *discontinue* the work at the time designated. I have therefore made arrangements for the employment of my time, in professional duties, at the State University from and after the close of the present year. This explanation is made for no other purpose than to account for the incomplete form in which the report is now presented.

Although it is believed that the report, as herewith presented, contains much material of great practical value and scientific interest, as well as a nearly complete general view of the geology of the State, it comprises only a part of the whole work to be done. Besides the matter more or less thoroughly digested and presented in this report, the Survey and its different members are in possession of much other valuable matter, the results of uncompleted observations, that is yet too imperfect for publication. This will necessarily be entirely lost unless the observations are completed. Again, a very important work is now arreste in the very midst of its usefulness. This is the detailed examination of th Lower coal-measure formation, which is known to contain far the most important part of the coal of the State. These observations could not have been intelligibly made before, by omitting others that have been made, because they must be based upon more general observations previously accomplished.

It is especially desirable that this unfinished work in the coal-field and elsewhere should be completed, and the results embodied in this report before it is published. A small appropriation only, in addition to what now remairs unexpended in the treasury, would be sufficient to do this if it is decided not to complete the whole work in an exhaustive manner. Should the next General Assembly desire it, the additional work can be accomplished within the next two years by myself and my able assistants during the vacations of the institutions with which we are respectively connected.

As the former geological report, made under the direction of Prof. James Hall, of Albany, New York, was devoted exclusively to the eastern half of the State, the labors of the Survey as organized under my own direction have been largely devoted to the western half. However, so far as the mineral and other material resources of the State are concerned, it has been my object to present them as fully as practicable in this report without regard to the part of the State in which they occur. In presenting the general geology of the whole State, as well as some of the details of that of its eastern half, I have necessarily repeated some of the matter contained in that former report, but even this is largely the result of observations made by the different members of the Survey as at present organized. This limited repetition was thought to be desirable rather than objectionable from the fact that, the former report being out of print, very few of those into whose hands this report shall fall would otherwise be able to obtain a general view of the geology of the whole State. The chapter in the former report by Prof. J. D. Whitney upon the lead mines of Dubuque, presented the subject in so complete a manner and the account of his labors there given has proven so reliable and satisfactory after a lapse of more than ten years, that I have deemed it unnecessary to make any special examination of that region, and have necessarily confined myself there to such investigations only as subsequent time has suggested as supplemental to his labors. There would be great propriety in republishing Prof. Whitney's report upon the Dubuque lead mines. With this exception, I have endeavored to embrace all the important matters connected with the geology of the State, giving especial attention to such subjects as pertain to its material wealth; leaving those of a more abstract scientific character to a future time.

This report, therefore, embraces the following subjects, namely:

1. Physical Geography and Surface Geology, including observations upon the soils and sub-soils, drainage systems, general topography, etc., with numerous illustrations.

2. General Structural Geology of the whole State illustrated by maps and diagrams.

3. County and Regional Geology, especially considered and illustrated.

4. Mineralogy, Lithology, and Chemistry, including, besides the Chemist's report, an account of the stone, clays, minerals, etc., of the State and of their economic value.

Referring more definitely to some of the many important and interesting subjects that have engaged the attention of myself and my assistants, I may mention the satisfactory solution of the question as to the relative position of the strata that underlie and overlie the coal-bearing formations and the determination of their dips and trends. As a result of this, the opinion is confidently expressed that coal may be sought for over the whole of southwestern Iowa with reasonable hope of finding plentiful supplies at a not unusual depth as mined in other countries and in other parts of our own. Thus we have reason to hope that the present known coal-area of the State, amounting to about seven thousand square miles, will be doubled by the discovery of coal at some depth beneath the surface of an equal area of southwestern Iowa.

The existence of large quantities of excellent peat has also been fully demonstrated and reported. I have also lost no opportunity of assuring the public that all kinds of our indigenous forest trees will grow with wonderful thriftiness upon all varieties of our prairie and other soils wherever they are protected from the prairie fires. These facts show that the future supplies of fuel for both the present and prospective inhabitants of our State are to be abundant and certain.

Of minor, but yet very important subjects, I may mention the demonstrated value of some of our magnesian limestones for the preparation of hydraulic lime; of the Fort Dodge gypsum for all the uses to which that substance is applicable in the arts, sciences, and agriculture, etc., etc.

For reasons given, I have not hesitated to discourage all explorations for mineral oil or the precious metals in any part of the State. I have also endeavored to show that although iron ore of good quality has been frequently found in various parts of the State, and in different formations, it is always in very limited quantity; and in view of the bountiful supplies to be obtained elsewhere in our country, the best of ours in Iowa is practically valueless so far as now known. I have endeavored to point out the hazard of exploring for coal beyond the northern and eastern boundaries of the coal-field as designated upon the geological map and explained in the text; and to indicate the certainty of failure if such explorations are undertaken at any considerable distance beyond those borders. These unpleasant truths have been plainly presented, knowing that the people would be as faithfully served by designating the character of such enterprises as will be sure to entail serious loss, as by designating the limits within which they may hope to succeed.

The reports of my assistant, Prof. O. H. St. John of the Iowa State Agricultural College, will be found in the chapters which bear his name. While calling your attention to these, I wish to express to you my indebtedness to him for important aid also in the labors, the results of which are given in the chapters on northwestern Iowa and on the gypsum region of Fort Dodge; of both of which he may with propriety be regarded as the joint author. Of the results of his labors the public have now an opportunity to judge, but I would do injustice to myself if I should allow this opportunity to pass without expressing to your Excellency my unqualified admiration of the manner in which he has performed his arduous duties during the past three years. He has shrunk from no labor, however severe, and from no exposure, however extreme, whenever labor and exposure were necessary to further, in any degree, the interests of the work. All but one of the maps, all diagrams, figures, and sketches which illustrate this report are also the work of his hands.

The chapter on Chemistry, by Prof. Rush Emery, formerly of the Iowa State

University, now of Genesee College, New York, is an important, nay an indispensable addition to this report. Prof Emery has performed his duties with a zeal and conscientiousness worthy of all admiration and I bespeak for his work the full confidence of the public.

It is matter of the greatest satisfaction to myself that both of these gentlemen, amid all the perplexities inseparable from our arduous and peculiar labors, have placed me under especial obligations for their constant kindness.

Besides the assistance of the gentlemen, regularly appointed to the work, I have received important aid from others, much of which was rendered gratuitously. The names of each of these persons will be found in the text in connection with the matter furnished. Among the most important of this gratuitous aid is a series of lists of elevations along the lines of nearly all the railroads in the State, both finished and projected, furnished by their respective Chief Engineers; and the chapter on Meteorology and Climatology by Prof. T. S. Parvin. Prof. Parvin's observations comprise the earliest and most extensive observations of the kind ever made in the State. When it is remembered how intimately Meteorology and Climatology are connected with the most important interest of our Commonwealth, namely: Agriculture; and how great an influence the presence of forests has upon the climate of a region, in connection with the fact that the woodland area of Iowa has constantly increased with the advancing settlement of the State, the value of Prof. Parvin's observations for present and future consultation will be quite apparent.

I employed Mr. W. R. Morley to reduce the data furnished by the railroad engineers, for use in the chapter on Physical Geography. In consequence of the liberal kindness of those gentlemen, the only cost to the survey of that important addition to the report has been the office-work necessary to prepare the material for the printer. The list of elevations will all be found in the form of an appendix (Appendix A) to this report.

Learning that Mr. J. A. Allen, Ornithologist of the Museum of Comparative Zoology, Cambridge, Mass., intended to spend the season of 1867 in Iowa to study its birds, I invited him to make the camp of the Geological Survey his headquarters. He did so, and has generously furnished a list of the birds of Iowa herewith accompanying this report as appendix B. The acknowledged importance of ornithology in relation to our great interest—Agriculture—makes any explanation of the association of such a list with this report unnecessary.

In consequence of the constant necessity of referring to the linear surveys of the general government, in describing the geology of the State in this report, it has seemed necessary that a full explanation of the system upon which those surveys are based should accompany it. I have therefore procured such an explanation from Mr. Chas. W. Irish, Civil Engineer, who is well acquainted with the subject in all its details. It accompanies this report as appendix C.

The chemical department of the survey has been placed under important obligations to Rev. Father Emonds, of St. Mary's Church, Iowa City, for the loan of apparatus from his private laboratory, which it was impossible to obtain elsewhere at the time it was needed.

The trustees of the State University have generously given the use of suitable rooms for the purposes of the survey from the beginning, thereby saving all expenses for rent which would otherwise have been necessary.

Besides the favors received from the gentlemen here named and referred to, the citizens generally have upon all occasions shown the utmost kindness to all persons connected with the work. So numerous indeed have been the kind offices received that the list would be too long to give in this place without doing injustice to some, and I am therefore reluctantly compelled to omit it.

I have the honor to be, your obedient servant,

CHARLES A. WHITE, *State Geologist.*

IOWA CITY, IOWA, Dec. 23, 1869.

GEOLOGICAL SURVEY OF IOWA.

INTRODUCTION.

1. HISTORICAL.

By act of the General Assembly of Iowa, in January, 1855, a geological survey of the State was ordered, and immediately afterwards Prof. James Hall, of Albany, New York, was appointed State Geologist, and Prof. J. D. Whitney, of Northampton, Massachusetts, as Chemist and Mineralogist. The work was continued during subsequent years, Mr. A. H. Worthen, now State Geologist of Illinois, acting a part of the time as field-assistant, when in the winter of 1858–9 their final report was printed in two volumes by order of the General Assembly.

This work has now been before the public more than ten years and its merits are well known. It was expected by those then having the work in charge, and also contemplated by the General Assembly that ordered it, that it would be continued until the whole State had been carefully examined and reported upon.

Consequently that report embraced only the results of labor performed in the east half of the State; and a full consideration also of much of the economic geology of that half was omitted.

No provision was subsequently made for continuing the work until the meeting of the Eleventh General Assembly, when in view of its unfinished condition the re-organization of the survey was ordered in April, 1866, by the following act:

CHAPTER 73.

AN ACT providing for the completion of the Geological Survey of the State of Iowa.

SECTION 1. *Be it enacted by the General Assembly of the State of Iowa*, that for the purpose of completing the Geological Survey of the State, Charles A. White, of Johnson county, is hereby appointed State Geologist and shall hold his office for the term of two years, or until his successor is appointed.

SEC. 2. The State Geologist shall be authorized to appoint a competent assistant, and also a skillful analytical and experimental chemist, who shall report to the State Geologist the analysis of such soils, rocks, coals, ores, and other mineral substances as he may submit to him for that purpose. He shall also have power to employ such further assistance as he may deem necessary to prosecute promptly and efficiently the field-work connected with the survey. All persons employed by him shall be under his direction and subject to removal by him. All the specimens of minerals, fossils, rocks, soils, coals, ores, or other geological or mineral substances of any value or interest to either the practical or amateur geologist, and any drawings or sketches of the same obtained or made by the State Geologist, as well as the copyright of the reports, and all books printed therefrom shall belong to the State, and no specimen, copy, draft, or part of the same, shall be given away or sold, or be permitted to be carried away contrary to the provisions of this act. And the State Geologist or any of his assistants or employes or any other person who shall violate any provision of this section shall be deemed guilty of a misdemeanor.

SEC. 3. It shall be the duty of the State Geologist and his assistants, to carry on with as much expedition as practicable the Geological and Mineralogical Survey of the State, including observations and examinations of the soil for agricultural purposes. He may also include in his report such matters as pertain to physical geography, and such other matters as properly and usually pertain to a survey of this kind; it being expressly required of the State Geologist and his assistant, that these duties be performed in such a manner as to give to the people of the State the greatest amount of practical information in relation to its resources.

SEC. 4. It shall be the duty of the State Geologist on or before the first Monday of January of each year, to prepare a report of said survey and its progress, accompanied by such maps and drawings as may be necessary to illustrate the same and transmit them to the Governor who shall lay a copy of such reports before the General Assembly. The State Geologist shall, as far as practicable, use such words in his reports as are in common use, and that he shall accompany each volume of his reports with a glossary. It shall also be his duty to prepare, from time to time during the progress of the survey, communications for publication in the newspapers of the State, provided it shall be done without expense to the State, embodying such information in reference to the character and quality of the soil, deposits of coal, minerals and other valuable substances as he may deem of general interest and importance to the public.

SEC 5. It shall be the duty of the State Geologist to cause collections to be made of rocks, soils, fossils, coals, ores, and other mineral substances discovered or examined, which shall be disposed of as follows, to-wit: all rare specimens of which duplicates cannot be found, and all specimens from which descriptions or illustrations are drawn for publication shall be deposited in the cabinet of the State University. A full series of the best of such specimens as more particularly exemplify the economic geology of the State shall be deposited in the cabinet of the State Agricultural College. All other specimens shall be distributed to the cabinets of all other organized institutions of learning in the State, giving preference to the State University, the State Agricultural College, and the Medical College at Keokuk.

SEC. 6. For the purpose of carrying out the provisions of this act the sum of six thousand five hundred dollars is hereby annually appropriated for the term of two years, out of such moneys in the treasury as are not otherwise appropriated. This fund shall be drawn from time to time for the purposes of the survey on requisitions signed by the State Geologist and approved by the Census Board. The salary of the State Geologist shall be two thousand dollars annually and the salary of his assistant shall be fixed by the State Geologist in such amounts, not exceeding fifteen hundred dollars annually, and for such periods as he may deem proper, but which shall not exceed the term of his own appointment. The rate of pay of all other persons employed by the State Geologist shall be fixed by him, but shall not exceed the usual price paid for the kind of labor performed, nor in any case shall it exceed four dollars per day.

SEC. 7. All acts and parts of acts in contravention of the provisions of this act are hereby repealed, and all appointments made under the provisions of said acts are hereby annulled.

SEC. 8. This act shall take effect and be in force from and after its publication in the Iowa State Register and Iowa Homestead, newspapers published at Des Moines.

B. F. GUE,
President of the Senate.
ED WRIGHT,
Speaker of the House of Representatives.

Approved, March 30th, 1866.
WM. M. STONE, *Governor.*

Under the authority of this act the work was immediately commenced and prosecuted with the following general objects in view, namely: to obtain a knowledge of the geological structure of the western half of the State and to gather all possible information concerning the mineral and other material resources of the whole State, especially the character and extent of its coal-field; also to make full observations concerning the character of its soils and the physical features of the State. Accordingly the years 1866 and 1867 were spent mainly in the examination of the southern and middle portions of western Iowa, the central portion of northern Iowa, and a number of counties within the coal-field.

At the close of the year 1867, a preliminary report of these labors was presented to the General Assembly which, together with the popular letters written during the two preceding years for the newspapers as required by law, were ordered published in pamphlet form, and the continuation of the work was provided for by the following act:

CHAPTER 178.

AN ACT Providing for the Further Prosecution and Completion of the Geological Survey of the State.

SECTION 1. *Be it enacted by the General Assembly of the State of Iowa,* That for the purpose of the completion of the geological Survey of the State, the present State Geologist be continued in office, and the sum of six thousand and five hundred dollars be hereby annually appropriated out of such moneys in the State Treasury, as are not otherwise appropriated, until the said Survey is completed or until the General Assembly shall order its discontinuance. This appropriation shall be drawn from time to time for the purposes of the survey and the payment of the salaries of its officers as defined and limited in Chapter 73 of the Acts of the Eleventh General Assembly, upon requisitions signed by the State Geologist, and vouchers approved by the Census Board and filed with the Auditor of State.

SEC. 2. The State Geologist is hereby required to complete the geological survey of the State on or before the first day of January, 1870, and to prepare a full and complete report of said survey, accompanied by such maps and drawings as may be necessary to illustrate the same and transmit them to the Governor, who shall lay a copy of such report before the next General Assembly.

SEC. 3. On or before the first Monday in each year the State Geologist shall prepare careful statements of his accounts with the survey for the previous year, embodying them in the form of a financial report, and send the same to the

Governor together with such vouchers as it may be practicable for him to obtain; and the Governor shall lay the whole before the General Assembly, together with the report of progress of the State Geologist.

SEC. 4. All acts and parts of acts in contravention of the provisions of this act are hereby repealed.

SEC. 5. This act shall take effect and be in force from and after its publication in the Iowa State Register and Evening Statesman, newspapers published at Des Moines.

JOHN SCOTT,
President of the Senate.
JOHN RUSSELL,
Speaker of the House of Representatives.

Approved, April 8th, 1868.
SAMUEL MERRILL, *Governor.*"

By reference to these legislative acts the readers of this report will understand the reason why much matter that usually finds a place in reports of this kind is excluded from the present volume, as well as why the work is again discontinued before its completion. The field-work for the years 1868 and 1869 was principally confined to northwestern Iowa and to a general review of various portions of the State that had been before examined.

The Thirteenth General Assembly failed to make any provision for the continuation of the work, but passed the following law providing for the publication of this report:

CHAPTER 111.

AN ACT Providing for the Publication of the Report of the State Geologist and for the Distribution of the same.

SECTION 1. *Be it enacted by the General Assembly of the State of Iowa,* That the Census Board be and are hereby authorized to contract with the present State Printer for three thousand copies of the report of the State Geologist as now presented to this General Assembly; *Provided,* the expense shall not exceed ten dollars per copy for the first one thousand copies, and four dollars per copy for each additional copy. Said report to be equal in every respect, mechanically, to Hall's Geological Report of Iowa, or to the Illinois Geological Reports; the engravings, views, maps, diagrams, etc., to be equally as well executed; and the whole to be bound in two royal octavo volumes; *Provided, further*, that the said State Printer shall in consideration of the copyright of the report, stereotype the work, and retain the plates and the engraved stones and electrotypes, and supply the State on future orders at five dollars per copy.

SEC. 2. The State Geologist shall superintend the publication of said report, and be allowed a reasonable compensation therefor, to be fixed by the Census Board, and paid out of the fund heretofore appropriated for the prosecution of the geological survey, and remaining unexpended.

SEC. 3. That for the purpose of carrying out the provisions of section one of this act, there is hereby appropriated out of any moneys in the State treasury, not otherwise appropriated, the sum of eighteen thousand dollars, or so much thereof as may be necessary.

SEC. 4. That the report, when printed and bound, shall be disposed of as follows, to-wit: Two copies to every member of the Thirteenth General Assembly, every officer of State, and each Judge of the Supreme Court; one copy to each person who was a member of the Eleventh and Twelfth General Assembl*ies*[y]; to each officer of the Senate and House, and each regular reporter of the Thirteenth General Assembly; to the office of each county auditor in the State; to each incorporated college and scientific institution in the State; to each Orphans' Home and Reform School; and to each person who has furnished gratuitous material for publication in the report; twenty-five copies to the State University, the State Agricultural College, the State Geologist, and the State Library; five copies to the Assistant and Chemist of the Survey; two copies each to the Institutions for the Deaf and Dumb, and Blind, and both Hospitals for the Insane; one hundred copies to be placed in the hands of the Governor and State Geologist for distribution to scientific men and learned societies and colleges beyond the limits of the State; the remaining copies to be placed in the hands of the Secretary of State, and disposed of as the Census Board may direct.

SEC. 5. That all acts or parts of acts in contravention of the provisions of this act, are hereby repealed.

SEC. 6. This act shall take effect and be in force from and after its publication in the Daily Iowa State Register, and the Daily Evening Statesman, newspapers published at Des Moines, Iowa.

Approved, April 13, 1870.

SAMUEL MERRILL, *Governor*.

2. POPULAR EXPLANATION.

Although much remains to be done before the geology of Iowa is fully understood in all its details, yet the labors of the survey thus far have resulted in the accumulation of sufficient material to illustrate the general geology of the whole State in an intelligible manner.

The scientific reader is able to select from the text such matters as are of especial use to him without the necessity of any explanation of the principles by which they are determined, but considering the fact that only a few years ago geology was not made a part of even a liberal education, and keeping in view also the further fact that this report is ordered by, and intended for the use of the people, it is thought advisable to give a brief popular explanation of its principles in this introductory chapter.

Even if these circumstances did not exist, it is always the case, that to draw correct inferences from a writer's statements the reader must have a clear understanding of the theories upon which he bases his opinions, and through the medium of which he observes his facts. In addition to this it is intended that the subject-matter of the whole report shall be as free as practicable from technical terms, as the law requires, and that it shall be so arranged by sub-headings that no one will have much difficulty in selecting such matters as he may particularly desire, without being obliged to search through those portions which may not then be of so immediate importance.

Rocks in general may be designated as stratified and unstratified; or in other words, such as lie in more or less regular layers and such as present no indication of layers; being composed of a more or less granular or crystaline mass throughout, and which may usually be broken and wrought in one direction as well as another. Of the latter, granite may be taken as the type and most common example, while of the former, the varieties are very numerous, embracing all the common limestones, sandstones, shales, &c. The term rock is used by geologists irrespective of the hardness of the substance composing it. Thus any regular beds of clay, sand, shale, marl, &c., come under the same general designation of rocks that limestone, sandstone, and granite do. Even coal, since it lies in continuous beds parallel with strata that both underlie and overlie it, is itself a stratified rock, geologically considered. Of the unstratified rocks, we have none whatever in Iowa except the granite boulders so commonly seen in the drift which almost everywhere covers the surface of the State like a mantle, and which forms the soil and sub-soil over much the greater part of Iowa. Therefore all the rocks of Iowa except these granite strangers are stratified rocks.

All such rocks have received their stratified form by having been originally deposited as a precipitate or sediment in water, and with rare exceptions they have been deposited in the waters of the sea when it occupied that portion of the surface of the earth where they are now found, and which has since become dry land by the gradual elevation of the continent or island mass, as the case may be, above the level of the sea. In other words, the majority of stratified rocks are of marine origin, the sediment subsequent to its deposition having become more or less hardened. All the rock formations of Iowa are stratified, and all are of marine origin, having been deposited in seas that gradually and successively receded to the southward and westward, as the continent was evolved, leaving their own consolidated and stratified sediment to form the foundations of what is now the State of Iowa.

The periodical changes in the character of these successive deposits, together with the characteristic remains of life that existed during the slow deposition of each, now afford us the material, by the classification of which we are able to construct a consecutive history, not only of the order in which the different rock formations were deposited, but also of the order in which the forms of life themselves were successively introduced and which characterized each epoch of time that each formation represents. These formations are composed of assemblages of strata which have characteristics in common and extend over very large areas like broad sheets as it were, lying the one above the other, the edges of each receding the one from the other at a greater or less angle of dip, so that although the greater part of every formation is out of reach beneath others, we have the opportunity at some point or other of finding exposures of each one at the surface. In Iowa the order of superposition of the different formations is comparatively simple because no great disturbance of the strata has taken place here to cause confusion in their identification, as has been the case in some other, particularly in mountainous regions.

Nearly all stratified rocks, as before intimated, are found to contain the fossil remains of various kinds of animal and vegetable forms, These in our rocks are principally shells and corals of many kinds, and in some of them plants also, all of which existed while the sediment was accumulating, of which the rock that imbeds them was formed.

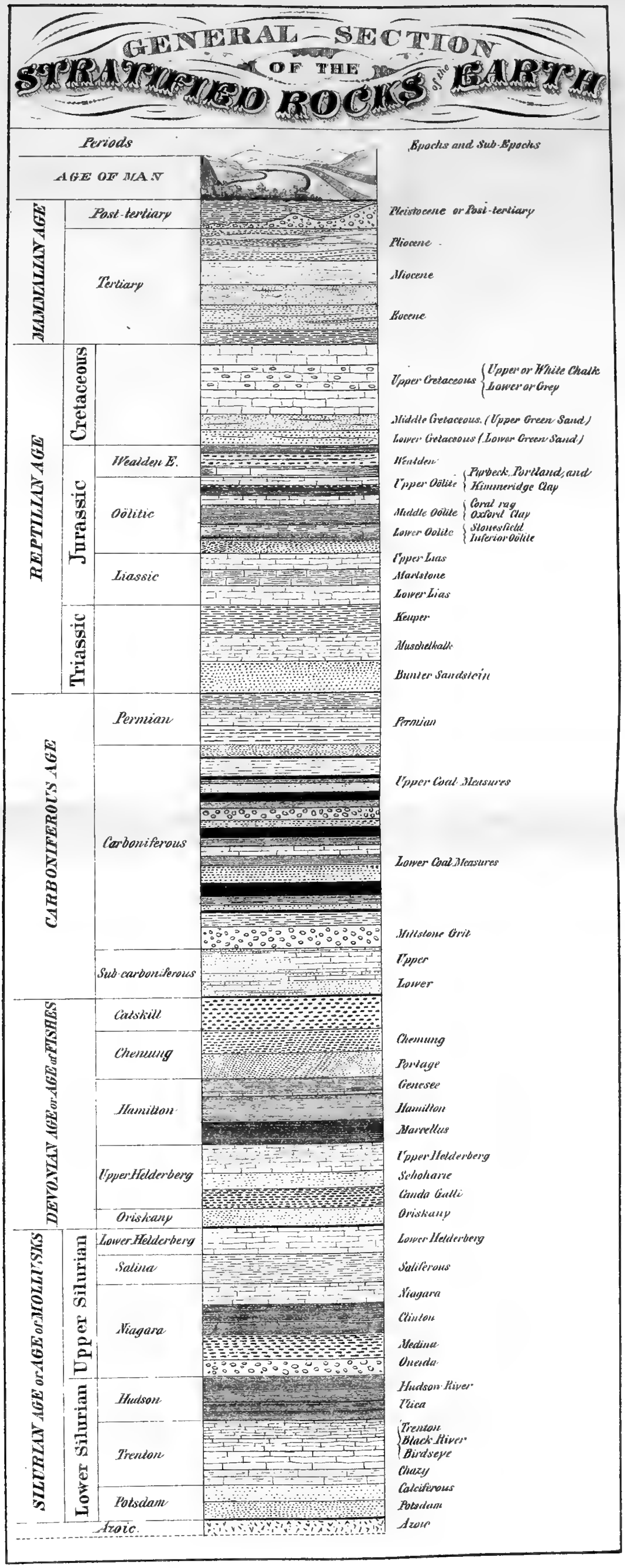
By the study of the fossil remains of all these formations the geologist finds that certain formations or assemblages of strata are characterized by certain fossils peculiar to them alone, and by which he is able to recognize the same wherever they may be found, even if the character of the rock itself is wholly different at different points. The order of one above the other and relative position of formations thus characterized is never reversed; never changed. Consequently, if but a single formation is found exposed anywhere, its proper position in the great scale of formations is as well known as if all the others were exposed to view in contact with it, and in their regular order. It is this that gives collections of fossils their great value, for without the information they thus afford, they would possess no more real value than the broken shells upon the shores of existing seas; and without that information, which we derive from that source alone, geology as a science could not exist.

The strata thus studied are, in consequence of certain characteristics possessed in common by a greater or less number of contiguous ones, divided into formations. A greater or less number of these contiguous formations constitute groups, and a greater or less number of these groups constitute systems, which are named in the order of their relative age. These systems, beginning with the oldest and geologically the lowest, are the Azoic, Lower Silurian, Upper Silurian, Devonian, Carboniferous, etc., etc. The accompanying ideal vertical section of the earth's crust, copied from Dana's Manual of Geology, presents each of these with their subdivisions in their recognized order from the lowest or oldest known fossiliferous rocks to the present time. At the commencement of the chapter on General Geology is another similar section of all the rocks of Iowa. By comparing the two, one may readily ascertain the place in the general geological scale to which any of our Iowa formations belong.

None of the strata of our State now lie in a perfectly horizontal position, although that was the position in which they were originally deposited. If they were all now perfectly horizontal or parallel with the general surface we could see only the uppermost one, except in cases where the river valleys had cut through that into others. But by a change in their level, which subsequently took place, or which was progressing slowly during the time of their deposition, they have been so elevated that they are not only much above the level of the sea in which they were deposited, but their edges are slightly upturned, so that they come to the surface successively, and may be seen in their regular order as one goes from the southwestern to the northeastern corner of the State. In the latter region are found the oldest of these formations, which are geologically the lowest although they occupy a higher actual level than the others thus passed over. It will thus be seen that the position of any geological formation beneath the surface has no necessary relation to, or coincidence with the outline of that surface. For example the surface of a region may be very much cut and broken by river valleys, and yet all the underlying strata occupy perfectly uniform and parallel planes. Again, of the rocks successively exposed along the valley of the Mississippi, those in Allamakee and Clayton counties are the lowest, geologically, although by actual level, the highest; and as one goes *down* the Mississippi river he goes *up* in the geological scale.

Through the kindness of Dr. Mark Ranney, Superintendent of the State Hospital for the Insane, at Mt. Pleasant, who presented a series of carefully preserved specimens of the borings of their artesian well, the knowledge we had before

geologists are almost entirely agreed in the opinion that after all the stratified rocks had been formed, there was a time when the whole northern hemisphere as far


GENERAL SECTION OF THE STRATIFIED ROCKS of the EARTH
Periods
Epochs and Sub-Epochs
AGE OF MAN
MAMMALIAN AGE
Post-tertiary
Pleistocene or Post-tertiary
Tertiary
Pliocene
Miocene
Eocene
REPTILIAN AGE
Cretaceous
Upper Cretaceous
Upper or White Chalk
Lower or Grey
Middle Cretaceous. (Upper Green Sand)
Lower Cretaceous (Lower Green Sand)
Jurassic
Wealden E.
Wealden
Upper Oölite
Purbeck, Portland, and Kimmeridge Clay
Oölitic
Middle Oölite
Coral rag
Oxford Clay
Lower Oölite
Stonesfield
Inferior Oölite
Liassic
Upper Lias
Marlstone
Lower Lias
Triassic
Keuper
Muschelkalk
Bunter Sandstein
CARBONIFEROUS AGE
Permian
Permian
Carboniferous
Upper Coal Measures
Lower Coal Measures
Millstone Grit
Sub-carboniferous
Upper
Lower
DEVONIAN AGE or AGE of FISHES
Catskill
Chemung
Chemung
Portage
Genesee
Hamilton
Hamilton
Marcellus
Upper Helderberg
Upper Helderberg
Schoharie
Cauda Galli
Oriskany
Oriskany
SILURIAN AGE or AGE of MOLLUSKS
Upper Silurian
Lower Helderberg
Lower Helderberg
Salina
Saliferous
Niagara
Niagara
Clinton
Medina
Oneida
Lower Silurian
Hudson
Hudson River
Utica
Trenton
Trenton
Black River
Birdseye
Chazy
Calciferous
Potsdam
Potsdam
Azoic
Azoic

Devonian, Carboniferous, etc., etc. The [redacted]
vertical section of the earth's crust, [redacted]
[illegible]

geologically, although by actual level, the [redacted]
one goes *down* the Mississippi river he goes [redacted]
logical scale.

Through the kindness of Dr. Mark Ranney, [redacted] of the State Hospital for the Insane, at Mt. Pleasant, who presented a series of carefully preserved specimens of the borings of their artesian well, the knowledge we had before obtained of the order of superposition of the formations was very satisfactorily corroborated. An examination of these enabled us to identify by their lithological characters, the formations which the drill passed through, because we were previously acquainted with the character of those formations, by having studied them as they successively make their appearance to the northward. The record of that boring says that the drill passed through no coal. This could have been predicted, because the work was commenced upon the surface occupied by the sub-carboniferous limestone, which of course underlies the coal bearing formations, as its name implies. If they had commenced the boring in Jefferson, the next county to the westward, they would doubtless have passed through at least a portion of the coal measure strata before the drill reached the limestone formation upon which they began to bore in Henry county.

From what has thus far been said, it will be seen that the general dip of all the formations of the State is to the southward and westward, but more nearly in the former direction. This general dip is so slight that it is never perceptible to the eye, and any dip of Iowa strata that is so perceptible, may be regarded as a local dip only, and will be found to change within a short distance. This general dip of all the formations to the southward and westward has one exception, namely, the Cretaceous strata. These occupy a considerable portion of northwestern Iowa, and have a general dip to the north of westward, but it is a very slight one.

These remarks apply thus far to the stratified rocks only which form the foundation, so to speak, of the State, but which are very generally covered from sight beneath the soil and subsoil. Geologists are almost entirely agreed in the opinion that after all the stratified rocks had been formed, there was a time when the whole northern hemisphere as far south at least as the Ohio river in our own country, was covered thickly with ice, as a large part of Greenland is at the present time. The ice is believed to have existed as an almost continuous glacier, which moved with an infinitely slow but constant motion to the southward, grinding up in its passage the surface portions of the formations upon which it rested and over which it moved, into the fine material that now constitutes the soil and subsoil, and which accumulation was left by the receding ice to cover those formations like a mantle. The granite boulders and pebbles so common in the surface deposits in all parts of the State, were brought down from the north by the same means and at the same time. This is known from the fact that granite exists in regular ledges at the surface in Minnesota, and does not so exist in Iowa. This mantle-like surface deposit, which everywhere covers the formations of stratified rocks except where they have since been exposed by the wearing away of it by the streams, composed of sand, clay, gravel, and boulders, in a heterogeneous mixture, is called "drift" by geologists, and the same designation is used for it throughout this report.

The accompanying map-model of Iowa will, in a good degree, illustrate the geological structure of the State in accordance with the principles thus far explained. It is not claimed that this model gives all the accurate details of the geological formations of Iowa. It is only intended to show at a glance the relations of the important formations to each other, and the relative extent of surface occupied by each. The geological map accompanying this report will show the details more fully. If it were possible to strip off completely from the whole State its mantle of drift, the stratified rock-formations which form its foundations would present an appearance in relation to each other, such as is represented by the different sheets in the map-model. The illustration would be still more complete if a separate sheet was devoted to each one of the formations that occur in the State, but this would make the model too bulky for introduction into the volume. However, as the principal object now sought to be accomplished is one of general illustration, it is thought that the present form of the model will be quite sufficient. It will be observed, therefore, that the sheets composing it are not of equal value, some representing whole systems, so far as they occur in Iowa, while others represent formations only. The title imprinted on each sheet will still further explain their relative representative value. For further illustration of the same subject, the reader is referred to the section further on, under the head of "Classification of Iowa Rocks." Lest some should fail to gather a clear idea of the intent of the model, the following detailed explanation is given:

The first sheet, the complete one, represents the whole lower Silurian system with its six formations mentioned in the table further on. The whole six of these formations, it will be seen, occupy only a small portion of the surface of the State, coming to the surface only in its northeastern corner; but they may with strict propriety be regarded as extending under all the other formations beneath the whole State, at a gradually increasing depth to the southwestward, as that sheet extends beneath all the other sheets in the model. Next comes the sheet that represents all there is in Iowa of the Upper Silurian System, which, by the way, is but a single formation here, although the system contains many other formations elsewhere. This single formation is the Niagara limestone and it rests directly upon the uppermost formation of the Lower Silurian System. The Upper Silurian, as will readily be seen, does not extend so far to the northeastward as the Lower Silurian does, but is bounded by it in that direction on one side and on the opposite side by the Devonian. This refers only to the surface it occupies, for it doubtless extends beneath all the other formations of later age in the State, which are represented as resting upon it by the following sheets in the model. The Devonian System in Iowa, like the Upper Silurian System here also, is represented by only a single formation, which is known as the Hamilton; yet the system elsewhere contains several others as will be seen by reference to the general section on a previous page.

Thus far each of the great systems in the geological scale are represented in the model by only a single sheet, but for the purpose of illustrating the relations of the coal-bearing formations to those which immediately underlie and overlie them, but which belong to the same system with them, (the Carboniferous) each of the other sheets is made to represent subdivisions of systems. Thus the one which rests upon the Devonian represents the sub-carboniferous group of formations, which in Iowa are four in number. This sub-carboniferous group of formations, although it belongs to the Carboniferous System, contains no coal, that being nearly all contained in the Lower and Middle coal-measures, both of which are represented by the single sheet which rests upon that which represents the sub-carboniferous. This sheet is seen to pass beneath another to the southwestward, which represents the Upper or barren coal measures. This last named formation is often styled the unproductive coal measures, and generally with great propriety; yet in Iowa the formation contains one rather unimportant bed of coal which appears at various points along the valley of the Nodaway river.

This arrangement of sheets in the model explains very clearly why we may expect to find coal by deep mining in southwestern Iowa, and why it is useless to look for it in the northwestern and other parts of the State. Finally the last sheet of the series represents all there is of the Cretaceous formations to be found in Iowa. These are the latest formed strata in the State, (the surface deposits of course not being included in this statement), but it will be seen by reference to the general section before referred to, that even they are very ancient compared with other formations found elsewhere in the world, and even farther west in our own country.

Following these explanations of the general principles of geology and of the geological structure of our State, it seems proper also to make further explanation of matters, concerning which many citizens have questioned every person connected with the survey.

After the explanation of the northern origin of the drift that has just been given, it need not excite any surprise to find in it various kinds of materials that did not originate where they are found. It is not unfrequently the case, however, that certain unusual substances are found in it which excite more than ordinary curiosity and interest. Such for example as lumps of copper, fragments of lead ore, wood, lumps of coal, and in rare instances also traces of gold. The occurrence of these substances in the drift in no case indicates an exception to the northern origin of much of the drift materials, for we have evidence that the glacier currents were seldom if ever directly south, but that they were variously deflected from that direction. Thus it is proper to infer that the lumps of copper might easily have come from the copper-region of Lake Superior; the fragments of lead-ore from the Dubuque lead region; the traces of gold from the northern part of Minnesota; the wood from forests which were growing when the glacial epoch commenced, and those lumps of coal which are found in the drift to the northward of the borders of the coal-field, doubtless came from a thin bed of impure coal that is known to exist in the Cretaceous strata of southwestern Minnesota. It is then almost needless to say, that the presence in the drift of such isolated lumps of coal is no indication at all of the existence of regular beds of that substance in the same vicinity, any more than the lumps of copper indicate valuable deposits of that metal, or than the granite boulders indicate the existence of regular ledges of granite where they are found in the drift.

People throughout the State have very often asked the following questions, by letter and otherwise: What relative position do beds of coal hold to limestone, sandstone, or other strata? What is "coal blossom?" or, what is a sure indication of the presence of coal beneath the surface? The terms "coal blossom" and "oil blossom" are not used by geologists, nor by any one else having correct scientific knowledge and a proper regard for the English language, but those who do use such terms, appear to mean the presence of per-oxide of iron, or simple iron-rust held in suspension in the water of springy places, and which impregnates the wet earth around the place where the water issues. So far as the presence of this substance is concerned, it amounts only to this: the strata associated with beds of coal, and also the coal itself, almost invariably contains more or less iron, which becoming oxidized, passes out with the water and is deposited upon the surface, where, from its conspicuous appearance, it always attracts much attention. While this appearance of iron is almost invariably present with coal and its associated strata, it is equally true that very many other strata which have no possible connection with beds of coal, also contain iron in similar form and in as great abundance; and it also produces the same appearance at the surface which that of the coal strata does.

The popular belief that the presence of any particular substance upon or near the surface, invariably indicates the presence of a bed of coal beneath, or associated with it, is erroneous. As to the relative position of coal-beds with other strata, the rule is that a bed of clay, commonly called fire-clay, underlies each bed of coal; and a bed of shale, popularly called soapstone, overlies it. Sometimes, however, sandstone and even limestone, have been found overlying or underlying a bed of coal with no other strata intervening. The rule mentioned is generally applicable to all coal-fields, both in this country and elsewhere, but if one should expect to find, farther than this, the same order of strata in different coal-fields he will be mistaken, for they follow no more definite order in this respect than the different strata of other formations do. To know the number and character of the beds of coal in any coal-field, as well as of the different strata associated with them, one must study the region itself; for, with the exception of obtaining a knowledge of some mere general principles—and, by the way, many fail to obtain even this before they are ready to offer their opinions for pay—all his experience in other coal-fields will avail him nothing.

We have found many persons holding the belief, that coal is never found beneath limestone. It may be found either above or beneath it, yet there is very little limestone, and that quite impure, in the productive coal-measures of Iowa; but, as will be seen by referring to the map-model before described, a formation composed principally of limestone (sub-carboniferous) underlies the productive coal-measures (the Lower and Middle) and another, also principally of limestone (the Upper coal-measures) overlies those coal-bearing formations. Beneath the first named limestone formation it is of course useless to search for coal, as that formation is already beneath all the coal-bearing strata, while we may reasonable expect to reach those last named strata if we pierce the upper formation of limestone represented in the map-model by the sheet marked "Upper Coal-Measures."

As before remarked, there are, strictly speaking, no surface indications that absolutely prove the presence of coal beneath any given spot, but since coal-beds are known to have very considerable extent beneath the surface, and to lie in a nearly uniform plane, irrespective of the inequalities of the surface, one may in certain cases make very accurate determinations as to its presence and position beneath the surface before digging down to it. This is not accomplished by observing any occult "signs," "indications," or "blossoms," but by legitimate deductions from facts personally known. Thus, if a bed of coal is known to crop out on one side of a valley, and the strata associated with it are known to be level or nearly so, we may expect to find the same bed at about the same level upon the other side. If a similar exposure should be found in another valley a few miles distant, it is reasonable to infer, that the whole space between the two valleys is underlaid by the same continuous bed of coal, and that it may be reached from the surface at a depth which may be calculated with considerable accuracy. Besides this, it will be seen from what has before been explained, that by a careful study of all the rocks of any given region the geologist may determine the limits of any formation, and if it is a coal-bearing one, he is able to indicate a line upon the map, at least approximately, and assure others that beyond this line it is useless to explore for coal, while within it there is reasonable hope of finding it.

Again, it is a very common belief that the number of separate beds of coal in every coal region is limited to three. This is also an error. There may in any region be no more than one bed of coal, or even none, although true coal-measure strata are present; or, there may be any unlimited number of separate beds of coal. For example, near the border of the coal-field, where of course the whole formation is thinning out, it is very commonly the case that there is but a single bed of coal existing, even if there be any at all, while farther within the borders there may be several distinct beds overlying each other with other strata between them. With the yet incomplete examination of the coal-field of Iowa, we have identified no less than seven or eight different beds of coal, but we have never found more than two or three of them in the same valley-side or bluff exposure. Explorations have not yet progressed far enough to determine how many of them actually overlie each other at any one given point. This must be demonstrated by future enterprise.

Without wishing to make disparaging reference to any one, it is nevertheless considered a duty to caution the public against a class of persons who go about the country claiming to possess great knowledge upon all mining matters, usually giving out that they are "old miners," when if they were really good miners they would have little occasion to bring reproach upon their calling by playing the vagabond. Their object is invariably fraud, as has been too often demonstrated to those who have trusted in them. It is easy for every one to learn who is reliable and worthy of confidence, if they will use only the ordinary caution they are accustomed to use in other matters.

We will close these remarks upon popular errors and illusions, by referring to the fact that whenever we have found a man entertaining extravagant hopes of discovering mineral wealth upon his own land, or upon land he expected to buy, a brief inquiry into his personal history would invariably reveal the fact, that he had previously suffered pecuniary disaster, and that he was indulging a morbid hope of retrieving his fortunes by the discovery of mineral resources of great value.

3. CLASSIFICATION OF IOWA ROCKS.

Every student of Natural Science will fully appreciate the necessity of employing names for the objects he studies that shall be entirely unequivocal in their meaning. But owing to the ever varying characters and groupings of the strata of the earth's crust, there seems to be a constant tendency on the part of geologists, unless vigilantly guarded against, to fall into a loose manner of naming them. For example: the words epoch, period, age, group, formation, etc., are, even by geologists, not unfrequently used in their general sense rather than as names having an invariable meaning. The condition of our language requires that for purposes of scientific nomenclature we should employ names already in common use, but the necessities of science require that we should specialize those names for this purpose as far as possible, holding them strictly to one definite signification and no other. I am well aware of the difficulty of establishing a strict and uniform classification of the stratified rocks of any region, but with the view of avoiding a loose or indefinite use of terms, in designating certain of the assemblages of strata of our Iowa and other rocks, I have decided to adopt in this report the following classification. This classification is followed throughout the volume and an effort is made at all times to designate the same object by the same name, and to express the same idea by the same word or sentence.

The term "formation" is restricted to such assemblages of strata as have been formed within a geological epoch; the term "group," to such natural groups of formations as were each formed within a geological period; and the term "system," to such series of groups as were each formed within a geological age. This arrangement has at least the merit of uniformity, and, so far at least as the Palæozoic rocks of Iowa are concerned, it seems to answer the purpose well.

The terms used in this arrangement may be referred to two categories, one applicable to geological objects and the other applicable to geological time, thus:

TIME:

Epochs constitute *Periods*, periods constitute *Ages*.

OBJECTS:

Formations constitute *Groups*, groups constitute *Systems*.

The changes made in accordance with this arrangement in the classification of the rocks of Iowa hitherto used, will be pointed out in the course of the descriptions contained in the chapter on General Geology; and may also be seen in the following table which has been constructed to show at a glance the classification proposed:

A TABLE

Showing the Classification of Iowa Rocks.

SYSTEMS. (*Ages.*)	GROUPS. (*Periods.*)	FORMATIONS. (*Epochs.*)	Approximate thickness in feet.
	Post-Tertiary	Drift	
Cretaceous	*Lower Cretaceous*	Inoceramus beds	50
		Woodbury sandstone and shales	130
		Nishnabotany sandstone	100
Carboniferous	*Coal Measures*	Upper coal measures	200
		Middle coal measures	200
		Lower coal measures	200
	Sub-carboniferous.	St. Louis limestone	75
		Keokuk limestone	90
		Burlington limestone	190
		Kinderhook beds	175
Devonian	*Hamilton*	Hamilton shales and limestone.	200
Upper Silurian	*Niagara*	Niagara limestone	350
Lower Silurian	*Cincinnati*	Maquoketa shales	80
	Trenton	Galena limestone	250
		Trenton limestone	200
	Primordial	St. Peter's sandstone	80
		Lower Magnesian limestone	250
		Potsdam sandstone	300
Azoic	*Huronian (?)*	Sioux quartzite	50*
Estimated total thickness of all Iowa strata			3170

*This is the thickness exposed in Iowa, only.

It is proper also in this connection, to state the views entertained by the writer concerning the post-tertiary deposits of Iowa, in order that the descriptions and references contained in the following pages may be more clearly understood. These deposits are the Drift, Bluff and Alluvium, all of which are separately described in subsequent pages, under the head of Surface Deposits. For all three of these deposits only two well defined epochs of the post-tertiary period are recognized in Iowa, namely, the Drift or Glacial epoch, and the Terrace epoch. The drift alone is referred to the former, and all subsequent deposits, and all modification of surface deposits, to the latter. Possibly a portion of the accumulations and modifications of the earlier part of the Terrace epoch, as recognized here, might with propriety be referred to the Champlain epoch of other geologists, but it is believed that all of them are of a different character from those phenomena nearer the sea-coasts that are relied upon for a recognition of the Champlain epoch. However this may be, it is believed that the phenomena to be observed in Iowa and the surrounding portions of the hydrographic basin of the Mississippi, exhibit a general and unbroken succession of changes, resulting principally, if not entirely, from causes that have been in operation ever since the disappearance of the glaciers. Farther than this, and also in accordance with the same views, none of the phenomena observed in this whole region, which are referable to the post-Tertiary period, are believed to afford indications that any elevation or subsidence of the surface has taken place during that period, nor since its commencement. The only phenomena regarded by others as indicating such past changes of level, appear to be the river terraces on the one hand, and the so-called deep old channels of rivers on the other; but these, in the first case, are all believed to consist of abandoned flood-plains or portions of them, which have been left by the streams as they have deepened their valleys by their own erosion alone, unaccelerated by an elevation of the surface over which they flowed. In the second case the associated phenomena do not appear to indicate that the necessary subsidence has formerly taken place to have by that means produced the erosion of river channels to the depth claimed.

PART I.

PHYSICAL GEOGRAPHY.

CHAPTER I.

SURFACE FEATURES.

1. BOUNDARIES AND AREA.

In consequence of the generally uniform character of the surface of the region which comprises the upper portion of the great hydrographical basin of the Mississippi, its linear surveys have been made with great facility, and were further greatly simplified by the peculiar system adopted by the general government when the surveys were ordered. The system is well explained in an appendix to this volume by C. W. Irish, Esq., and frequent reference is made to it throughout the text, because these linear surveys were constantly used as a basis for geological observation. This system has given rise to a general prevalence of rectangular boundaries of all the subdivisions of land extending from the nearly uniformly mile-square sections, up through the townships and counties, and has produced more or less rectangular outlines of the States also. The latter, however, have always some portions of their boundaries modified or determined by natural features, such as rivers, lakes, etc.

The State of Iowa has an outline figure nearly approaching that of a rectangular parallelogram, the northern and southern boundaries being nearly due east and west lines, and its eastern and western boundaries determined by southerly flowing rivers—the Mississippi on the east and the Missouri, together with its tributary, the Big Sioux, on the west. The northern boundary is upon the parallel of 43 degrees, 30 minutes, and the southern is approximately upon that of 40 degrees, 36 minutes. The distance from the northern to the southern boundary, excluding the small prominent angle at the southeast corner, is a little more than two hundred miles; and the extreme width from east to west is upward of three hundred miles. Owing to the irregularity of the river boundaries, however, the number of square miles does not reach that of the multiple of these numbers, but according to a statistical report of the Secretary of the Treasury to the United States Senate, March 12th, 1863, the State of Iowa contains 35,228,200 acres, or 55,044 square miles.

2. GENERAL TOPOGRAPHY.

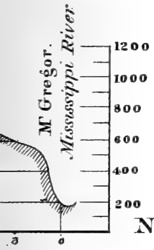
No complete topographical survey of the State of Iowa has yet been made, and no appropriation yet devoted to its geological work would warrant its undertaking. Therefore, all the knowledge we yet have upon the subject has been derived from incidental observations of the geological corps, from the published results of barometrical observations by various persons in the employ of the general government, and by levelings done by the engineer corps of the various railroads within the State. By the use of data obtained from these sources we attempt to give a general outline only, of the topography of the State. We even omit here much information that we possess concerning its details, a large part of which, however, will be found under the heads of Rivers, Lakes, Surface Deposits, etc. Railroads have already become so numerous in Iowa, that we are able to derive from their levelings alone a very correct general knowledge of the topography of our Commonwealth. Fortunately for the Geological Survey, the chief engineers and other officers of these roads have cheerfully and gratuitously furnished all desired data for this purpose, in the form of lists of the elevation of points along their respective lines. All these lists will be found in an appendix to this volume, each under the name of its author. From these and other data Mr. W. R. Morley has constructed for this report the following table, showing the elevation of some of the principal points in the State, and another on a following page showing the slope of the principal rivers. From the same data, he has also compiled material for the accompanying diagrams which show five profiles of the surface of the State, on lines running from east to west across it. These tables and diagrams together will alone serve to give a good general idea of the topography of Iowa, but for more information concerning its details the reader is referred to the tables in the appendix in addition to the following descriptions:

A TABLE

Showing the elevation of some of the principal points in the State above low-water in the Mississippi river, at Keokuk, Iowa.

LOCALITIES.	ELEVATION.	AUTHORITY.
Ames' station, railroad track at depot	500 ft.	Railroad levels.
Burlington, low water in the Mississippi	42 ft.	Railroad levels.
Cedar Rapids, railway depot	261 ft.	Railroad levels.
Tip-Top station	993 ft	Railroad levels.
Clinton, railway bridge across the Mississippi	143 ft.	Railroad levels.
Corner of the State, northeast, low water in the Mississippi	216 ft.	Estimated from slopes.
Corner of the State, northwest, low water in Big Sioux	900 ft.	Estimated from slopes.
Corner of the State, southwest, low water in Missouri	510 ft.	Estimated from slopes.
Council Bluffs, low water in the Missouri	550 ft.	Railroad levels.
Cresco, railroad station	836 ft.	Railroad levels.
Davenport, low water in the Mississippi	84 ft.	Railroad levels.
Des Moines, railroad station	351 ft	Railroad levels.
Eddyville, railroad station	234 ft.	Railroad levels.
Fort Dodge, water in Des Moines river	556 ft.	Railroad levels.
Iowa City, top of northeast corner stone of the middle building of the State University	220½ ft.	Railroad levels.
Iowa Falls, water in the river at the railroad bridge	626 ft.	Railroad levels.
McGregor, low water in the Mississippi	178 ft.	Nicollet.
Mt. Pleasant, railroad track at the station	262 ft.	Railroad levels.
Highland, railroad track at the station	836 ft.	Railroad levels.
Nashua, railroad track at the station	549 ft.	Railroad levels.
Oskaloosa, railroad track at the station	380 ft.	Railroad levels.
Sioux City, railroad track at the station	669 ft.	Railroad levels.
Waverly, railroad track at the station	516 ft.	Railroad levels.
Spirit Lake, high ground near the lake, probably the highest ground in the State	1250 ft.	Estimated from slopes.

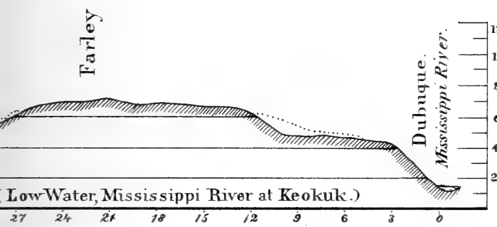
IOWA GEOLOGICAL SURVEY
1870



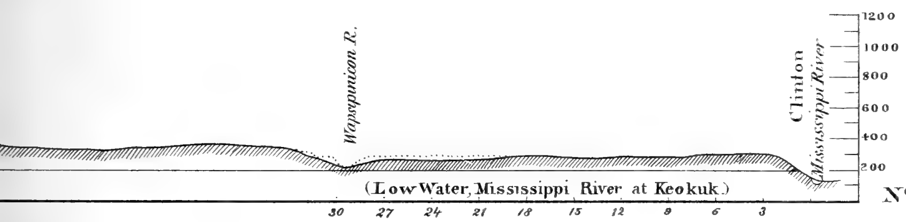
N°. 1.

TABLE of ELEVATIONS.

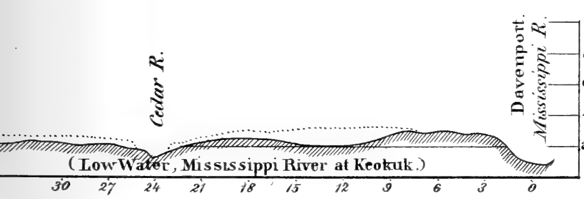
M'Gregor.	above	low-water	at Keokuk.	198	FEET.
Dubuque.	"	"	"	"	166	"
Clinton.	"	"	"	"	143	"
Davenport.	"	"	"	"	84	"
Burlington.	"	"	"	"	42	"
Keokuk.	"	the	Sea	"	444	"



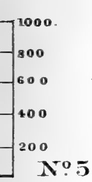
N°2.



N°3



N°. 4.



N°5

PROFILE N°1 General Elevations from M'Gregor to the Big Sioux River.
" N°2 " " " Dubuque to a point 12 miles north of Sioux City.
" N°3 " " " Clinton to Decatur, Neb.
" N°4 " " " Davenport to De Soto, Neb.
" N°5 " " " Burlington to Plattsmouth.

PROFILES ON EAST AND WEST LINES ACROSS THE STATE OF IOWA, SHOWING ELEVATIONS ABOVE LOW-WATER IN THE MISSISSIPPI RIVER AT KEOKUK.

IOWA GEOLOGICAL SURVEY 1870

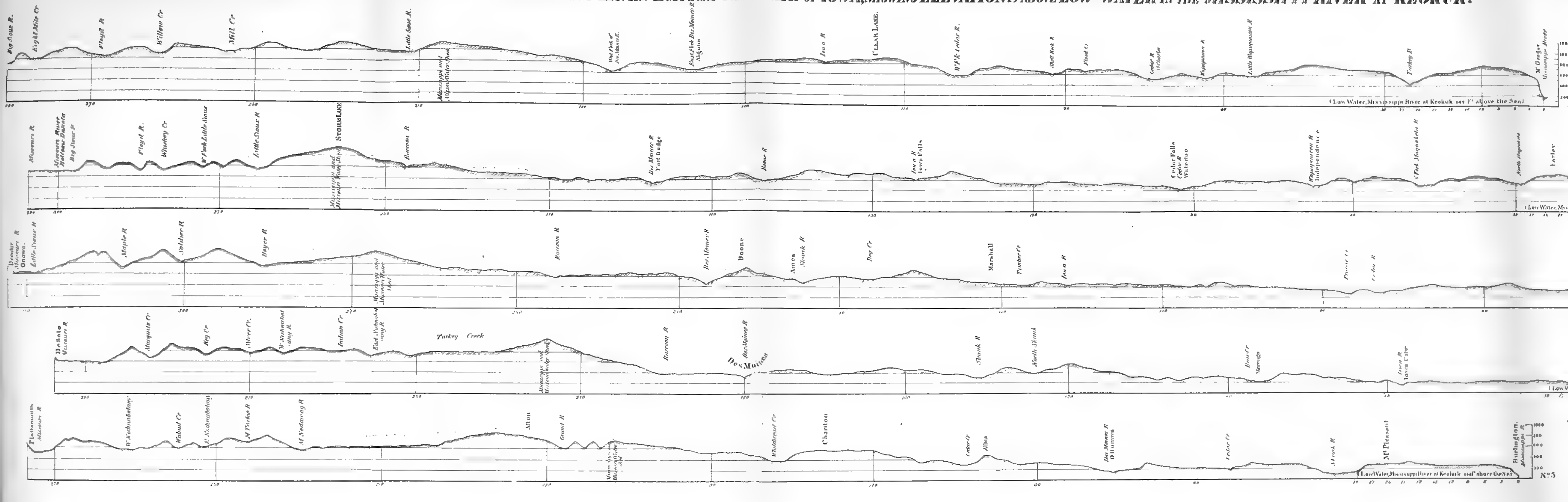


TABLE of ELEVATIONS.

M'Gregor	above low water at Keokuk	198 feet
Dubuque		[illegible]
Clinton		[illegible]
Davenport	- - -	[illegible]
Burlington		[illegible]
Keokuk	the Sea -	444

PROFILE Nº 1 General Elevations from M'Gregor to the Big Sioux River
" Nº 2 " " " Dubuque to a point 12 miles north of Sioux City.
" Nº 3 " " " Clinton to Decatur Neb.
" Nº 4 " " " Davenport to De Soto Neb.
" Nº 5 " " " Burlington to Plattsmouth.

It will be readily understood that profiles on so small a scale as that upon which these are drawn upon the accompanying sheet can do no more than to give an approximate outline of the surface, which indeed is all that they are intended to do. The difficulty also of constructing such profiles from the independent notes of so many different persons will be understood. Mr. Morley says, in explanation of his work:

"In preparing these profiles, I have used as far as practicable the elevations just as they were given by the different railroad surveys, but in some cases I have been obliged to depend upon other data. Much of this was furnished by yourself and Prof. St. John, and the remainder was calculated from the known slopes of rivers and watersheds. The elevations west of the Great Watershed which were furnished by the railroad engineers, for the most part run down some river valley instead of keeping on a direct line across the State. To follow these would not give a correct idea of the general elevations of the summits between the streams, I have, therefore, been obliged, to some extent, to use other data in determining general elevations of the surface in such cases.

In profile No. 1, a part of the elevations are from railroad surveys, but the greater part are from data furnished by the Geological Survey, and by estimates from known river slopes. There are, however, enough accurately known elevations to insure a fair degree of accuracy along the whole line.

In profile No. 2, we had a continuous line of levels from Dubuque to Sioux City, furnished by Mr. J. E. Ainsworth, and also another line from Fort Dodge to Sioux City by a different route, furnished by L. Burnett. Use has been made of both of these, and the whole profile is constructed from them except that portion of it between the Floyd and Big Sioux rivers. This part of the line was, as in the case of the others also, produced directly westward from Floyd river instead of following down its valley to Sioux City.

In profile No. 3, the elevations are obtained from surveys made by the Cedar Rapids and Council Bluffs Railroad Company (now the Chicago and Northwestern.) These elevations are those of the located line of that company from Clinton to the Boyer river, where instead of following down its valley as the road now does, the profile is continued directly westward to the Missouri river. I was enabled to do this by the aid of notes of a former survey made by Mr. C W. Irish in the interest of the same company.

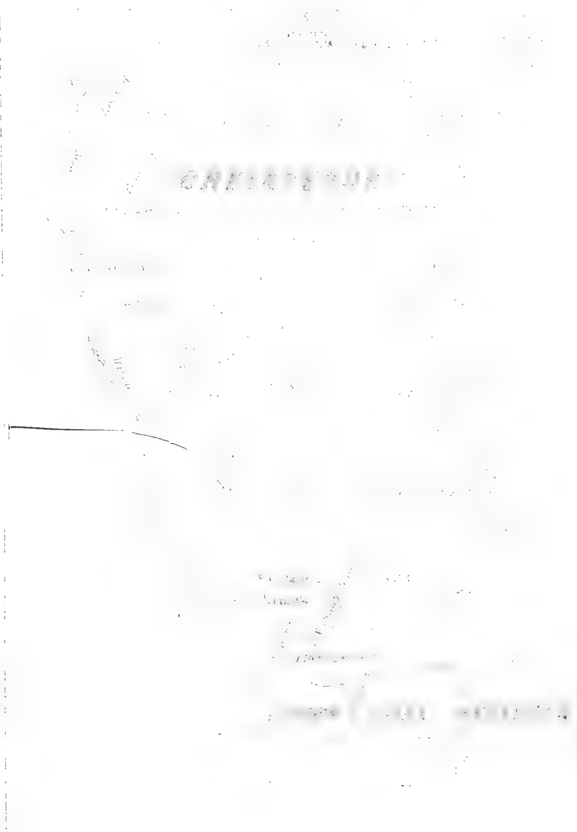
Profile No. 4, was constructed from Davenport to Cass county from notes furnished by the Chief Engineer of the Chicago, Rock Island, and Pacific Railroad. In Cass county, the road bends much to the northward, and again, soon after, almost directly southwestward, but the profile is continued directly westward in order to show the contour of the country along a line running across the streams nearly at right angles with their course. That portion of the profile westward from Cass county was constructed from data furnished from the Geological Survey notes, and by estimating the elevations from known slopes of rivers and watersheds.

Profile No. 5. The elevations on the line of this profile from Burlington to Highland in Union county, (the highest point on the line between the two great rivers) are those of the Burlington and Missouri River Railroad. Westward from Highland, there being a discrepancy of from fifty to seventy feet between the elevations as given by that railroad and those obtained from other sources, and which may be connected with the same terminus, the elevations given in the profile are somewhat raised to correspond with those other data, all of which point to higher elevations than those of that part of the Burlington and Missouri River Railroad levelings.

Regarding other work, with the data furnished by the railroad engineers and obtained from other sources, there has been some difficulty in correcting the levels and reducing them all to the same datum, owing to the fact that in the majority of cases where two different lines intersect, but one gives the elevation of that particular point, thereby rendering it somewhat difficult to determine the exact difference of data. In some cases, however, both lines have given their elevations at the point of intersection. In such cases the results are generally satisfactory. We have Nicollet's elevations along the Mississippi river with which we are able to compare the lines of railroad levelings at their outset, and where it has been possible to test the accuracy of his determinations, the error, if any, has generally been found to be small.

The differences from a true level in the various lines of railroads across the State seem to be cumulative towards the west; or, in other words, the farther they are extended in that direction from their starting point, the greater the error from a true level; so that we may expect greater error in the elevations as given in the vicinity of the Missouri river than in those nearer the Mississippi. When authorities differ as to the elevation of any point, if the difference is slight I have taken the mean. If the differences were considerable I have adopted those which seemed most authentic and fully corroborated. On the whole, however, the elevations given have all a degree of accuracy that reflects great credit upon all the engineers concerned in their determination, and the results will give a good general idea of the topography of the State."

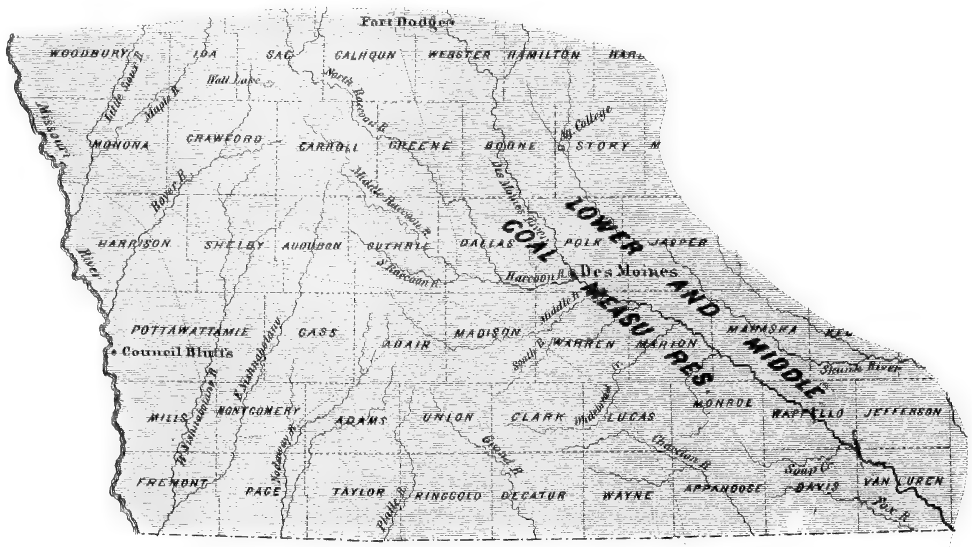
Since, with few exceptions, the different railroad levelings show the actual position of the road-bed, and since those roads necessarily follow the valleys of streams as far as practicable, for the purpose of securing an easy grade, profiles drawn from their data alone would not present an outline exactly corresponding to the general contour of surface along independent lines across the State. Therefore a dotted line has been added to each of those profiles for the

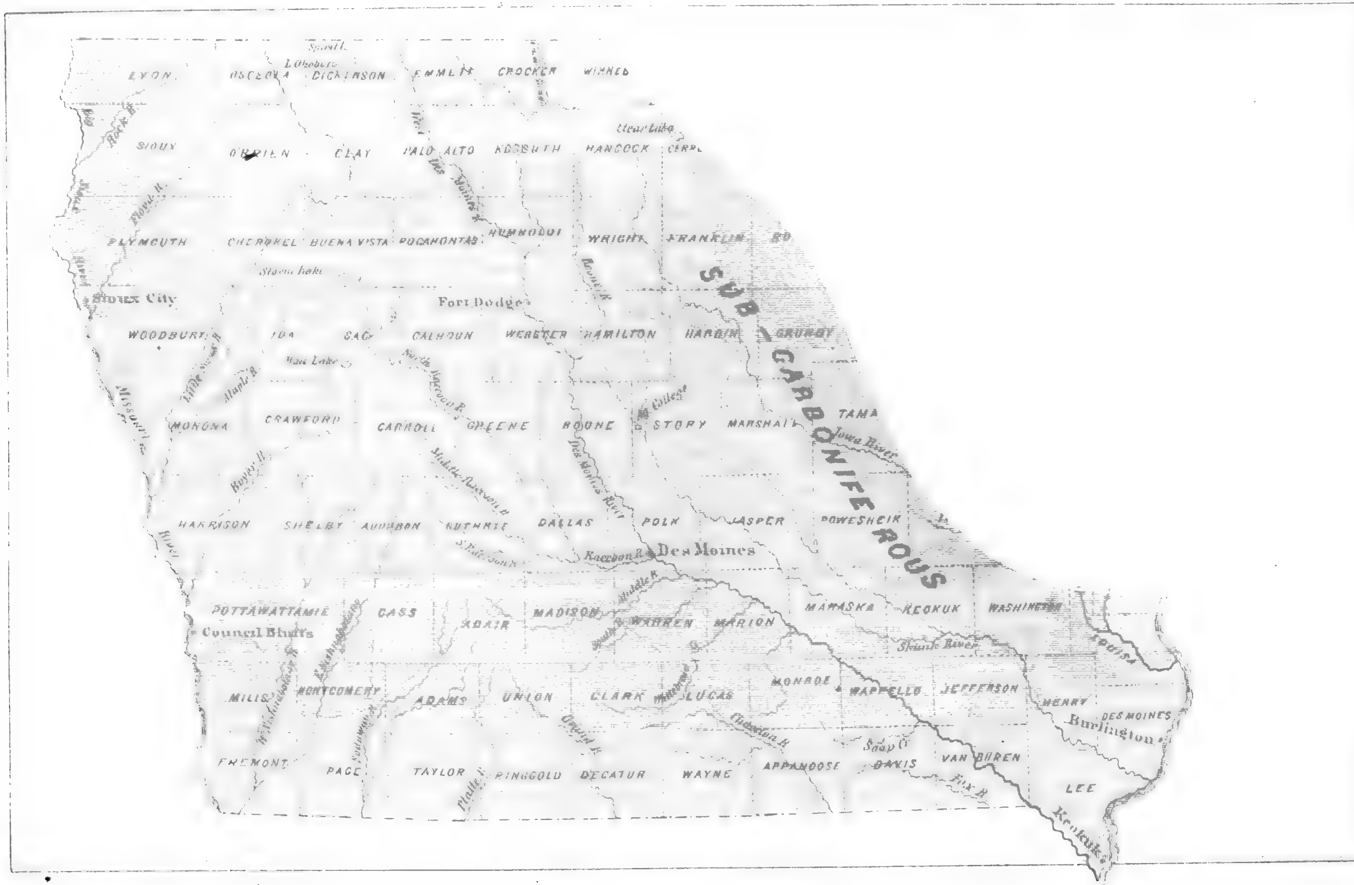


GEOLOGICAL MAP MODEL.

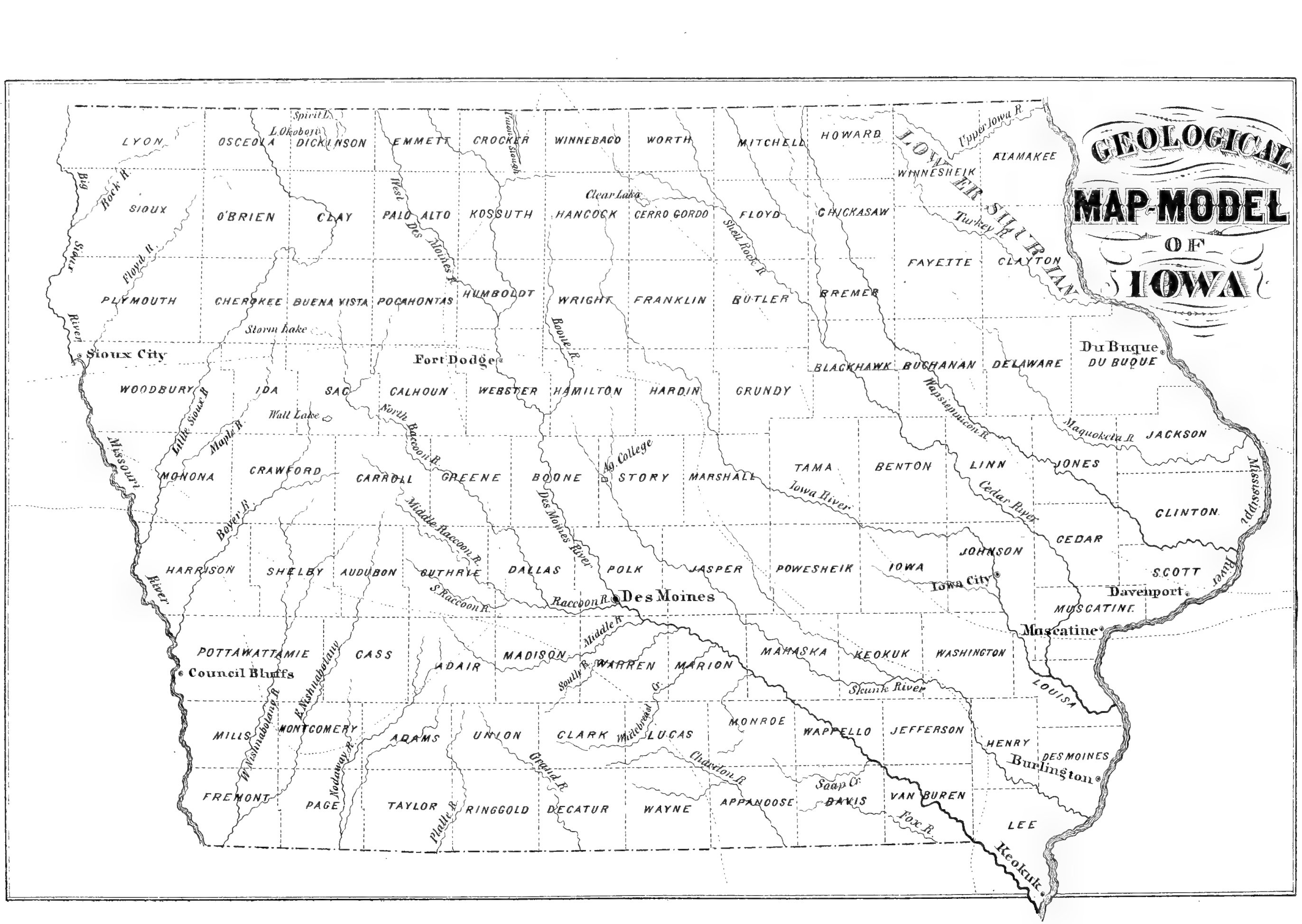
To prepare this Map-Model for use it is only necessary to cut away the blank portion of each sheet successively, along the outer dotted line.

The lowest sheet, having a full border and containing the ... is to remain uncut.


Fort Dodge
WOODBURY
IDA
SAC
CALHOUN
WEBSTER
HAMILTON
Little Sioux R.
Maple R.
Wall Lake
North Raccoon R.
Ag. College
MONONA
CRAWFORD
CARROLL
GREENE
BOONE
STORY
Missouri
River
Boyer R.
Middle Raccoon R.
Des Moines River
LOWER
COAL
HARRISON
SHELBY
AUDUBON
GUTHRIE
DALLAS
POLK
JASPER
S. Raccoon R.
Raccoon R.
Des Moines
AND
MEASU
RES.
MIDDLE
POTTAWATTAMIE
CASS
ADAIR
MADISON
MAHASKA
Middle R.
South R.
WARREN
MARION
Council Bluffs
Skunk River
MONROE
MILLS
MONTGOMERY
ADAMS
UNION
CLARK
LUCAS
WAPELLO
JEFFERSON
Chariton R.
Soap Cr.
FREMONT
PAGE
TAYLOR
RINGGOLD
DECATUR
WAYNE
APPANOOSE
DAVIS
VAN BUREN
Nodaway R.
Platte R.
Grand R.
Fox R.



LYON
OSCEOLA
DICKINSON
EMMET
WINNEB
SIOUX
O'BRIEN
CLAY
PALO ALTO
HANCOCK
Clear Lake
HUMBOLDT
WRIGHT
FRANKLIN
PLYMOUTH
CHEROKEE
BUENA VISTA
POCAHONTAS
Storm Lake
Sioux City
Fort Dodge
WOODBURY
IDA
SAC
CALHOUN
WEBSTER
HAMILTON
HARDIN
GRUNDY
SUB CARBONIFEROUS
MONONA
CRAWFORD
CARROLL
GREENE
BOONE
STORY
MARSHALL
TAMA
Iowa River
HARRISON
SHELBY
AUDUBON
GUTHRIE
DALLAS
POLK
JASPER
POWESHEIK
Des Moines
POTTAWATTAMIE
Council Bluffs
CASS
ADAIR
MADISON
WARREN
MARION
MAHASKA
KEOKUK
WASHINGTON
Skunk River
MILLS
MONTGOMERY
ADAMS
UNION
CLARK
LUCAS
MONROE
WAPELLO
JEFFERSON
HENRY
DES MOINES
Burlington
FREMONT
PAGE
TAYLOR
RINGGOLD
DECATUR
WAYNE
APPANOOSE
DAVIS
VAN BUREN
LEE
Keokuk
Des Moines River
Raccoon R.
Middle R.
Missouri
Rock R.
Floyd R.
Little Sioux R.
Maple R.
Boyer R.
Chariton R.
Fox R.
Platte R.


GEOLOGICAL
MAP-MODEL
OF
IOWA
LOWER SILURIAN
LYON
OSCEOLA
DICKINSON
EMMETT
CROCKER
WINNEBAGO
WORTH
MITCHELL
HOWARD
WINNESHEIK
ALAMAKEE
SIOUX
O'BRIEN
CLAY
PALO ALTO
KOSSUTH
HANCOCK
CERRO GORDO
FLOYD
CHICKASAW
FAYETTE
CLAYTON
PLYMOUTH
CHEROKEE
BUENA VISTA
POCAHONTAS
HUMBOLDT
WRIGHT
FRANKLIN
BUTLER
BREMER
WOODBURY
IDA
SAC
CALHOUN
WEBSTER
HAMILTON
HARDIN
GRUNDY
BLACKHAWK
BUCHANAN
DELAWARE
DU BUQUE
MONONA
CRAWFORD
CARROLL
GREENE
BOONE
STORY
MARSHALL
TAMA
BENTON
LINN
JONES
JACKSON
CLINTON
HARRISON
SHELBY
AUDUBON
GUTHRIE
DALLAS
POLK
JASPER
POWESHEIK
IOWA
JOHNSON
CEDAR
SCOTT
MUSCATINE
POTTAWATTAMIE
CASS
ADAIR
MADISON
WARREN
MARION
MAHASKA
KEOKUK
WASHINGTON
LOUISA
MILLS
MONTGOMERY
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LUCAS
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PAGE
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WAYNE
APPANOOSE
DAVIS
VAN BUREN
LEE
Sioux City
Fort Dodge
Du Buque
Des Moines
Council Bluffs
Iowa City
Davenport
Muscatine
Burlington
Keokuk
Ag. College
Spirit L.
L. Okoboji
Clear Lake
Storm Lake
Wall Lake
Big Sioux River
Rock R.
Floyd R.
Missouri River
Little Sioux R.
Maple R.
Boyer R.
W. Nishnabotany R.
E. Nishnabotany
Nodaway R.
Platte R.
Grand R.
West Des Moines R.
Des Moines River
Boone R.
North Raccoon R.
Middle Raccoon R.
S. Raccoon R.
Raccoon R.
Middle R.
South R.
Whitebreast Cr.
Chariton R.
Soap Cr.
Fox R.
Skunk River
Iowa River
Cedar River
Shell Rock R.
Wapsipinicon R.
Maquoketa R.
Turkey R.
Upper Iowa R.
Mississippi River

purpose of indicating more correctly, the general contour of surface.

It will of course be borne in mind, that diagram profiles of this kind cannot be drawn so as to show the natural proportion of the distance to the height, because the actual height of the highest elevations of any region bears so small a proportion to the distance across it. Therefore due allowance must be made for the great apparent inequality of surface, as shown in the diagrams, necessarily consequent upon representing the distance upon a much more reduced scale than the height.

Taking into view the facts that the highest point in the State is but a little more than twelve hundred feet above the lowest point; that these two points are nearly three hundred miles apart, and that the whole State is traversed by gently flowing rivers, it will be seen that in reality the State of Iowa rests wholly within, and comprises a part of, a vast plain with no mountain or hill-ranges within its borders.

Perhaps a still clearer idea of the great uniformity of the surface of the State, may be obtained from a statement of the general slopes in feet per mile, from point to point in straight lines across it.

The following table of general slopes are approximately correct:

TABLE OF SLOPES OF THE GENERAL SURFACE OF THE STATE.

From the N. E. corner to the S. E. corner of the State....	1 foot 1 inch per mile.
From the N. E. corner to Spirit Lake....................	5 feet 5 inches per mile.
From the N. W. corner to Spirit Lake..................	5 feet 0 inch per mile.
From the N. W. corner to the S. W. corner of the State	2 feet 0 inch per mile.
From the S. W. corner of the State to the highest ridge between the two great rivers (in Ringgold county)....	4 feet 1 inch per mile.
From the dividing ridge to the S. E. corner of the State..	5 feet 7 inches per mile.
From the highest point in the State (near Spirit Lake) to the lowest point in the State (at the mouth of Des Moines river)....................................	4 feet 0 inch per mile.

Thus, if it were possible to reduce the surface of the State to a perfect plain, preserving only the general slopes as just given, the greatest of these would be so slight that it could not be distinguished by the eye from a perfect level. It will be seen, therefore, that there is a good degree of propriety in regarding the whole State as a part of a great plain, the lowest point of which within its borders, the south-eastern corner of the State, is only 444 feet above the level of the sea. The average height of the whole State above the level of the sea is not far from 800 feet, although it is more than a thousand miles inland from the nearest sea coast.

The foregoing remarks are of course to be understood as applying to the surface of the State as a whole, taking a general view of it; but when we come to consider its surface features in detail we find a very interesting diversity, and even much romantic beauty in some parts. Nearly all this diversity of surface, however, has been produced by the formation of the valleys out of the general level, as will be explained on following pages, under the heads of Rivers and Surface Deposits.

The general level that has just been assumed for the State has even now to some degree a real existence, for we are usually able to detect in all parts of it a general upper level of surface between all the streams, down from which the valleys of those streams have been eroded by the action of their own waters during the unnumbered years of the Terrace epoch. This character of surface is strikingly seen in the southern part of the State, where the upper surface, usually prairie, often presents to the eye a well marked level line upon the horizon as seen in the distance. In the northern part of the State, however, the surface has from the beginning been more undulatory, but this subject will be again referred to under the head of Drift Deposit and elsewhere in the report.

It is in the northeastern part of the State that the river valleys are deepest; consequently, the country has there the greatest diversity of surface, and its physical features are most strongly marked. In all parts there is a pleasing diversity of surface, which becomes much increased in appearance with the cultivation of the country and the growth of trees upon former prairie surfaces.

3. DRAINAGE SYSTEM.

Those two great rivers, the Mississippi and Missouri form respectively the eastern and western boundaries of the State, and receive respectively the eastern and western drainage of it.

The drainage of Iowa was very properly divided into two systems by Prof. Whitney, the one comprising the tributaries of the Mississippi, and the other those of the Missouri; those of the eastern system running in a southeasterly direction, and nearly at right angles with those of the western system, which latter most generally run in a southwesterly direction. I cannot however agree with Prof. Whitney that the courses of these streams were respectively predetermined by a series of folds or flexures in the strata, the courses of which coincide with those of the streams; for our investigations have satisfied us that such flexures do not exist in such positions. The reasons for this opinion may be found in the chapter on General Geology, in that on surface deposits, and in the long plate of sections accompanying this report. In the first of these it is shown that the folds or flexures of strata which really do exist have different directions from the courses of those streams; and in the second it is shown that the streams, particularly those of Western Iowa, have through a large part, and in some cases through the whole of their courses, eroded their valleys out of the incoherent surface deposits alone, and would have run in any other direction just as well if a similar slope had been given to the surface they traverse. To assume the existence of folds coincident with the courses of the streams, it seems necessary to assume also that the disturbance which caused them took place immediately upon the close of the Glacial epoch, and that the drift surface which the waters there rested upon took part in the same folding. Of this we have no corroborative evidence, but we have much reason to believe that the surface deposits received their positions independently of any folds of the strata, and that they have not since been disturbed by folding. It is worthy of remark in this connection that the general course of the streams of the eastern system—these having more generally reached the underlying strata than those of the western system—coincides *very* nearly with the trend of the outcrop of the formations along or upon which they run. Possibly, some of these eastern streams received their initial direction by longitudinal depression left in the surface of the drift, consequent upon the greater or less facility with which they were respectively eroded along the lines of their outcrop during the Drift epoch.

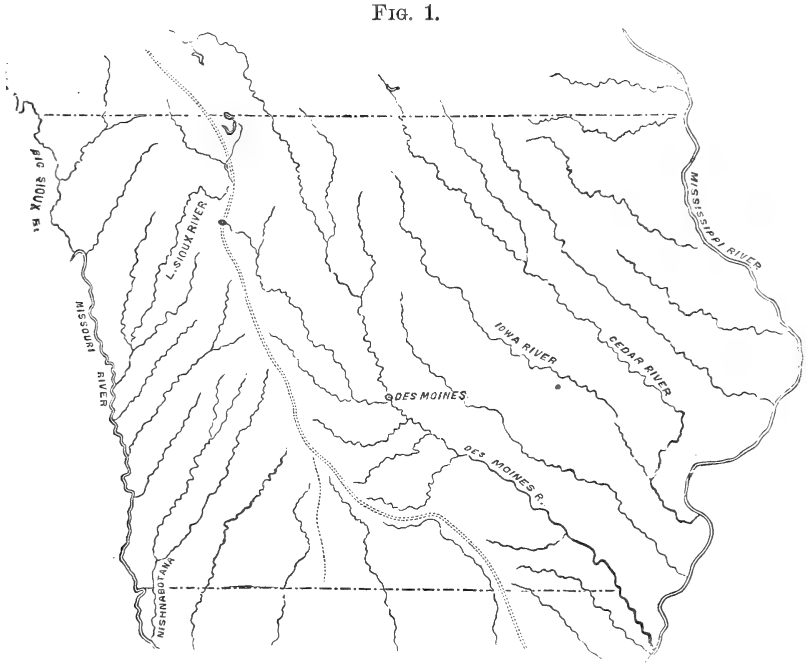
The eastern drainage system comprises not far from two-thirds of the entire surface of the State, and is more complete in itself than the western system, because its rivers are larger and have the principal part of their courses within the State; while a large part of the area occupied by the western system is drained by the upper branches of streams that constitute a large part of the drainage system of the State of Missouri. An interesting feature of the division of these two systems consists in the peculiar character of the Great Watershed, or that which divides the drainage between the two great rivers. This watershed is formed by the highest land between those rivers along the whole length of a line running southward from a point on the northern boundary line of the State near Spirit lake, in Dickinson county, to a nearly central point in the northern part of Adair county.*

From the last named point, this highest ridge of land,

*Preliminary railroad levelings along the western part of the line of the Chicago and Northwestern Railway, show that at a few points along the secondary watershed, between Boyer and Soldier rivers, the elevation is actually greater than that of the Great Watershed where the railway crosses it. This may have resulted from a greater erosion of the Surface Deposits at that point than at others, both along the Great Watershed, and along the upper portion of the secondary watershed just named; or, it may be, that the Bluff Deposit which constitutes that secondary watershed, was originally so accumulated, that its surface actually occupied a higher level than the surface of the Drift Deposit did further eastward. This subject is again referred to under the head of Bluff Deposit in the chapter on Surface Deposits.

between the two great rivers, continues southward without change of character through Ringgold county into the State of Missouri; but southward from that point, in Adair county, it is no longer the Great Watershed. From that point another and lower ridge* bears off more nearly southeastward, through the counties of Madison, Clarke, Lucas, and Appanoose, and becomes itself the Great Watershed. Thus, as one goes westward along the line of the Burlington and Missouri River Railroad, or along the southern boundary of the State, he passes the Great Watershed long before he reaches the highest land between the two great rivers, and at points that have more than two hundred and fifty feet less elevation. The accompanying diagram, Fig. 1, gives a general view of the drainage system of the state:

FIG. 1.



*The meaning of the word "ridge" as used here should not be misunderstood. The ridges which constitute the watersheds of Iowa, are seldom sufficiently elevated above the surrounding surface to be distinguished by the eye, and their presence is usually recognized only by observing the direction of the drainage, or by actual leveling with instruments.

The double dotted line indicates the position of the Great Watershed, while the single one indicates that of the highest ridge of land between the two great rivers where that ridge does not constitute the Great Watershed.

The general surface of the State, as before stated, is gently undulatory, and it is mainly the development of its drainage systems that has caused it to be so. This fact is beautifully illustrated upon the prairies of southern Iowa which have a better defined general level than those of other parts of the State. As one stands upon those broad prairies and sweeps the well-defined, ocean-like horizon with his level, he finds the bubble everywhere resting upon the cross-wire, except where the distant, dark line of forest foliage reveals the presence of a stream; here the original level has been lost by erosion. Approaching these slightly depressed regions he finds the surface to become undulating, like the smooth rolling of a sea; but looking closely, he will see that every depression leads into a still deeper one, until the upper branches of the streams are reached, the waters of which are often more than a hundred and fifty feet below the prairie level from which he started, and the surfaces of the larger streams are sometimes near a hundred feet deeper still.

These details of the drainage are too minute to be represented in the foregoing diagram, or even upon the largest maps. The streams themselves are considered under the following head:

4. RIVERS AND THEIR VALLEYS.

Since rivers, next to mountains, constitute the most conspicuous features in the physical geography of a region, and Iowa being, as already shown, quite destitute of mountains, or even ranges of hills, a brief description of its rivers and river systems is here introduced, for the purpose of presenting as clear an idea as possible of the surface features of our State.

Its inequalities of surface are due almost alone to its streams, for these, as before intimated, have eroded their own valleys out of a primitive general level. Thus our so-called hills are only valley-sides; or, in other words, their apparent elevation is due to their having been left in their original positions, when the surrounding or intervening material was removed by the denuding action of water and the atmosphere; which agencies are perhaps as active now as they have ever been. Consequently the rivers and streams of Iowa, and more especially their valleys, constitute its most conspicuous physical features.

All streams that rise in Iowa, rise upon the incoherent surface deposits, occupying at first only slight depressions in the surface, and scarcely perceptible. These successively coalesce to form the streams. Those portions of the valleys of the upper branches thus formed which run upon the surface deposits alone have usually sloping sides, indistinct flood-plains and muddy banks. In the following descriptions of rivers, these portions so generally uniform in all, are omitted, the depressions they occupy being included when reference is made to undulations of the surface.

As preliminary to the consideration of the rivers of Iowa, in groups or as individual streams, the reader is referred to the map of the State accompanying this report, to show its geographical as well as geological features; and also to the following table which is intròduced to show the slope in feet per mile of the more important of them. In the case of the two great rivers, those portions of their courses which border upon Iowa almost alone are considered; and in the case of the smaller rivers, it will be seen that the slope of their principal portions only are given in the table, the upper portions of them and their branches being omitted.

Physical geographers use definite terms to designate different portions of the courses of rivers, and also of different parts of their valleys. Thus the river valley is divided into sides, flood-plain* and channel or bed. There is hardly

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*The flood-plains of rivers are usually called "Bottoms" and "Bottom-lands" in this part of the country.

a river in the world whose valley does not possess all these features more or less distinctly marked. They also divide streams rising in mountainous regions into *cascade*, *torrent*, and *river* portions, or upper, middle and lower. This division of the stream itself is more especially applicable to such rivers as take their rise in mountainous regions, and flow down into and through a level country, thence into the sea or another river.

Remembering what has been said of the general topography of the State, it will at once be seen that such a division of the different parts of the courses of our Iowa streams is not applicable, because they run through a flat country all the way from their sources to their mouths. It will also be seen that those portions of them which are omitted from the table are free from torrents or cascades, because they pass along upon the incoherent surface deposits alone, not having reached the firm underlying strata:

A TABLE

Showing the Slopes of the Principal Rivers of Iowa.

NAMES.	PART OF COURSE.	SLOPE PER MILE.	AUTHORITY.
Mississippi	From Lansing to the confluence of the Missouri	0 ft. 6 in.	J. E. Ainsworth.
Missouri	From Sioux City to Council Bluffs....................	1 ft. 0 in.	Railroad levels.
Des Moines	From Fort Dodge to Ottumwa	2 ft. 4 in.	Railroad levels.
Des Moines	From Ottumwa to the mouth.	1 ft. 11 in.	Railroad levels.
Raccoon	From forks of the river to its mouth	2 ft. 11 in.	Railroad levels.
N. Raccoon	From Jefferson to the forks..	4 ft. 0 in.	Railroad levels.
Skunk	From Colfax station to Oakland	2 ft. 2 in.	Railroad levels.
Skunk	From Oakland to the mouth .	1 ft. 6 in.	Railroad levels.
Iowa	From Iowa Falls to Iowa City	3 ft. 1 in.	Railroad levels.
Iowa	From Iowa City to the mouth	2 ft. 4 in.	Railroad levels.
Cedar	From State boundary to Cedar Falls	3 ft. 7 in.	Railroad levels.
Cedar	From Cedar Falls to Moscow.	2 ft. 5 in.	Railroad levels.
Cedar	From Moscow to the mouth .	2 ft. 0 in.	Railroad levels.
Wapsipinicon....	From Independence to the mouth....................	2 ft. 10 in.	J. E. Ainsworth.
Maquoketa......	From Manchester to the mouth	3 ft. 4 in.	J. E. Ainsworth.
Turkey........ .	From Crane creek to the mouth....	5 ft. 0 in.	Railroad levels.
Upper Iowa....	From Decorah to the mouth.	8 ft. 6 in.	Railroad levels.

Slopes of the Principal Rivers of Iowa—Continued.

NAMES.	PART OF COURSE.	SLOPE PER MILE.	AUTHORITY.
E. Nishnabotany.	From C. R. I. and P. Railroad to the mouth	2 ft. 5 in.	Railroad levels.
W. Nishnabotany	From C. R. I. and P. Railroad to the mouth	2 ft. 8 in.	Railroad levels.
Boyer	From Dennison to the mouth.	3 ft. 3 in.	Railroad levels.
Little Sioux.....	From Cherokee to Smithland,	2 ft. 6 in.	Railroad levels.
Little Sioux.....	From Smithland to the mouth	0 ft. 4 in.	Railroad levels.
Big Sioux.......	From N. W. corner of the State to Indian creek......	3 ft. 2 in.	Approximate estimate.
Big Sioux.......	From Indian creek to the mouth	1 ft. 4 in.	Approximate estimate.
Floyd	From fork of Willow creek to the mouth	3 ft 0 in.	J. E. Ainsworth.

The rivers of Iowa alone would furnish material for a much more lengthy discussion than the limits of this report will allow, but the most that can be done at the present time is to give an outline of their general and peculiar characters, confining remarks in reality more to the valleys than to the the streams themselves.

Notwithstanding the general flatness of the country through which our rivers pass, the characters of their valleys are somewhat varied by the difference in the character of the formations out of which they have been eroded, and over which their waters flow; and also by the depth to which the slope of the surface from their sources to their mouths have required their erosion. The conditions being the same, the character of the valleys and their streams would everywhere be uniform, and there is consequently a great degree of uniformity among Iowa streams. This uniformity is due to the depth and universal prevalence of the surface deposits more than to any other cause. It is especially so in Western Iowa where the stratified rocks are generally and deeply covered by those deposits.

In attempting to divide the rivers of Iowa into classes for more convenient description, each class having certain characteristics in common, no more natural division can be made than that which separates the two drainage systems as before described.

The Drift and Bluff Deposits are both so thick in Iowa that its streams not only rise upon their surfaces, but they also frequently reach considerable size upon, and have eroded their valleys to a considerable depth into these deposits alone. In a few cases, as for example near the dividing ridge between the two great rivers, where the Drift Deposit is deepest, the valleys, small as the streams are there, have been eroded by those streams to a depth of nearly or quite two hundred feet from the general prairie level, showing nothing but drift anywhere in their bottoms or sides. It is known that the Bluff Deposit also reaches fully as great a thickness in southwestern Iowa, where some of the valley-sides and bottoms are composed entirely of that homogeneous material.

In consequence of the great thickness of the surface deposits, many of the streams, more especially those of western Iowa, are very largely and some of them wholly without exposures of rocky strata along their whole course. In other words, such streams rest wholly or in large part upon the incoherent surface deposits alone, and into which they have eroded their valleys.

When the material out of which a valley is eroded, especially in Iowa, consists of alternating hard and soft strata, the valley is usually wide and the soft beds frequently give rise to broad, flat, flood-plains; but if the valley is cut out of material of uniform character it is usually deep, narrow, and gorge-like. When the valley sides are wholly composed of the incoherent surface deposits, they are of course never precipitous like those which contain rock in their composition. They are sometimes, however, quite steep, but always slope more or less directly from the surrounding highland to the flood-plain or the stream. The upper branches are, almost without exception, prairie streams; their valleys not being well defined as such, but form a part of the general undulatory character of the surface. When the valley is cut out of the stiff, clayey drift, like some of that of southern Iowa, the sides are usually steeper than they are when it is eroded out of the more sandy and gravelly drift of a part of northern Iowa. If the valley is eroded out of the Bluff Deposit, its sides may be either gently sloping, or even occasionally so steep that a man can climb them only with great difficulty. The peculiar physical properties of this strange deposit are described upon subsequent pages.

The majority of the streams that constitute the western system of Iowa drainage run, either along the whole or a part of their course, upon that peculiar deposit described in another part of this report under the head of Bluff Deposit. As these streams seldom reach any more solid material, their banks and beds are always muddy; the stream itself occupying a narrow, tortuous ditch in usually a narrow flood-plain, and having banks so steep and muddy that they are almost impassable to man or animals except by bridges. Other portions of some of these streams and the whole of some others of the western system, as well as the upper branches of all those of the eastern system, rest upon and within the Drift Deposit alone.

As the last named deposit is not quite so uniform in its composition in all parts of the State as the Bluff Deposit is, the characters of the beds and banks of the streams which run upon it are a little different in different parts of the State. Thus as sand and gravel are more prevalent in the drift of northern than in that of southern Iowa, the beds and banks of the streams in the first named portion of the State, are frequently pebbly and firm, while those upon the same deposit in southern Iowa are sometimes nearly as muddy, and possess much the same characters as those do which run through the Bluff Deposit. The immediate beds, however, of all streams upon the drift are usually gravelly; the gravel being the residue from the large amount of the finer drift material that has been removed by the streams to form its valleys.

From the foregoing description of the beds and banks of the streams of western Iowa, it will be properly inferred that they afford comparatively few secure mill-sites, although their fall per mile is very considerable, as shown by the table on a preceding page. Wherever any practicable mill-site does occur upon these streams, they are occasioned by the exposure to a greater or less degree of some of the strata that underlie the very heavy surface deposits.

Another cause of the great uniformity in the character of the river valleys of western Iowa, is the simplicity of the stratigraphical geology of the region. Almost the whole of the region occupied by the streams of the western drainage system is underlaid by only two formations; namely, the Upper coal-measures and Cretaceous. The strata of the last named rocks are usually so friable and easily disintegrated that they have offered very little impediment to the erosion of the valleys; and, for the same reason, they do not often appear as exposures along the valley sides, even when they are known to exist beneath the surface. It is for this reason, in addition to the fact that the surface deposits are upon the whole thicker in western Iowa, that exposures of strata are so much more rare there than they are along the rivers of the eastern system.

In view of the intended limit of this chapter, comparatively little discussion can be devoted to each individual stream, which fact must serve as a sufficient explanation of the brief manner in which they are treated.

5. RIVERS OF THE WESTERN SYSTEM.

All of the rivers of the western system of drainage, except the Missouri itself, are quite incomplete as rivers, in consequence of their being really only branches of other larger tributaries of that great river; or, if they empty into the Missouri direct, they have yet all the usual characters of upper branches of Iowa rivers, from their sources to their mouths.

Chariton and *Grand rivers* (or rather the upper branches of rivers which bear those names in, and drain a part of the

State of Missouri), both rise and run for the first twenty-five or thirty miles of their courses upon the Drift Deposit alone. The first strata that are exposed by the deepening valleys of both these streams belong to the Upper coal-measures, and they both continue upon the same formation until they make their exit from the State, near the boundary of which they have passed nearly or quite through the whole thickness of that formation down to the top of the Middle coal-measures. Therefore, as might be expected, both these streams are very similar in their general characters so far as their Iowa portions are concerned. Their valleys are usually pretty well defined; but sometimes the surrounding high land slopes for a mile or more gently towards the stream. They gradually deepen from their upper portions downward, so that within fifteen or twenty miles, they have reached a depth of near a hundred and fifty feet below the general level of the adjacent high land, which depth they retain with little increase until they pass beyond the limits of the State, because the general slope of the country is nearly concurrent with the slope of the streams.

The strata of the Upper coal-measures consist, in this part of the State, of beds of limestone alternating with those of clayey and shaly composition. The latter readily soften and disintegrate upon exposure to atmospheric influence and the action of the streams. Thus when the rivers have cut their valleys down through the series of limestone strata, they reach those of clayey composition before mentioned. Upon these they widen their valleys and make for themselves broad flood-plains which become conspicuous features in their scenery; the soil of which, owing to its origin, is stiff and clayey, except where it is modified by sandy washings. These broad bottom lands are particularly noticeable in the southern parts of both Appanoose and Decatur counties.

A considerable breadth of woodland occupies the bottoms and valley sides along a great part of their length, but their upper branches and tributaries are mostly prairie streams.

Platte river. This is also a river belonging mainly to the State of Missouri, the upper branches of which pass through Ringgold county from north to south, and together with those of the West Fork of Grand river,* drain a considerable region.

The highest ridge of land between the two great rivers (not the Great Watershed as before explained), also passes through it in the same direction. Here the Drift Deposit reaches its maximum thickness on an east and west line across the State, and the valleys are eroded in some instances to a depth of two hundred feet below the general level of the adjacent prairie, apparently through this deposit alone, and not even then exposing its base except in a single instance, which occurs near the south line of Ringgold county. There all the valleys of these streams have the general features before described as characteristic of drift valleys. These characteristics are well marked in Ringgold county, because the valleys there are so much deeper than drift valleys average throughout the State.

The county is nearly all prairie, and as the traveler is passing across it, he is hardly aware of the existence of the valleys until he is just upon their borders. Then he sees the stream winding through a narrow, scarcely defined flood-plain, usually having a narrow, often interrupted belt of forest trees along its banks, which were quite invisible at a distance in consequence of the depth of the valley.

One-Hundred-and-Two river is represented in Taylor county by its East and West Forks, the valleys of which have the same general character as those just described, only they are not so deep. The East Fork has an exposure of Upper coal-measure limestone upon its banks at Bedford, but it is not sufficient to modify the general drift character of the valley. Nothing but drift appears in the valley of the West Fork so

*The meagre nomenclature of the pioneers has given rise to much subsequent inconvenience, for, instead of giving a separate name to each stream, they often applied the name of the main stream to each one of its principal tributaries with the addition of North, South, East, West or Middle, as the case might be. Thus we have the North and South Chariton, East, West, and Middle Nodaway, East and West Nishnabotany, etc., etc.

far as now known. The country around and between these streams is almost entirely prairie.

The East, West, and Middle Nodaway rivers and their valleys are very fine examples of the small rivers and valleys of southern Iowa. They have the general characters of drift valleys with beautifully sloping and undulating sides. These characters are very slightly modified at several distant points, by the presence in their beds and immediate banks of limited exposures of Upper coal-measure strata. As the southerly dip of these strata, however, coincides almost exactly with the slope of the southerly flowing streams, they offer comparatively little obstruction to their flow, yet they are sufficient to cause a few good mill-sites on each of the streams.

The Nodaways drain one of the finest agricultural regions in the State, the soil of which is tillable almost to their very banks. These banks and the adjacent narrow flood-plains are almost everywhere composed of a rich, deep, dark loam. The average depth of these valleys, from the surrounding prairie level, is not far from one hundred and fifty feet, the southerly slope of the country keeping the depth of the valleys nearly uniform along a great part of their length. Their width varies from an eighth to a quarter of a mile, but their margins blend gradually with the prairie surfaces of the high lands.

The East and West Nishnabotany. Both these rivers, from their sources to their confluence, and also the main stream from thence to the point where it enters the great flood-plain of the Missouri, run through a region the surface of which is occupied by the Bluff Deposit described in a following chapter. They have so eroded their valleys that the underlying Drift Deposit is exposed in their immediate beds along almost their entire length; but the valley sides, flood-plains, and even the banks, are everywhere composed of the Bluff Deposit. This is owing to the fact that near their sources the Bluff Deposit is thin and gradually increases in thickness towards the Missouri river, at a rate that coincides very nearly with the slope of the streams.

The characters of these valleys receive very little modification from the presence of the Drift Deposit, yet they do not differ very greatly from the drift-valleys in general appearance, more especially along their upper portions. Both these rivers have a few exposures of the underlying strata in their valleys, but they occur only along their middle portions above their confluence. These do not, in consequence of the great thickness of the surface deposit, modify the character of the valleys to any extent. The West Nishnabotany is probably without any valuable mill-site, although it has a few slight exposures of Upper coal-measure, limestone, and Cretaceous sandstone in its valley. These occur only in the southern part of Pottawattamie county and in the western part of Mills county.

In the western part of Cass county, the East Nishnabotany loses its identity by becoming abruptly divided up into five or six different creeks, near which point several exposures of the Upper coal-measures, and a few also of Cretaceous sandstone are found in their valleys, and also in that of the main Nishnabotany. A few exposures of the same rocks are also found at rare intervals below the point referred to, in the counties of Pottawattamie, Montgomery, and Page. A few good mill-sites occur on this stream in the western part of Cass county, near the exposures of stata before mentioned; but none that are thought to be really reliable, exist on either of these rivers or on the main stream below the confluence, except perhaps, one or two in Montgomery county.

The general appearance and character of the valleys of these two rivers from their sources to the middle, respectively, of Cass and Pottawattamie counties, are those of ordinary prairie creeks, or of valleys excavated in the drift alone. The valley sides are gently sloping and undulatory like those of such streams; but below the points named they begin to assume their peculiar characteristics. The valleys gradually widen to a width of from a quarter of a mile to one or two miles, or even more; their sides being still undulatory and usually sloping very gently to the flood-plain. The flood-plains of these valleys are in some respects unlike those of other streams, for they usually have a slight but regular slope from the valley-side to the stream without any appearance of terraces; and yet much the larger part of the surface of these plains is entirely above the reach of the highest floods. Near the confluence of the two streams the valleys are still further widened, and the slopes of their sides from the uplands are very gentle. Below the confluence the united valley has much the same appearance, and from the distant high ridge, which separates it from that of the Missouri river, the view is often very beautiful and extensive, for the elevation at that distance from the river is upward of two hundred feet above the Nishnabotany. From the point where the Nishnabotany enters the great flood-plain of the Missouri river, it meanders through it for many miles as a tortuous, muddy canal, and finally empties into the great river within the State of Missouri.

The two valleys throughout their entire length possess considerable, but unromantic beauty; and the soil, both of the valleys and the entire intervening uplands, possesses remarkable fertility. It is seldom the case that the valley sides are steep, like the bluffs of the Missouri river flood-plain, although they are composed of the same material that those are; but when we approach the point where the united valley joins that of the great river, we begin to see the abrupt and peculiar outline of the bluffs so characteristic of the valley-sides of the Missouri river.

Boyer river, until it enters the flood-plain of the Missouri river, runs almost, if not quite its entire course, through the region, the surface of which is occupied by the Bluff Deposit; but like all others of the principal streams that run through this deposit, it has cut its valley out of, and entirely through it along almost its whole length. In consequence of this, some pebbles and sand are usually to be found in its immediate bed, but nothing except the fine material of the Bluff Deposit is elsewhere to be seen. This prevails so fully that the bed and immediate banks are everywhere muddy; and the soil of the whole valley differs little if any from that of the upland.

The only rocks exposed along the entire course of Boyer river are those of the Upper coal-measures, and these occur only at a single locality near Reel's mill in Harrison county. The exposures here are slight, and unimportant, except that they are the only exposures of underlying strata in the county, and the most northerly ones of the Upper coal-measures now known in Iowa.

The valley of Boyer river has usually gently sloping sides, and an indistinctly defined flood-plain. Its depth from the adjacent uplands varies from one hundred to one hundred and fifty feet; but the upland borders of the valleys of the stream which traverse the Bluff Deposit, are not usually so well defined as those of the streams which traverse the Drift Deposit alone frequently are. Along the lower half of its course, especially, the adjacent upland loses the originally well defined surface level, and presents a surface of the billowy character, so common near the valley of the Missouri river and peculiar to the Bluff Deposit. An unusually well marked example of this billowy surface of the same deposit, may be seen in the sketch accompanying the chapter on northwestern Iowa. It will thus be seen that the whole valley receives its characters from the surface deposits alone, without any modification from the underlying strata.

Soldier river presents very little that is peculiar to it, as compared with the other rivers which traverse the Bluff Deposit thus far described. However, near the point where its valley joins the great flood-plain of the Missouri river, it presents some examples of more or less distinct terraces, which are comparatively more rare in the Bluff Deposit than in the drift, owing to the peculiar composition of the former. The mode of formation of these terraces will be discussed in the chapter on Surface Deposits, accompanying which, will be found a sketch of the locality where the valley of Soldier river joins that of the Missouri.

The whole course of Soldier river, except that part which traverses the great flood-plain, is through the region occupied by the Bluff Deposit. It has cut its valley down through this deposit to the drift, along a great portion of its course but nowhere far into it. It has no exposure of strata along its entire course, and is consequently, a characteristic stream of the surface deposits unmodified by underlying strata.

Little Sioux river. Under this head are included both the main and west branches of that stream, together with Maple river, which is also one of its branches. Like Soldier river, both the West Fork and the Maple run their entire courses—except their upper branches which are mere prairie creeks upon the Drift Deposit—through the region occupied by the Bluff Deposit, and are so similar to the Soldier in all respects, that they need no separate description. The main stream, however, has its rise near the northern boundary of the State, and runs a great part of its course upon the Drift Deposit alone, before it enters the region occupied by the Bluff Deposit, which it does in the southern part of Cherokee county. That portion of the valley of the Little Sioux, from its source to the place where it enters this region, may be regarded as a typical drift-valley as they occur in Iowa, for nothing but this deposit is to be seen within or around it, and so far as is now known, it is not at all modified by the underlying strata whatever they may be.

The two principal upper branches near its source in Dickinson and Osceola counties, are merely small prairie creeks with gravelly beds and banks, and shallow, indistinctly defined valleys. Upon entering Clay county the valleys begin to have considerable depth, and after their confluence there, the valley soon reaches a depth of about one hundred and fifty feet. The depth continues to increase so that the part of the valley that has a westerly course along and near the boundary line, between Clay and Buena Vista counties, reaches a depth from the general prairie level, which is here quite distinct, of nearly two hundred feet. The valley here apparently cuts across the ridge which constitutes the Great Watershed in this part of the State, along which portion of its course it has well-defined borders, and a width of from one quarter to half a mile. Even here, where the valley is so deep, nothing but drift is to be seen in its bottom or sides, from which fact it is inferred that the Drift Deposit is about two hundred feet thick at this point. Just as the valley enters Cherokee county it turns to the southward, and becomes much widened and has its sides usually gently sloping to the uplands, which gives it the appearance of being shallower than it is farther up; but this is really not the case. When the valley enters the region of the Bluff Deposit, the surface soon begins to assume that billowy appearance before described, and its borders are consequently more or less obscured; yet it retains a general depth of about two hundred feet from the adjacent uplands until it joins the valley of the Missouri.

The lower portion of the river, from the last named point, is wholly unlike any other part of it; but is like similar portions of every other stream that crosses the great flood-plain within the State. It is a narrow, sluggish ditch, which is frequently filled with back-water from the Missouri river, so as to cause an overflow of the water of the upland portion of the stream upon the flood-plain. Indeed, the lower portions of these streams are only accidental channels for the escape of their waters to the great river across its flood-plain.

The Missouri river in former times ran along the foot of the bluffs on the Iowa side of its valley, where traces of its channel still remain. The Little Sioux now flows along a portion of the old channel of the great river, where it unites the West Fork, the Little Sioux, and Maple rivers into a common channel as they successively come down upon the uplands. Formerly these were independent streams and each emptied directly into the Missouri river. No exposures of strata of any kind have been found in the valley of the Little Sioux nor in those of its branches.

Floyd river is a small stream, essentially like those just described. It rises upon the drift, and flowing southward, it enters the region of the Bluff Deposit a little north of the centre of Plymouth county, and continues upon this deposit from thence to its mouth near Sioux City. Along this part of its course it has not, like the other streams of the region of the Bluff Deposit, cut its valley down through it, so as to expose the drift, except at a few points near Sioux City; although it seems certain that the drift cannot be anywhere very far beneath its bed.

This river is, almost from its source to its mouth, a prairie stream, with gently sloping valley-sides which blend gradually with the uplands, giving the valley the appearance of being very shallow. It reaches a depth of about one hundred and fifty feet from the adjacent uplands. A single slight exposure of sandstone of Cretaceous age, occurs in the valley near Sioux City, and it is the only known exposure of rock of any kind along its whole length. Near this exposure is a mill-site, but farther up, the stream is not very valuable for such purposes.

Rock river. This stream was evidently so named from the fact that considerable exposures of the red Sioux Quartzite occur along the main branch of the stream in Minnesota, a few miles north of our State boundary. Within the State, however, both it and all its branches are drift-streams; that is, no strata of any kind are exposed in their valleys, and nothing but drift is to be seen in and around them. They are shallow valleys, with gently sloping sides, which gradually blend with the undulating prairie surface. The beds and banks of the streams are usually sandy and gravelly with occasional boulders intermixed.

Big Sioux river. The valley of this river from the northwest corner of the State to its mouth, possesses much the same characters as all the streams of the surface deposits. This results from the friable character of the strata that underlie the surface along its borders, in addition to the fact that the surface deposits also cover them quite thickly, especially on the Iowa side. At Sioux Falls, a few miles above the northwest corner of the State, the stream meets with remarkable obstructions from the presence there of the Sioux Quartzite. This formation outcrops directly across the stream at that point, and causes a fall of about sixty feet within a distance of half a mile, producing a series of cascades and some fine examples of wild and romantic scenery, quite in contrast with that of the valley below and of the surrounding monotonous prairies.

From the northwest corner of the State downward, the river slope is comparatively gentle and similar to that of the other streams of western Iowa. For the first twenty-five or thirty miles above its mouth, the valley of the Big Sioux is very broad, and has a broad, flat flood-plain, which is in all respects like, and indeed continuous with, that of the Missouri river. Above the point named the character of the flood-plain changes, and like those of the drift-valleys, it becomes usually undulatory with very gentle slopes from the base of the retreating valley-sides to the stream, occasionally showing indistinctly defined terraces. The material of these terraces and valley bottoms—they are not here true flood-plains—is principally drift, slightly altered, and not alluvium properly so-called. They constitute some of the finest agricultural lands of the region, being quite above the reach of the highest floods.

On our side of the valley, however, the upland presents abrupt bluffs, as steep as the incoherent materials of which they are composed will stand. They are from one hundred to nearly two hundred feet high above the stream, while the Dakota side of the valley slopes away gently, its border gradually blending with the prairie surface beyond. The abrupt bluffs are almost continuous upon the Iowa side, while the flood-plain and sloping valley-side are almost as continuous on the other. Occasionally, however, along the borders of Sioux and Lyon counties, the abrupt bluffs appear on both sides of the valley, which is there quite narrow. These bluffs are frequently scored upon their faces with deep gorges, each with a small rill at its bottom. These gorges have very little length, for the adjacent upland is mainly drained by creek-branches of the Big Sioux, some of the upper subdivisions which reach around behind the faces of the bluffs, and drain the surface-water back from their very brows, and carry it by their own channel to the main stream.

At rare intervals, along about fifteen miles above the mouth of the river, the Cretaceous strata are found exposed in the face of the bluffs of the Iowa side. No other strata are exposed along all that part of the valley of the Big Sioux which borders our State, except a single exposure of Sioux Quartzite at its extreme northwestern corner. None of these strata, as before remarked, can be said to have characterized that part of the valley below the vicinity of Sioux Falls. Some good mill-sites may be secured along that portion of the Big Sioux which borders Lyon county, but below this the fall will probably be found insufficient or the location for dams insecure.

With the exception of the drift-streams of northwestern Iowa, the waters of which are usually clear, that of the rivers hitherto described has generally a stained appearance, even at low-water. When flooded, all of them carry out much sediment suspended in the water, which sediment is derived mainly from the surface deposits through which they flow, but none of them can be said to be constantly muddy as the water of the Missouri river is. All these streams are comparatively small; but an idea of their actual and relative length may be obtained from the geological map accompanying this report.

The Missouri river. The only discussion of this remarkable river that can be given in this report, must relate alone to the characters of the stream and its valley along that part of its course which goes to form the western boundary of Iowa. We have no information of the amount of water annually flowing past the State of Iowa in this great river, because no detailed hydrographic survey of it has been made along our border.

It is, however, one of the muddiest streams on the globe, and its waters are known to be very turbid far toward its source. Two collections of its waters have been made from its channel at Council Bluffs, and the solid contents determined by Prof. Emery. One parcel was collected at low water on November 9th, 1868, and the other on July 5th, 1868, when the river was just bank-full. The amount of sediment filtered out of the water in both instances is as follows:

Low-water, .462 grams in one liter=52 grains in one gallon.

High-water, 5.672 grams in one liter=404 grains in one gallon.

It will thus be seen that the amount of suspended sediment at times of high water, is more than twelve times as great as it is at low water.

The amount of solid matter held in solution in the same water, was also determined by Prof. Emery, and will be found on another page of this report. The turbidity of the water is at all times so great that no object can be seen beneath its surface. The amount of solid matter brought down by the river has always been very great, as will be explained under the head of Bluff Deposit, but it seems necessary here to anticipate the description of that deposit, so far as to say that it is composed of fine sedimentary material, similar to that which the river now deposits from its waters, and consists of material which the same river really did deposit, in a broad depression, in the surface of the drift that formed a lake-like expansion of that river in the earliest period of the history of its valley. That lake, as shown by its deposit which now remains, was about a hundred miles wide and more than twice as long. The water of the river was muddy then as now, and the broad lake became completely filled with the sediment which the river brought down, before its valley had deepened enough in the lower portion of its course to drain it. After the lake became filled with the sediment, the valley below became deepened, by the constant erosive action of the waters, to a depth more than sufficient to have drained the lake of its first waters; but the only effect then was to cause it to cut its valley out of the deposits also, its own muddy waters had previously formed. Thus, all along the valley of that river, so far as it forms the western boundary of Iowa, the bluffs which border it are composed of that fine sedimentary material known as the Bluff Deposit. These bluffs form a distinct and abrupt border along each side of the broad, level flood-plain, the width of which varies from five to fifteen miles, while the original sedimentary deposit stretches far inland on both sides.

6. RIVERS OF THE EASTERN SYSTEM.

The eastern system of Iowa drainage is rendered more complete as a system, if we include with it the drainage of a part of southeastern Minnesota. By doing so we find the interesting fact that the greater part of the region thus drained, is entirely enclosed by three rivers and their tributaries, which complete enclosure is caused by two of the streams having a common source and flowing from it in different directions. These are the East Fork of the Des Moines and the Blue Earth, a tributary of the Minnesota river. They rise in Crocker county, in what is called Union Slough by the inhabitants. The slough is a shallow, longitudinal depression in the general prairie level, having a north and south direction and much the appearance of the valley of an ordinary prairie creek. It is without water during the greater part of the year; but in wet seasons it is filled to a depth of several feet, and as each end of it opens into the respective streams named, one might then start there with a light boat, and choose whether he should perform a water-journey to the Mississippi by way of the Blue Earth and Minnesota rivers, or by way of the Des Moines. At such times, a large part of the region of the eastern drainage system of Iowa, together with its adjacent part of Minnesota, becomes an island.

The rivers of the eastern system have as a whole quite a different character from those of the western system. They are larger, longer, and have their valleys modified to a much greater extent by the underlying strata. For the latter reason, water-power is much more abundant upon them than it is upon the streams of the western system.

The Des Moines river is almost entirely an Iowa stream, having, it is true, its rise a few miles over the border in Minnesota, but it enters Iowa before it has attained any considerable size, and flows almost centrally through it from northwest to southeast, emptying into the Mississippi at the extreme southeastern corner of the State.

As a river, it is more complete in itself than any other of the Iowa rivers, except the Mississippi and Missouri, draining a greater area, and being the largest and longest. The upper portion of it is divided into two important branches, called in the usual nomenclature of the pioneers, the East and West Forks. These unite in Humboldt county to form the main stream. The valleys of these branches above their confluence are entirely drift-valleys, except that a few comparatively small exposures of sub-carboniferous limestone occur in the immediate banks of both streams, from three to five miles above their confluence. But these are not sufficient to even modify the general character impressed upon the valleys by the Drift Deposit. They are sufficient, however, to produce several fine mill-sites at those points upon both the streams.

The valleys vary in depth from fifty to one hundred and fifty feet below the general prairie level. Their sides are usually gently sloping, and they gradually blend with the undulatory prairie surface of the upland. The beds are more or less gravelly, but their banks are usually muddy from the abundant fine material of the drift. The valleys vary from a few hundred yards to half a mile in width; the flood-plain is seldom well marked, but the bottom of the valley is often a very gently sloping and slightly undulating prairie, quite above the reach of the highest water, and, as might be expected, are the finest of agricultural lands.

In the northern part of Webster county the character of the main valley is slightly modified by the presence there of ledges and low cliffs of the sub-carboniferous limestone and even by the gypsum; but the Drift Deposit is so thick that the general contour of the valley is such as might be expected from the prevalence there of this incoherent material. At Fort Dodge the valley has reached a depth of one hundred and seventy feet from the adjacent general prairie level. From Fort Dodge below, it begins to assume more of the usual characters of a river valley, having its winding course through a well marked flood-plain. From a point a little below Fort Dodge to near Amsterdam, in Marion county, the river runs all the way through and upon the Lower coal-measure strata. These strata, all being friable and easily disintegrated, they do not produce strongly marked features in the valley. For the same reason, and also in consequence of the usual heavy deposit of drift, natural exposures of those strata seldom appear. Along this part of its course the valley has generally irregularly sloping sides, sometimes abrupt, but usually blending with the uplands in the distance. The flood-plain varies from an eighth to half a mile or more in width. From Amsterdam to Ottumwa the sub-carboniferous limestone appears at intervals in the valley-sides again, forming low cliffs occasionally; but the exposures are generally small and distant from each other. Near Ottumwa the sub-carboniferous rocks pass beneath the river again, bringing down the coal-measure strata into its bed, but they rise again from it in the extreme northwestern corner of Van Buren county, and sub-carboniferous strata resume and keep their place along the valley from there to the mouth of the river. From Fort Dodge to the western part of Lee county, the strata of the Lower coal-measures are present in the valley, either at its bottom or resting upon the sub-carboniferous strata and forming the upper portion of the valley-sides. The drift is everywhere present, covering all the strata, except where it has been removed by erosion, but in the valley it is in a more or less modified form.

It is difficult to state any definite average depth to the valley of the Des Moines, because its borders are so indistinctly defined; but it seldom exceeds one hundred and seventy-five from the adjacent uplands. Its flood-plain is frequently sandy, from the debris of the sandstone and sandy shales of the coal-measures, produced by their removal in the process of the formation of the valley. The valley almost nowhere receives strongly marked features from any of its underlying strata, except perhaps, in Van Buren county, where there is an uplift that has brought up the Keokuk member of the sub-carboniferous limestone. In this county the valley is in some places quite narrow, the uplands approaching the stream on both sides.

The principal tributaries of the Des Moines are upon its western side. These are the "Three rivers" and the Raccoon, which together drain a large part of central Iowa.

The "three rivers," namely, *South, Middle, and North rivers*, have their rise in the region occupied by the Upper coal-measure limestone formation, flow eastward over the Middle coal-measures, and enter the valley of the Des Moines, upon the Lower coal-measures. These streams, particularly South and Middle rivers, have the sides of their valleys frequently bordered by high, rocky cliffs, along those parts of their courses which traverse the Upper coal-measure limestone.

Raccoon river has its rise by three principal branches upon the heavy surface deposits of the Middle region of western Iowa, and along the greater part of its course it has excavated its valley out of those deposits and the Middle coal-measures alone. The strata of the last named formation have yielded readily to denuding action, and consequently they are not often exposed in the banks or valley-sides, being covered by drift and their own debris. For this reason also, they do not strongly characterize the valley, although it is a well marked one, and sometimes reaches a depth of one hundred and seventy-five feet from the general level of the uplands.

The valleys of the Des Moines and its branches are destined to become the seat of extensive manufactures, both in consequence of their numerous mill-sites of immense power, and the fact also that the main valley traverses the entire length of the Iowa coal-field.

Skunk river runs almost its entire course, after it has reached any considerable size, upon the border of the outcrop of the Lower coal-measures, or perhaps more properly speaking, upon the sub-carboniferous limestone, just where it begins to pass beneath the coal-measures by its southerly and westerly dip. Its general course is nearly due southeast, and its slope being nearly coincident with the dip of the formation upon which it runs, its valley is not strongly marked by outcrops of strata, except along the lower part of its course in Henry and Des Moines counties. Here the limestone forms frequent cliffs from twenty to fifty feet high, but it is only in the immediate valley that any exposures appear, because the whole country elsewhere is covered with drift.

From the western part of Henry county, up as far as Story county, the valley of Skunk river has been a terror to travelers from the earliest settlement of the country until the introduction of railroads. It was the broad flat flood-plain that formed the obstruction to travel, for it is covered with a rich, deep, clayey soil, which in times of long continued rains and overflows of the river, made the whole a bed of adhesive mud, through which men and animals could pass only with great difficulty. The sides of the valley are usually so gently sloping along this part of its course, that it has the appearance of being very broad and shallow. The stream has really a considerable current, and the table on a previous page shows its slope also to be considerable; yet, as viewed from the uplands, it appears to be a sluggish stream, as it meanders through its broad flood-plain, with its slightly raised and muddy banks, bordered by willows, or a few scattered elms.

There are some excellent mill-sites on Skunk river, especially upon the lower half of it, but usually they are not so valuable nor so numerous as they are on many of the other rivers of the eastern system.

Iowa river. The Iowa river rises in Hancock county, in the midst of a broad, flat, or slightly undulating drift-region. The first rock exposed in its valley is the sub-carboniferous limestone, which occurs in the form of rocky banks to the stream in the southwestern corner of Franklin county. The river then enters Hardin county, and cuts across the north-eastern corner of the Iowa coal-field in a southeasterly direction, and enters the region of the sub-carboniferous limestone again, which it crosses, continuing in the same direction, and enters the region of the Devonian strata near the southwestern corner of Benton county. It continues in the region occupied by the Devonian rocks all the way to its confluence with the Cedar, having made an abrupt bend to the southward in the northern part of Johnson county. From the point of its confluence with the Cedar it is known to traverse a part of the region occupied by the sub-carboniferous strata, but they being the friable ones of the Kinderhook formation, no exposures of them are to be seen along that part of its course. Below its junction with the Cedar, and for some miles also above that point, its valley is broad and flat, especially upon its northern side. Bluffs of from one hundred to one hundred and fifty feet in height, border the southern side of the valley, near the foot of which the river runs until it enters the flood-plain of the Mississippi.

Above the point just named the valley is generally broad, with gently sloping sides, seldom too steep to be readily cultivated, and everywhere very beautiful if not romantic. The exposures, along its course, of the sub-carboniferous and Devonian limstones are usually in the form of low cliffs or smaller ledges, and long distances often occur without an exposure of rock of any kind to be seen, for the whole valley is covered with excellent soil and deep subsoil derived from the drift which profusely covers the whole region. The valley has generally a well-marked flood-plain, and more or less distinct traces of terraces are not unfrequently seen along its sides. Its borders are not often distinctly defined either in height or width, for they gradually blend with the uplands as they slope away in the distance from the river.

The Iowa furnishes numerous and very valuable mill-sites.

Cedar river. Cedar river is usually understood to be a branch of the Iowa, but it ought really to be regarded, as it is in fact, the main stream, and the Iowa as the principal branch. It rises by numerous branches, near the northern boundary of the State, and together with the greater part of these branches, large and small, it flows its entire length through the region occupied by Devonian strata, and along the general trend of the outcrop of that formation. Both it and its branches have more numerous and extensive exposures of rock along their valleys than any of the other rivers hitherto described. This arises in part from the fact that the formation over which they run is largely composed of firm, compact limestone, which is not readily disintegrated and covered by its own debris, as friable rocks often are after they have once been exposed. It is also largely due to the fact that the drift of northern Iowa is comparatively thin in the region drained by the Cedar and its tributaries. There is, however, enough of the drift everywhere to cover the surface with excellent soil, except where it has been removed by the wearing of the water in deepening the valleys.

The valley of this river in the upper part of its course, as well as those of its tributaries also, is narrow, and frequently without a well-defined flood-plain. The valley-sides slope so gently that it is often impossible to say where the low-lands end and the uplands begin. The exposures of rock are sometimes quite numerous in the valleys, usually appearing as rocky banks to the streams, and sometimes as cliffs from twenty to thirty feet high above them. Below the confluence of the Shellrock with the Cedar, the stream assumes more of the true characteristics of a river. The flood-plain is more distinctly marked, the cliffs upon its banks are less frequent, but occasionally higher, yet they seldom exceed forty feet in height. The valley throughout is broad and shallow, at least in appearance, and its borders are indistinctly defined from the upland. Below the confluence of the Shellrock, the drainage area of the river is greatly reduced in width; at one point in the southwestern part of Linn county, it scarcely reaches ten miles in width.

Although exposures of the underlying strata are so much more numerous than they are along any other river hitherto described, their cliffs are seldom high, and the stream meets with comparatively little obstruction from them from the fact that its course coincides so nearly with the trend of the formation it flows upon.

The valley of the Cedar is one of the finest regions in the State, and both the main stream and its tributaries furnish abundant and reliable water power, both as regards constancy of flow and security of mill-sites.

Wapsipinicon river. This river, in each corresponding portion of its course, is so similar to the Cedar in all respects that it hardly requires a separate description. It rises near where the Cedar does, and runs parallel with and near it along almost its entire course, the upper half of which is upon the same formation—the Devonian. In the northeastern part of Linn county it enters the region occupied by the Niagara limestone, upon which it continues until its confluence with the Mississippi. The features produced in its valley by this formation are similar to those produced by the Devonian strata along the upper part of the same valley, and also along the Cedar.

A striking peculiarity of this stream is the narrowness of the area drained by it compared with its length. It is upward of one hundred and eighty miles long, and the width of its drainage area, in its widest part, is only about twenty miles, and toward the lower portion of its course this area is reduced in some places to ten or twelve miles in width. In consequence of this, the stream is not subject to extravagant floods, and its mill-sites, which are very numerous, are hence more than usually secure.

Maquoketa river has its course entirely upon the region occupied by the Niagara limestone, and the character of its valley is not unlike those of the Cedar and Wapsipinicon. The magnesian limestone of this formation, however, weathers into rougher and more irregular forms when exposed along the banks and valley-sides, than the Devonian rocks of the Cedar valley do, in consequence of which the valley of the Maquoketa has frequently a more wild and romantic aspect than those of the other rivers just named. The depth of the valley, however, is not often great, seldom reaching two hundred feet from the general level of the uplands, and the valley-sides usually slope gently from them on both sides of the stream. This river is more tortuous, and together with its branches, it drains as great an area as the Wapsipinicon, although it is much shorter than the latter. There are many excellent mill-sites along the course of this river.

Turkey river. The Turkey and Upper Iowa rivers are both in many respects quite unlike any of the other rivers of Iowa hitherto described. The difference is principally due, however, to the great depth to which they have eroded their valleys, and the somewhat different character of the material through which they have been eroded. Turkey river rises within the State, and in comparison with its size it has a shorter course than any of the others mentioned. In Winneshiek county, within a few miles of its source, its valley has already attained a depth of more than two hundred feet from the general level of the uplands; and in Fayette and Clayton counties, its depth is increased to three hundred and even near four hundred feet in some places. When the latter height above the stream is attained, however, the slope of the valley-side has carried it back to some distance. The summit of the uplands bordering nearly the whole length of the valley, is capped by the Maquoketa shales, which, on account of their friable character, seldom appear as natural exposures. These shales are in turn underlaid by the Galena limestone, a magnesian limestone formation, which is here between two and three hundred feet thick. The valley has been eroded entirely through both of these, and runs the greater part of its course within and upon the Trenton limestone. Thus all the formations along and within this valley are Lower Silurian.

That portion of the valley which traverses Fayette and Clayton counties is a deep gorge, in comparison with the valleys of the other rivers hitherto described, with steep and often precipitous sides. High, rocky cliffs are not uncommon, but usually the steep sides are covered with debris of sufficient fineness to sustain a good growth of trees. The valley is usually narrow, and without a well marked flood-plain. Along a large part of its course the valley is too narrow to contain much good farming land; and hitherto, it has been found difficult to open a good wagon road along its entire length. Its fall is so great that water-power is abundant, but it is not accessible at all places, on account of the steepness of the valley-sides.

Upper Iowa river. There is frequent reason to complain of the meagre nomenclature of the early pioneers as applied to our rivers as before intimated. We have in consequence of it two Iowa rivers with only the addition of the word "upper" to distinguish the name of the one under discussion from that of the one already described as Iowa river. The Upper Iowa rises in Minnesota just beyond the northern boundary of Iowa, but enters our borders before it has attained any considerable size. Its course, although it has many windings, is nearly eastward until it empties into the Mississippi. It rises in the region occupied by Devonian rocks, and flows across the outcrops respectively of the Niagara, Galena, and Trenton limestones, the St. Peter's sandstone, the Lower Maguesian limestone, and Potsdam sandstone; into, and through all of which, except the last, it has successively cut its valley.

Its valley is the deepest of any in Iowa, reaching a depth in its lower part of more than four hundred feet from the highest ground in the vicinity. That portion of it which traverses Allamakee county has the Potsdam sandstone composing the base of its valley-sides, the Lower Magnesian limestone forming the remainder of them. The greater part of the portion which traverses Winneshiek county, has its sides composed almost entirely of strata of the age of the Trenton limestone, which has a thickness in this part of the State of not less than two hundred feet. In the lower part of the valley the flood-plain sometimes reaches a width sufficient for the location of small farms; but usually the valley is too narrow for such purposes, and is often without any flood-plain at all. The valley sides are almost everywhere high and steep, and cliffs of Lower Magnesian and Trenton limestones often give them a wild and rugged aspect.

The farming lands of the higher surface, however, extend almost to the very verge of the valley, so that in most cases as soon as one leaves the valley in any direction, he comes immediately upon a cultivated country. This stream has the greatest slope per mile of any in the State; consequently it furnishes immense water-power. This is particularly the case with that portion of it which traverses Winneshiek county. In this county especially, the valley is very beautiful and picturesque. In some places, as for example where creeks come into it, the valley widens and affords good locations for farms and villages. The town of Decorah is located in one of these widened parts of the valley which makes it a lovely location and the almost unlimited water-power of the river and smaller spring-streams around it, offer fine facilities for manufacturing and for fish-culture. This river and its tributaries are the only trout streams in the State.

The Mississippi river. It seems almost like mockery to pass over this grand old river with so few remarks as are here devoted to it, but the object of this chapter is only to describe the general surface features of the State. Therefore, only a very brief outline of the character of that portion of its valley which borders upon Iowa can be given here. This may be described in general terms as a broad canal cut out of the general level of the country through which the river flows. It is bordered upon either side by more or less abrupt hills or bluffs, which have been left standing while the valley was gradually being deepened by the erosive action of its own waters. The bottom of this valley, between the ranges of bluffs upon each side, varies from one or two to six or eight miles in width. The whole space between the bluffs is occupied by the river and its bottom or flood-plain only, if we except the occasional terraces or remains of ancient flood-plains which are not now reached by the highest floods of the river, and have never been reached by them since the river attained its present level. The height of the bluffs above the flood-plain varies from one hundred and fifty feet to upward of four hundred feet, the highest being at the northern part of the State, where also the valley is narrowest.

The Lower Silurian formations compose the bluffs there, but they gradually disappear by a southerly dip, and the bluffs are continued uninterruptedly by being successively composed of the Upper Silurian, Devonian, and sub-Carboniferous rocks. Each of these formations, according to its lithological composition, modifies to some degree the outline and aspect of the bluffs. Thus, from the northeast corner of the State to a point several miles below Dubuque, the valley has a deep, broad, gorge-like appearance compared with what it has below. This is largely due to the firm character of the two great magnesian limestone formations, that compose the greater part of the bluffs along that portion of the valley. Below this, the bluffs are composed of the Niagara, and Devonian limestones and are more retreating and rounded in their outlines, but with diminishing height, they recover something of their abruptness upon the accession of the sub-Carboniferous limestone near the southeastern corner of the State.

The river itself is from half a mile to nearly a mile in width, and winds from side to side through the flood-plain, so that it runs near the foot of the bluffs upon one side or the other, along a great part of its course. There are, however, only three or four points along the whole length of the State where the bluffs approach the stream upon both sides. Its waters, although always having a stained appearance, are quite clear, especially as compared with those of the Missouri.

7. RELATIVE AGES OF THE RIVER VALLEYS.

There is evidently much difference in the relative ages of the river valleys of Iowa, if we take into consideration the full history of their formation; but if we consider them only in their relation to the present general surface of the State, they all evidently date back only to the close of the Glacial epoch. At the close of that epoch, as will be explained more at length in the next chapter, the surface of the whole State, as well as that of the surrounding region, was evidently so covered by the Drift Deposit as to present a surface nearly as level as that which has been assumed in the description of the Surface Features of the State on a previous page. That is, upon the recedence of the glaciers, the surface waters gathered into rivers, and had all their valleys to cut out anew, for the deep, continuous mantle of drift had filled, and covered all the valleys of the rivers that had drained the land before the Glacial epoch.

To what extent our rivers of to-day occupy pre-glacial valleys it is difficult, if not impossible to determine; but that the Mississippi, together with all the rivers of northeastern Iowa, if no others, had at least a large part of the rocky portions of their valleys eroded by pre-glacial, or perhaps even by palæozoic rivers, can scarcely be doubted.

When, at the close of the Glacial epoch, the new-formed rivers selected their courses by the law of gravitation, some of them doubtless found their way along the valleys of ancient rivers, and gradually swept out the incoherent drift that had filled them, leaving the rocky cliffs up each side as the ancient rivers had left them. Others seem to have followed those ancient valleys only a part of their course, while still others, especially those of the western system of drainage, date the earliest period of the history of their valleys back only to the close of the Glacial epoch. Indeed the valleys of the upper branches of every river in the State, have no greater antiquity than this, for they all rise and flow upon deposits no older than the drift. Some of the valleys of western Iowa are wholly of more recent origin than the drift. These are excavated out of the Bluff Deposit alone, which is of lacustral origin, and, as will be shown in the next chapter, is wholly of later date than the drift.

8. LAKES.

The largest bodies of still water in Iowa are so small that they would receive in some parts of the country only the designation of "ponds;" but no distinction of this kind is made by our people, all such bodies of water, whether large or small, being called lakes. The lakes of Iowa, taken as a whole, are not very conspicuous features, but they are well worthy of separate consideration. They may be properly divided into two distinct classes, the difference being not only in their existing characteristics, but also in the mode of their origin, and in the relative age of the deposits upon which they rest, for although they are all of post-Tertiary age, they were not simultaneously formed.

The first may be called *drift-lakes*, having had their origin in the depressions left in the surface of the drift at the close of the Glacial epoch, and have rested directly upon the undisturbed surface of the Drift Deposit ever since the glaciers disappeared. The others may be properly called *fluvatile* or *alluvial lakes*, because they have had their origin by the action of rivers, while cutting out their own valleys from the general surface of the drift as it existed at the close of the Glacial epoch, and are now found resting upon the alluvium as the others rest upon the drift. The erosion of the valleys having been accomplished by the vibration of the stream from side to side of its bottom or flood-plain, alternately occupying and abandoning all portions of it successively; the fluvatile lakes have all been formed since the others were, and originated in

Mills & Co. Lith. Des Moines.

VIEW OF SPIRIT LAKE, LOOKING NORTH.

1868

(Head of Lake Okoboji in foreground on right)

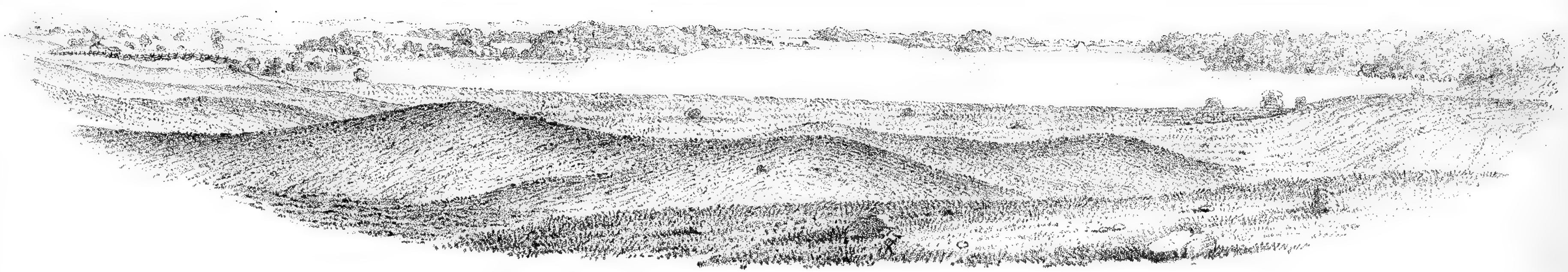
this way:—Some of the channels formed and abandoned by the river, as before intimated, were never afterward re-occupied by it, because the general deepening of the channel progressed considerably in some instances before changes above or below certain points, induced a change of occupancy there. Therefore these previously isolated portions of the old channel have remained to this day as bodies of still water, and have now a position a little above the present highest floods of the river. These lakes, resting upon alluvial material, show evident traces of their fluvatile origin, in their general character and form. Some of these fluvatile lakes, indeed, are not entirely above the reach of the highest floods of the streams near which they are located, and it is not impossible that a part of them may yet be re-occupied by the shifting channel, particularly as their location often suggests a more direct or favorable course for the stream than the one it is now taking. Such lakes as these are not uncommon upon the flood-plains of the Mississippi and Missouri rivers, but they are not common elsewhere in Iowa. They are usually well stocked with fish, and also in their season, with an abundance of wild water-fowl; but their vicinity is never attractive as a place of residence on account of the marshy surroundings and low situation.

On the contrary, the shores of the majority of the drift-lakes of northern Iowa, are some of the most delightful spots for residence to be found within the limits of the State. Their waters are always clear and excellent, and their borders usually gravelly and clean. These lakes, resting as they do in gentle undulations of the surface, have few very bold features in the landscape which surrounds them, and their depth, for the same reason, is usually slight. This is indicated by the evident continuation of the gently curved contour of that portion of the surface which is now above their water-levels.

For reasons elsewhere explained, the regions to which the drift-lakes are principally confined are near the head-waters of the principle streams of the State. We consequently find those regions of northern Iowa which lie between the Cedar and Des Moines rivers, and between the Des Moines and the Little Sioux, to possess the character of surface necessary to the existence of such lakes, more distinctly marked than in other regions, because no accumulation of water beyond or within them has been sufficient to cut channels of necessary depth to drain the surface of its originally collected waters, as has doubtless been done in all that portion of the State occupied by the principal streams, especially in southern Iowa, where we find no drift-lakes.

The largest of these lakes to be found in the State are Spirit and Okoboji lakes, in Dickinson county; Clear lake in Cerro-Gordo county; and Storm lake, in Buena Vista county. The width and length of the first named lake are about equal; and it contains by estimate about twelve square miles of surface, its northern border resting directly upon the northern boundary of the State. Its shores are almost everywhere gravelly, and its banks are mostly wooded for a short distance away from the water. The country around is gently undulating fertile prairie, the highest of the elevations within range of vision not exceeding eighty feet above the surface of the lake. These are, doubtless, the highest points in the State, since the lake lies almost directly upon the Great Watershed. The accompanying sketch will give a good idea of the appearance of the lake and the adjacent country.

Okoboji lake lies directly south of Spirit lake, and has somewhat the shape of a horse-shoe with the point of its eastern prong coming up to within a few rods of Spirit lake, where it receives the outlet of the latter, as shown in the sketch. There being about six feet fall from Spirit to Okoboji lake a small flouring mill has been erected upon the outlet. The supply of water seems sufficient for so small a mill as the one now erected, but the proper basis for estimating the reliable water-power in this instance is the amount of water the lake receives, exclusive of what actually rests within its basin. The latter should only be relied upon as a reservoir. These drift-lakes, resting as they do upon the watersheds, do not receive a large



LAKE OKOBOJII-LOOKING NORTH-DICKINSON CO. IOWA
1868

amount of water annually, and consequently have comparatively little to furnish as water-power for continuous use. Okoboji lake extends about five miles southward from the point nearest Spirit lake, thence about the same distance westward, and then bends northward again, extending about as far north as the eastern portion does, making a continuous length in all its bendings of about fifteen miles. The eastern portion is comparatively narrow, so that in one of its narrowest places it is spanned by a long bridge, and also at the point where it joins the western portion, by a still shorter bridge; but the western portion is larger and deeper, for which reason it was called "Minnetonka"* by the Indians, to distinguish it from the other. The depth of these lakes was not ascertained, but Minnetonka is reported to be near a hundred feet deep at one point.

The accompanying sketch gives a good idea of the appearance of Minnetonka and its surroundings. The view is taken from its southern end, looking north. The beaches are almost everywhere good, but those upon the right hand shore afford excellent bathing places. The surroundings of these lakes are everywhere pleasant, and they have already begun to be a favorite resort for those in pursuit of health or pleasure. Fish are abundant in them, and in the autumn especially, they are the resort of myriads of water-fowl.

Clear lake is a pleasant sheet of water, situated upon the watershed between the Iowa and Cedar rivers, in Cerro-Gordo county. It is about five miles long and two or three miles broad, and has a maximum depth of only about fifteen feet. Its shores are mostly gravelly and its banks for the most part wooded. The country around it is undulatory like that around Spirit lake.

Storm lake is situated upon the Great Watershed in Buena Vista county, and on the line of the Iowa Falls and Sioux City Railroad. It is, like the others, a clear beautiful sheet of water, containing a surface area of between four and five square

* Great water in the Sioux dialect.

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miles. Its beach is clean and gravelly; and nothing is lacking to make it a beautiful and interesting region but the presence of forest trees, for the region all around is an open prairie. Trees will grow so rapidly when planted and protected from the fires, that this defect will, in a few years, be remedied.

The outlets of all these drift-lakes, except that of Okoboji, are dry during a portion of the year, when they appear to have no outlet, as they are usually shallow and small, and frequently covered with a growth of coarse grass and sedge. In the wet portion of the year the water escapes through these, but at other times the escape is evidently through the gravelly drift subsoil.

9. WALLED LAKES.

The lakes thus far mentioned are the largest in the State; but along the watersheds of northern Iowa great numbers of smaller ones exist, varying from half a mile to two or three miles in diameter. They are usually pleasant, shallow sheets of water, occupying the depressions among the undulations of the surface. One of these small lakes in Wright county, and another in Sac county have each received the name of "Walled Lake" on account of the existence of embankments upon their borders which are popularly believed to have been the work of ancient aboriginal inhabitants, and concerning which many fanciful stories have been circulated in the public prints. These two lakes are no more worthy of such distinction than any others of their class, because all the drift lakes that have been examined, and this comprises nearly all that exist in the State, not one of them has been found destitute of the so-called walls along some portion of its shore; and some of them even exceed in interest the two that have attracted so much attention.

A true description of these popularly-called walls, but which I shall term embankments, will be best understood if given in connection with an account of their origin.

When a pile of sand from the river shore has been left by the workmen for a long time exposed to the rains, the gravel which it contains and which was at first hardly visible, becomes in time even more conspicuous than the sand itself, because a part of the latter has been wasted while the gravel all remains. Thus it has been, upon an extended scale, with the drift upon which all these lakes rest. It is composed of soil, clay, sand, gravel, and boulders; the former being usually so much in excess upon the surface around the lakes as to cover the boulders so completely that sometimes none are to be seen there. They doubtless exist in greater or less numbers everywhere in the drift, although they may not appear on the surface, for wherever a stream has cut its valley down through it, all the boulders contained in the whole mass removed, become and remain exposed, while the fine material has been swept away as sediment suspended in the flood-waters of the streams. The boulders thus left collect upon the valley-sides and many of them roll down into the stream collecting in its bed. For this reason, we find them more numerous there and upon other eroded surfaces than anywhere else.

Again, the ceaseless dashing of a lakelet's waves stirs up the finer material of the drift which rests beneath its waters. This passes off as sediment at the time of their overflow, leaving the gravel and boulders strewn abundantly upon its bed, even if none of either is to be seen upon the prairie surface around. This latter fact being misunderstood, has led to the belief that their absence upon the adjacent prairies was caused by their having been collected by human hands and brought to the lakes to build the "walls" (?) of; while the truth is, the embankments, as well as the presence of the separated material of which they are composed, are due to natural causes alone, the origin of the embankments being wholly referrable to the periodic action of ice, aided to some extent by the force of the waves.

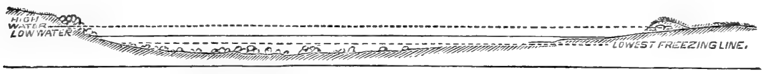
The lakes are almost without exception very shallow and the water in them is usually low in late autumn, so that when winter comes, it is frozen to the bottom over so wide a margin from the shore, as to leave in some of them very little unfrozen water in the middle. In some of the shallower ones, indeed, the water is occasionally all frozen and the fish killed by that means. This was the case a few years ago with Walled lake in Wright county, but it has since been partly re-stocked by the fry that reaches it from the rivers by way of the outlet at the time of overflow.

The ice, of course, freezes fast to everything upon the bottom, whether boulders, sand, gravel, or mud, and the expansive power of the water in the act of freezing is exerted upon them, acting from the center of the lake in all directions towards its circumference. Those who are familiar with the expansive power of ice in the act of forming, will readily see that under such circumstances it would be more than sufficient to move the largest boulder up the gentle slope of the bed of the lake. It is true that the motion resulting from one winter's freezing would hardly be perceptible, but the act repeated from year to year, and from century to century, would ultimately move everything upon the bottom beyond the reach of the ice. The tracks of boulders thus moved have been observed, being as unmistakable in their character as those are which the river mussel leaves behind it in the sand.

Thus it will be seen that whatever was originally upon the bottom of the lake within the reach of the ice, whether boulders, sand, gravel, or mud, has been constantly carried toward the shore, where we find them collected in perfectly natural disorder, and forming a ridge just where the expansive power of the ice ceased. Below the line of freezing the same kind of material would of course remain unmoved upon the bottom, because there is nothing to disturb it.

The real embankments are only found separating a piece of low land from the lake, because the material thrust out by the ice against the steeper banks, merely accumulates there upon the slope which rises above any such accumulation, and also, of course, above the high water line of the lake. In such cases the shore is often thickly studded with the boulders thrust against it, but the material meeting no such obstruction on a marshy side accumulates in circular ridges around the lake, and these are the walls that have excited so much wonder.

FIG. 2.



The above diagram shows the relative positions of the embankments, the high and low water levels, and the lowest level of freezing.

The embankments vary in height from two to ten feet, and from five to twenty or thirty feet across the top, their size and outline varying according to the materials which compose them. If boulders were numerous upon the bottom, the adjacent embankment is largely composed of them; if sand prevailed, a broad, gentle, rounded embankment resulted, just such as might be expected from that material; and if mud, filled with the fibrous roots of water plants and sedges, were brought out by the ice, a steep, narrow embankment was formed, because such material will stand more erect in a ridge or embankment than sand and boulders will. Such embankments of fibrous mud are often found separating a peat-marsh from the lake which was once a part of it. These are erroneously called Beaver dams by those who forget that beavers never attempt to dam still waters; but dam running streams only, that they may have ponds of still water for the use of their colonies.

It has been observed that the embankments are often largest on the sides opposite the prevailing winds. This may be accounted for, at least in part, by the fact that the ice being burthened with the materials to which it had frozen fast, would be floated to those shores when the spring-floods had raised the water in the lakes; and in part also, by the fact that the dashing of the waves would be most constant and forcible against those shores. The objection that the material thus taken up and floated by the ice would be as likely to drop anywhere else as at the shore, loses force when it is remembered that wherever else they may drop they are subject to be again removed by the causes before mentioned, but once dropped at the shore they remain there.

Thus we see that the same natural force that brought the boulders down from their northern home, also placed them in the embankments of those lakes; namely, the expansive power of ice.

These embankments are really very interesting natural objects, and it is not strange that they have attracted much attention; but with a correct knowledge of natural forces it is difficult to understand how any person could suppose that human hands had anything to do with their construction. There is certainly nothing in the arrangement of the materials that indicates such an origin; and the liveliest imagination refuses to suggest any object for which human beings could have desired them, or to point out any evidence of human intelligence in their location and plan.

10. SINKHOLES AND SPRINGS.

Among the minor features that are found to mark the surface at some limited localities in the State, and which always arrest considerable popular attention, are small circular depressions known as sinkholes. They are almost without exception in the surface of the uplands, and only where these immediately border a valley in the sides of which limestone ledges or cliffs are exposed.

The mode of their formation is this: the water which falls upon the surface finds its way by percolation down to the underlying strata, and through fissures and interstices in these, out upon the valley-side below, where it issues in the form of springs. A little of the fine surface material is constantly taken into the subterraneous passage by the water which falls upon the surface, and is conveyed by it into the valley in the form of sediment. Upon the surface immediately above the point where the percolating water enters the fissure in the rocks, a depression is formed by the caving in of the surface material. Depressions thus commenced deepen by the same cause until the sinkholes are formed, having the shape of an inverted hollow cone, with a depth at the apex, sometimes reaching twenty or thirty feet from the surface, and even more. Water accumulates in these sinkholes from every hard rain, but it soon drains out again through their subterraneous passages—hence their name of sinkholes.

Sometimes they are larger than has just been indicated, and have miniature ravines leading into them through which little rills of water flow in time of rain. Just eastward from the town of Decorah, in Winneshiek county, a good sized creek empties into the south side of the Upper Iowa river. About a mile up from the mouth of this creek, it is seen to issue from the abrupt end of its valley in the form of a huge spring, and is immediately set to work by an enterprising citizen to furnish power for a woolen factory. Going back from this point upon the undulating uplands, we come upon the creek valley again within about half a mile, and see the creek disappear beneath the surface in a depression, which is really a sinkhole on a large scale, with a constant stream of water running into it. With the exception of this half a mile of subterraneous passage, however, the creek is in all respects an ordinary one. It is the peculiar fissured and laminated character and great thickness of the strata of the age of the Trenton limestone, which underlies the whole region, and forms the valley-sides of its streams, that has produced this interesting phenomenon, and which also gives origin to numerous sinkholes along the upland borders of the Upper Iowa valley. From the same cause, also springs of large size are very numerous in that valley, a number of which, since they have so great a fall, give sufficient water-power for small mills.

Springs, of course, issue from all formations and from the sides of almost all valleys, but they are more numerous and important when the underlying strata are of such a character as to facilitate the percolation of the surface-water down to a certain level there to be arrested, so that it will flow out upon the surface below.

No mineral springs, properly so-called, have yet been discovered in Iowa, but the water of artesian wells is frequently found charged with soluble mineral substances, as will be seen in the report of Prof. Emery, in volume two.

11. CAVERNS.

Although a large part of Iowa is underlaid by limestone formations, there are no caverns in the State that are remarkable as such; yet, in consequence of associated circumstances, some of those that do exist are worthy of mention in this connection. The most noted of these are the lead caves of Dubuque and the ice-cave of Decorah. The lead-caves are usually mere vertical fissures extending through a great portion of the whole series of strata which constitute the Galena limestone formation. They vary in width from a mere fissure to two or three yards. They are very numerous and are fully described by Prof. Whitney, in his chapter on the Dubuque lead region in the former geological report.

The *Ice-Cave* at Decorah is a vertical fissure in the face of the cliff of Trenton limestone that forms a part of the north valley-side of the Upper Iowa river. The fissure is nearly parallel with the face of the cliff, and seems to have been produced by a slight settling away of a portion of its face at the base, causing its slight separation from the solid portion. The fissure or cave is about one hundred feet long in all its windings, and varies from two to six or eight feet in width. Its height is irregular, as the two walls come together irregularly at the top.

The ice collects upon its bottom and upon its inner wall near its base, in the form of an encrusting mass. No water was seen flowing or accumulating anywhere; the ice seemed dry and well frozen, and was evidently accumulating at the time of our visit, (June 1st, 1869). The cave was cool and apparently dry, and no strong current was passing through it. The ice is said to be most abundant about midsummer and entirely absent in winter.

The formation of the ice is probably due to the rapid evaporation of the moisture of the earth and rocks, caused by the heat of the summer sun upon the outer wall of the fissure and valley-side. This outer wall is from ten to twenty feet in thickness where the ice was seen to be most abundant. The water for its production seems to be supplied by slow exudation from the inner wall of the cave.

Ice caverns, more extensive than this are known in various parts of the world, but this is, so far as now known, the only one in Iowa, and has consequently excited much popular interest.

CHAPTER II.

SURFACE DEPOSITS.

The surface deposits, which it is proposed to discuss in this chapter, are those to which the names of Drift, Bluff, and Alluvium have been applied; all of which rest upon or above the stratified rocks that form, so to speak, the foundation of our State. It is from these almost alone that our soil has been derived, and, covering the underlying rocks so generally, the materials of which they are composed are more familiar to our eyes than any others which enter into the composition of the earth's crust.

1. DRIFT.

The deposit to which the name of Drift is applied, has a far wider distribution than any other surface deposit. It meets our eyes almost everywhere, covering the earth like a mantle and hiding the stratified rocks from view, except where they have been exposed by the removal of the drift through the erosive action of water. It forms the soil and subsoil of the greater part of the State, and in it alone many of our wells are dug, and our forests take root. Occasionally it is itself covered by another deposit; as for example, by the Bluff Deposit of western Iowa, in which case, the latter forms the soil and subsoil. No other deposit, however, intervenes between the drift and the stratified rocks.

Physical Composition. The drift is composed of clay, sand, gravel, and boulders, promiscuously intermixed, without stratification or any other regular arrangement of its materials. It varies in character in different parts of the State, but the variation is principally due to the varying proportions of the component materials. These materials are always incoherent; that is, they are not cemented nor consolidated into rock, but may always be excavated with more or less facility. All the materials of the drift being so intermixed, it is somewhat difficult to give any definite description of each, especially of the finer ones. Such descriptions, therefore, must be merely general.

The clay of the drift, which is always present in greater or less proportion, is always impure; always finely disseminated throughout the whole deposit, but not unfrequently, irregular masses of it are separated from the other materials. Its color is usually yellowish from the per-oxyd of iron it contains, and which when it is burned into bricks gives them their red color.

The clay is frequently sufficiently separated from the other materials, to assume the peculiar fissured character which separates the mass into small, irregular, angular divisions, in which condition it is popularly called "joint clay." Again, particularly within the limits of the coal-field, it has frequently the same character as that into which the clayey and shaly beds of the coal formations are seen to become weathered, where they crop out in the valleys of the streams of that region.

Much of the so-called clay of the drift, and also of the soil, is however, not wholly a silicate of alumina, as true clay is, but it is often largely intermixed with more or less pure silica in a finely divided condition. Besides this, it usually contains varying proportions of the carbonates and silicates of lime and magnesia, the carbonates being much the most abundant.

The proportion of lime in the drift of Iowa, is so great that the water of all our wells and springs is too "hard" for washing purposes; and the same substance is so prevalent in the drift clays that they are always found to have sufficient flux when used for the manufacture of brick.

It is frequently the case, that the sand and gravel have naturally combined with the clay in such proportions as to produce a mass of extreme hardness, which, together with the toughness imparted by the clay, renders its excavation almost as difficult as that of rock.

The sand of the unaltered drift is seldom separated from its other materials in any degree of purity, but it is not unfrequently the case that it exists in excess of the others; and in some cases small local accumulations or pockets of it are found, having a considerable degree of purity. The sand is quite variable as to fineness, and it sometimes approaches or grades into gravel.

The gravel of the drift is derived largely from rocks that are more or less purely silicious, but occasionally they are found to be of granitic composition.

In southwestern Minnesota, the Sioux quartzite is often found in the form of beds of considerable thickness, composed of a mass of silicious pebbles, varying in size from coarse grains of sand to three or four inches in diameter. Such beds are not so hard and compact as the ordinary quartzite is, but the pebbles often separate with considerable facility; although this, as well as the quartzite, has undergone metamorphism. In western and northwestern Iowa also, the Cretaceous sandstones are found to contain beds of silicious pebbles scarcely cemented together at all. The pebbles of both these formations are silicious and never granitic.

From these sources, and also from the beds of rivers that existed upon the surface at the commencement of the Glacial epoch, it is believed a large part of the pebbles of the drift were derived. These of course were already formed as pebbles at the commencement of the Drift epoch, some having been worn in Azoic and some in Cretaceous seas; while others received their form in the beds of pre-glacial rivers. It is not denied that a part of the drift pebbles may have received their rounded form by glacial attrition, or other causes subsequent to the glaciers; but there can be no doubt that a large part of the drift gravel of Iowa existed as gravel before the Glacial epoch. Gravel constitutes only a small proportion of the bulk of the drift, but it is always a characteristic constituent of it.

Boulders constitute a very conspicuous and characteristic feature of the drift, although they form but a small proportion of the bulk of that deposit in Iowa, where its fine materials are everywhere greatly in excess of all others. The boulders of Iowa drift are composed of granite, quartzite, and limestone rocks; those of granite being much more numerous than all others in eastern Iowa, and those of granite and quartzite both largely prevailing in the western part of the State. Limestone boulders are comparatively rare anywhere, but they are found most frequently in the middle portion of the State as one traverses it from east to west. The largest as well as the most numerous of the boulders are those of granitic composition. Occasionally these are quite large, reaching fifty tons in weight or upwards, but they are usually very much smaller than this. Although generally they have at least a somewhat rounded form, they seldom present any real appearance of having been water-worn as the pebbles have. Their rounded forms seem due rather to the concentric decomposition of the broken fragments of rocks, thus rounding off their angles; or to the somewhat concretionary character of the mass of which it was originally a part. This, it is thought, is particularly true of the granite, which is known sometimes to contain concretionary centres in which the rock is harder and more compact than the greater part of the mass is.

Rare Substances and Fossils are sometimes found in the drift of Iowa. The fossils are always those of the older rocks, none of any kind having been discovered in it that are properly referable to the age of the drift itself. Lumps of copper, lead-ore, and even traces of gold, have been found in it. Also lumps of impure coal, pieces of wood, and other traces of vegetation. All these have been transported and are as much strangers in Iowa as the granite boulders are. Their origin will be referred to on a subsequent page.

Distribution of the Drift. No evidence of anything like general stratification, or successive changes in the vertical accumulation of the materials of the drift as originally deposited, has been observed in Iowa. Modifications of it, in some cases closely approaching true stratification, have taken place, but this was evidently subsequent to its original deposition, and will be presently noticed under the head of Altered Drift. It may be remarked here, however, that the eye may occasionally catch a trace of a horizontal arrangement of large pebbles and small boulders in such places, for example, as the face of a railroad excavation in the drift upon the high prairies of the State. This apparent modification probably has no direct connection with the more distinctly stratified altered drift of the valleys, but the subject will be again referred to further on.

Neither the clay, sand, gravel, or boulders, are confined to any particular part of the deposit vertically, but either or all of them may occur at its base, middle or surface. Generally, however, the whole surface of the drift, especially that of the higher prairies, is covered with the finest materials alone, the coarse materials and stiff clays being usually covered from sight. This is particularly the case in eastern and southern Iowa, where boulders upon the higher surface are rarely seen, but in northern Iowa the higher surfaces sometimes have boulders and gravel exposed quite conspicuously upon them.

The different materials of the drift have little more regularity in their geographical distribution than in their vertical arrangement, but that distribution, indefinite as some of its outlines are, throws considerable light upon the origin of the deposit. It may be said in general terms that in northern and northwestern Iowa the drift contains proportionally more boulders, pebbles, and sand, than elsewhere, and that in other parts of the State it contains proportionally more clay and other finely comminuted materials; yet in the first named region there is enough of the clayey material, as a general rule, to produce an excellent soil. Occasionally, however, the elevated ridges and knolls there have a poor soil, composed of little besides gravel and scattered boulders; but such places are very small compared with the space occupied by good soil, and would hardly attract attention anywhere except in a region so fertile as Iowa.

Boulders being more definite in their character than the other materials of the drift, we are able to make more satisfactory observations concerning their distribution. We find that they are more abundant in some places than in others; and also, that those having a certain composition prevail in some parts while such are entirely absent in others. Besides this, we find that in one limited part of the State, boulders of all kinds are almost entirely absent. The outline of this boulderless region may be approximately described as follows:

Commencing upon the north line of Winneshiek county, go southeastward to the center of the west line of Clayton county, thence to the northwest corner of Jackson county, and thence to the Mississippi river, near Clinton, the space between this line and the Mississippi river, is the region referred to. It is not entirely boulderless, but boulders are exceedingly rare there. It is, however, by no means a driftless region; because the other characteristic materials of the drift are present, except upon some of the hills and in some of their valleys near the great river. Occasionally the drift clays are found to be of considerable thickness within this region.

Going westward from this boulderless region, we find inmediately bordering and parallel with it, extending from Mitchell, to Cedar county, another region in which boulders are unusually prevalent as compared with other parts of the State. Even in this region, where boulders are most abundant, they are never so numerous as to constitute a blemish upon the fair surface, nor to cause any impediment worth naming to farming operations.

After crossing the Des Moines river we find, in western Iowa, a variety of boulders that do not appear at all in eastern Iowa. These are of red quartzite, identical with the Sioux quartzite, and are distributed, in connection with the common granite boulders, from the northern to the southern boundary of the State.

In that portion of the middle third of the State, extending from its northern boundary to the city of Des Moines, occasional boulders and transported masses of light yellowish magnesian limestone are found. These are usually rare, but they have been found sufficiently numerous in some places to serve the first settlers with material for limited quantities of lime.

With the exception of the quartzite and limestone boulders, all others of the drift of Iowa are of some of the varieties of granite, usually a reddish syenite. Even this variety varies considerably by the varying proportions of its characteristic minerals with occasionally slight additions of mica.

The Drift Deposit varies much in thickness in different parts of the State. This difference is partly due to the original deposition, and partly to subsequent erosion. It is thickest all along the dividing ridge before described, which constitutes in great part the watershed between the two great rivers. Along this ridge it evidently reaches a depth of not less than from one hundred and fifty to two hundred feet. It is known to reach a hundred feet in thickness in many other parts of the State, and with few exceptions, it covers the surface everywhere so deeply that wells or other artificial excavations very rarely reach the stratified rocks, unless made upon a valley-side. For this reason we have no present means of knowing what the real depth of the deposit is over a great part of the State.

There are two principal regions in the State where the Drift Deposit is comparatively thin. One of these regions is traversed by the Shellrock river, from the southern part of Worth county to the confluence of that stream with the Cedar; and the other is that portion of southwestern and western Iowa which borders the Missouri river, and within which the Bluff Deposit rests upon the accumulation of drift. It is true that the underlying strata are there covered deeply from view, but it is mainly the Bluff Deposit, and not the drift, that covers them.

These regions of varying thickness of the Drift Deposit, and varying distribution of its boulders, have a more or less definite northerly and southerly extension, so that as one goes westward across the State, he crosses them successively For example, starting from the Mississippi river in Clayton county, he has already crossed the boulderless region when he reaches West Union, in Fayette county, and he there enters upon the region in which boulders are more than usually abundant. Reaching the valley of the Shellrock, at Clarksville, he is in the midst of the region where the Drift Deposit is comparatively thin. From this point the drift gradually increases in thickness until he reaches the Great Watershed beyond the Des Moines, where it is evidently some two hundred feet thick. From the Great Watershed westward, it continues of considerable thickness to the Big Sioux, but crossing that river into Dakota, it is found to cover the Cretaceous strata there only to a very slight depth.

Again, if he starts westward on the line of the Burlington and Missouri River Railroad, he finds the drift to be of considerable thickness all the way, and reaching the dividing ridge in Union county, he finds indications that the drift there is upward of two hundred feet thick. Continuing westward, he finds it to diminish in thickness so rapidly and gradually that less than a dozen feet of it intervenes, in many places along the valley of the Missouri river, between the Bluff Deposit, which there overlies it, and the underlying rocks *in situ*. Occasionally in that region the drift is entirely wanting, the bluff material resting directly upon the stratified rocks.

2. ORIGIN OF THE DRIFT.

It is not proposed here to discuss at length the question of the origin of the drift, but as reports of this kind are expected to be more or less devoted to popular instruction concerning the principles involved in the statement of facts observed, brief explanations of that kind are here made.

Every one who examines the drift attentively cannot fail to see that it is composed of more or less finely comminuted rock which existed in other forms prior to its accumulation as drift, and that the questions to be considered are: to what extent it has been derived from rocks that now underlie it, to what extent from rocks elsewhere, and by what agency was the comminution, transportation, and accumulation of the material accomplished.

After long and extensive examinations of the drift in all parts of Iowa, no doubt remains that a large part—probably much the largest—of it was derived from rocks within the limits of the State, and very largely from the rocks that immediately underlie it. It is also just as certain that a considerable part of it, including nearly all its boulders, was derived from the region lying wholly beyond the northern boundary of the State.

As to the means by which the drift has been accumulated and transported, the greatest number and most important of known facts warrant the belief that it was accomplished through the agency of ice, which, during the Glacial epoch, covered the whole or the greater part of the northern hemisphere, far enough to the southward to reach quite beyond the southern boundary of our State. This former wide-spread glacier has receded until the southern limit of its remnants is now quite within the frigid zone, and they are now producing phenomena there similar to those the effects of which we daily witness in the drift of Iowa.

The Evidences of the Northern Origin of at least a large part of the material composing the drift, consists mainly in our ability to trace up the boulders it contains to their original ledges far to the northward, and also in the fact that they cannot be so traced in any other direction. This is the most tangible proof; but there is a vast amount of evidence which corroborates this, and nothing which disproves it. It is quite evident also that much of the finer material of the drift, as well as the boulders, is of northern origin, but as its identification would be doubtful or impossible we rely upon the identification of the boulders alone.

For example, profusely scattered in the drift of all western Iowa we find boulders of a very hard red quartzite intermixed with those of granitic origin. Following these northward we are able to trace them step by step until we come upon the original ledges from which they were derived, in the extreme northwestern corner of Iowa and the adjacent parts of Dakota and Minnesota. These ledges belong to the Sioux quartzite formation, described elsewhere in this report, and are the most southerly exposures of that formation yet known. Continuing northward into Minnesota we find these quartzite ledges to disappear, and the quartzite boulders also to disappear from the surface with them, while those of granitic composition remain as plentiful as ever. Going still farther northward into the valley of the Minnesota river we find there extensive ledges of the same kind of granite as that of which the boulders are composed, and no doubt the same ledges from which a part, at least of our Iowa boulders were derived. These granite ledges are found all along the valley of that river from Fort Ridgely to near its source, and similar granite is also known to exist in northern Minnesota, extending as far east as the Mississippi river. Therefore, we are not surprised to know that boulders of this granite are found in the drift of all parts of Iowa.

But going back to southwestern Minnesota, near where we first found the Sioux quartzite in place, we are able to trace it eastward as far as New Ulm, a town on the Minnesota river, and no farther in that direction. Now no red quartzite boulders are found in the drift of northern Iowa at any point eastward of a line directly south from New Ulm; but if a line be drawn from that town to Algona, on the East fork of the Des Moines in Iowa, thence down the Des Moines river to the southern boundary of the State, it will describe approximately the eastern limit of their distribution. It thus seems evident that the glacial current which transported these quartzite boulders, at least those along the eastern limit of the region they occupy, was not directly south, but that its general direction was a little east of south until it reached the centre of the State, and there it then swept more directly to the southeastward.

Again, occasionally in the central and eastern parts of the State we find loose masses of buff colored magnesian limestone in the drift, which, in addition to its lithological identification with strata in Minnesota and northeastern Iowa, we have the evidence also of the contained fossils that they are identical with and derived from those ledges.

Evidences of Glacial Origin. Drift scratches and other phenomena observed in relation to that deposit are regarded as quite unmistakable evidences of its glacial origin since we have become better acquainted with the character of the glaciers of Greenland and the Alps; but they are in reality no more so than the great fact of the existence of the drift itself, but which loses its force as an illustration on account of our familiarity with it, now that it is no longer associated with ice, and of our unfamiliarity with glaciers in action. The drift scratches are found both upon the upper surfaces of the rocks in their natural position and upon the flattened surfaces of the boulders themselves. The flattening of the surfaces, together with their scratches, were produced upon each respectively by rubbing upon each other, the boulders having been frozen firmly into the bottom of the glacier while it was moving over the ledges,

The scratches vary in distinctness with the difference in the character of the rock acted upon. Upon limestone, the scored surfaces are usually quite flat and the scratches distinct. The scratches vary from mere lines to grooves of such a depth that one might lay his finger within them, all being as straight and parallel as the joints in a floor. Upon granite, the rock being harder, they are less distinct and deep, but still, they have the same general character. Those upon the Sioux quartzite are less distinct than any others on account of the extreme hardness of the rock, but yet they are quite unmistakably of the same origin.

On account of the friable character of a large part of the rocks of Iowa,or the facility with which they become disintegrated, the scratches and other traces of glacial action that were once doubtless abundant upon them, have to a great extent gradually become obliterated. For this reason, together with the fact that the drift so generally and deeply covers those surfaces which may be supposed to yet contain such traces, we seldom have an opportunity to observe them in our State. The only places where such scratches have been observed upon ledges of rock in Iowa, thus far, are upon the Burlington limestone—sub-Carboniferous—near Burlington; upon the Upper coal-measure limestone, in Mills and Pottawattamie counties, and upon the Sioux quartzite in Lyon county. Boulders, having their sides flattened and striated are however found in various parts of the State, and at great distances from the localities just mentioned.

We observed a very interesting fact in southwestern Minnesota in connection with the glacial-scored surface of the Sioux quartzite. This rock, as before said, is intensely hard, almost glassy in fracture, and has the peculiarity of containing numerous vertical fissures at right angles to the plane of stratification. These fissures or cracks were observed to have their angles splintered in a peculiar manner when their direction was eastward and westward. If in other directions, particularly northward and southward, they were comparatively intact. These fissures are really but mere cracks, the vertical faces being only very slightly separated, so that they form sharp right angles with the upper surface. These angles were found to be unbroken upon the distal or southern side of the cracks, but on the northern or proximal side the angle was alwas chipped off, as if by the presence of some ponderous, southerly-moving, unyielding body, the chips remaining in the fissure. It is only in such hard and glassy rock as this that such effects could be produced, or that would admit of such distinct preservation after they were produced. The instruments which produced this smoothing, scoring, and chipping of the quartzite, were the granite boulders which were frozen firmly into the bottom of the glacier that once moved over it, and the power was the moving glacier itself. These granite boulders we found there with their sides also flattened and scored by the contact, resting upon the surface of the quartzite; thus, as far it was possible, we detected them in the very act of producing the effects we have described. This scoring and chipping of the rocks in place is regarded as not only satisfactory evidence of glacial action, but also of the southerly movement of the glaciers.

Direction of Glacial Currents. Speaking in general terms we say that the movement of the glaciers was from north to south; but the distribution of the boulders which were derived from any particular northern point or region, shows that the current or currents in which they were transported varied from a true north and south line. So also we find the direction of the striæ or scratches which the glaciers have produced to have been various, and considering that the country is, and has always been without strongly marked surface-features that would have necessarily deflected the ice-currents, the great variation from a south line in the direction of some of the striæ is quite remarkable.

The direction of the striæ observed upon the Burlington limestone, near Burlington several years ago, was found to be south,* about twenty-two degrees east.† The locality in Mills county, described in another part of this report, is upon section 16, township 71, range 43 west, being upon the borders of the valley of the Missouri river and about twenty miles below Council Bluffs. Here there are two distinct sets of scratches upon the same surface and crossing each other, showing that the current was changed while the glacier was moving over it, or that one of two neighboring currents overpowered and displaced the other. One set has a direction south, twenty degrees east, and the other, south, fifty-one degrees east. The striæ of both sets were found to be, as is

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* As we have such unmistakable evidence that the glaciers moved from the north, we always take the most southerly end of the striæ to indicate the direction in which the glacial current was moving at that particular place.

† No allowance is made in any of these cases for the variation of the magnetic needle, which the local surveyors in the Missouri valley estimated at 11° east of north.

usually the case, perfectly parallel with their fellows, distinct and straight.

An exposure of the same limestone on the Nebraska side of the Missouri river, opposite Council Bluffs, and only some six or eight feet above the ordinary stage of water in the river, shows similar scratches. These, however, have a very different direction from any of the others, it being south, forty-one degrees west. Those observed upon the Sioux quartzite in southwestern Minnesota and the adjacents parts of Iowa and Dakota, have various directions, usually east of south, from ten to twenty degrees.

It is of course not supposable that the glaciers had a uniform movement to the south, even if we had no evidence to the contrary, for it is evident that their currents would be more or less deflected from that direction by the inequalities of surface over which they passed. On the contrary, we have abundant evidence that the currents of the glaciers were numerous and various in their directions, even in so flat and open a country as ours; but what was the cause that actually did determine the direction of those currents in every case we may never know. Our observations, however, show certain coincidences that are worthy of mention, but they are not presented as anything like conclusive evidence. By referring again to the degrees of divergence of each of the sets of striæ just described, it will be seen that those of the set near Burlington coincide pretty nearly in direction with the general direction of the streams of the eastern system of Iowa drainage. Those of the set which were observed opposite Council Bluffs coincide quite as nearly with the general direction of the streams of the western system; while the two sets observed upon the same surface in Mills county, represent currents which, at that point at least, are approximately coincident in direction respectively, with the general course of the Missouri and Platte rivers.

It is not impossible that these currents of the great wide-spread glacier, which it is assumed in former times, spread over the surface of the State, and the currents of the present streams are not only coincident but also that they were both determined by a common cause. It is evident, however, that we cannot rely upon the direction of glacial scratches at any one particular point to indicate the general direction of former glacial currents, because these may have changed a few degrees within the distance of as many miles, even in the flattest country, so that the most reliable indications we can ever hope to obtain of the direction taken by those glacial currents must be derived from a study of the distribution of the materials they have transported. At present this subject is not well understood and needs long and careful study; but a few facts, however, have been brought out with considerable clearness during the last two or three years of the Geological Survey. Among these are the known distribution of red quartzite, granite, and limestone boulders before explained; but we have observed other facts that do not now admit of so complete an explanation as these do, and yet further investigation will doubtless cause them to be as clearly understood as the others. This refers especially to the discovery in the drift of substances that, however well satisfied we may be as to the places of their origin, we do not know it so positively as we do those of the boulders before mentioned.

Native Copper has been found in the drift in various parts of the State. It occurs in irregular lumps of a few ounces or a few pounds in weight. One lump found in Lucas county by Col. W. S. Dungan, of Chariton, weighed upwards of thirty pounds. These specimens are in all respects like the native copper of the Lake Superior mines, and this region is the only one known to us in which they could have originated. If they did originate there the fact implies the existence of a glacial current, during some part of the Glacial epoch, having a southwesterly direction, and at right angles with the one supposed to have coincided with the eastern drainage of Iowa.

Lead Ore. Fragments of the common sulphuret of lead have also been found in the drift, but these are quite rare.

They were probably derived by glacial action from the Dubuque lead region.

Gold. Traces of gold are reported to have been found in the drift of Iowa, and such no doubt exist. If so, it may be supposed to have originated in northern Minnesota. It seems almost unnecessary to say, what every person may be expected to infer, that the existence in the drift of any of these substances is no indication whatever of the existence in the vicinity where they are now found, of natural deposits of the same metals or minerals. Neither is there any reason to hope that any of them will be found in the drift of Iowa in sufficient quantity to pay for the trouble of seeking for them.

Coal. Lumps of impure coal have frequently been found in the drift of northern Iowa, so much to the northward of the northern boundary of the Iowa coal-field, that its origin in that coal-field is not believed to have been possible. It is known that a bed of impure coal, a few inches in thickness, exists among the Cretaceous strata of northwestern Iowa and southwestern Minnesota. This bed is believed to be the real origin of the coal found in the drift of northern Iowa. Unless that formation extended much farther eastward in pre-glacial times than it does now, the existence of these lumps of coal in the drift where we now sometimes find it, pre-supposes a southeasterly direction of the current which transported it.

Wood. Pieces of wood are frequently found in the drift of different parts of the State, by digging wells and other excavations. They have not only been found in the Altered Drift and Alluvium, but also in the unaltered drift. This wood must have been of pre-glacial origin, because we cannot suppose that trees grew in Iowa during the Glacial epoch, any more than they now grow in the glacial region of Greenland. These pieces of wood are not petrified, but are always so far mineralized that they are but slightly, if at all, combustible. Every piece thus far examined by the microscope, shows the peculiar structure of coniferous wood in a good state of preservation. This wood had its origin to the northward of where it is now found without doubt, but exactly where and how far, we can probably never know.

Fossils. No fossils of any kind have been found in the drift of Iowa which may be said to properly belong to it. Those found in it belong to other formations, and have been transported from their original strata together with the other materials of the drift. Mr. P. McIsaac, of Waterloo, Iowa, has shown me a specimen of a Cretaceous Ammonite which he found in the drift near that place, and a fragment of a Baculite has been found in the drift near Iowa City. Coal-measure fossils have been found in boulders in Des Moines county, and Lower Silurian fossils have been previously mentioned as occurring in the limestone drift-boulders of central Iowa. Some shark's teeth have been found in the drift of southeastern Iowa, and supposed by others to have originated in a northern prolongation of the Gulf-border Tertiary formations; but it seems not improbable that they originated in the Cretaceous strata to the northwestward, and were transported thither during the Glacial epoch; although, it is not to be denied that they approach more nearly to Tertiary than to Cretaceous forms. The last indication of glacial action we shall notice here, is that of

Moraines (?) The phenomena here referred to with doubt as moraines, may be properly regarded as of doubtful character; but yet, they are nevertheless well worthy of notice. They seem at least to be accumulations of drift material which mark periodical arrests of the recedence by melting, of the glaciers to the northward as the Glacial epoch was drawing to a close, as a consequence of a gradual change of climate. They consist of two well-marked but slight elevations in the general surface of the country. They both have an easterly and westerly direction, and are gradually lost at either end in the general prairie surface. One of them extends through the northern part of Boone and Story counties, and is known to the inhabitants as "Mineral ridge." It consists to a considerable extent of a collection of slightly raised ridges and knolls, sometimes interspersed with small, shallow ponds;

the whole having an elevation probably nowhere exceeding fifty feet above the general surface, but being in an open prairie region it attracts attention at considerable distance. It is composed wholly of drift, and it is perhaps needless to say, that it is not likely to yield any "mineral" to explorers, as its name might suggest a hope for.

The other ridge extends from the eastern part of Palo Alto county through Kossuth into Hancock. The greater part of this ridge has the general, but indistinct character of a terrace, facing the south, and elevated only from fifteen to twenty or thirty feet above the general level of the surface to the southward, while the general level to the northward stretches away from the top of it. It is nowhere very distinctly marked even in so flat a region as this, but yet it is sufficiently so to have caused its existence to become generally recognized by the inhabitants. Its eastward extension into Hancock county becomes broken up into a well-marked strip of "knobby country." Here it consists of elevated knobs and short ridges wholly composed of drift, and usually containing more than an average proportion of gravel and boulders. Interspersed among these knobs and ridges are many of the peat marshes of that region. One knob in the extreme northeastern corner of Hancock county, is well worthy of especial notice on account of its height. It is visible above all the others, and at considerable distances in the country around. It is estimated to be at least three hundred feet above the water of Lime creek, near which it is located. It is a conspicuous object in the region around, and is called "Pilot Knob," by the inhabitants. Some other matters relating to the drift, but more especially local in their character, will be referred to in the chapters on County and Regional Geology.

Close of the Glacial Epoch. What was the real condition of the surface previous to the Glacial epoch we can never fully know; but its features were certainly largely obliterated by the action of the glaciers and the accumulation of the drift, so that at its close the surface of our State was comparatively a uniform level, unmarked by strong features and without a completed system of surface drainage. That the waters derived from the melting of the receding glaciers modified the surface of the drift to a considerable extent is quite certain; but how far they did so or how much the present condition of the surface between the valleys is due to such modification, and how far it remains now in the condition in which the glaciers left it, seems impossible to determine. There seems very little reason to doubt, however, that much of the surface of Iowa is now essentially in the same condition that it was left at the close of the Glacial epoch.

We may safely assume that after the recedence of the glaciers, which was, of course, accomplished by a change of climate, and before the surface waters had formed new valleys for the present rivers, or re-excavated for themselves the old valleys which existed before the Glacial epoch, but which became filled by the drift, numerous shallow depressions existed upon the surface. These filling with water from the rains or melting ice, became ponds and lakes, some of which exist at the present day, but the majority have doubtless become drained. If these depressions were longtitudinal or connected in chains, as many of them doubtless were, they would have given initial direction to the future rivers, and become drained by their deepening valleys so that no trace of them would remain. Those lakes and ponds that now exist are mostly found in the regions where the streams have their rise; many of them rest directly upon the watersheds. They have remained because no accumulation of water beyond has sent currents across them to cut channels for their outlet. A part of these have been described under the head of Lakes, and a part of them will be found referred to under the head of Peat, in another part of this report.

The depressions in the primitive drift surface here more especially referred to, were all comparatively shallow; but one of extraordinary size and depth existed upon the western border of the State. Like the others, it became filled with water as the glaciers receded, and afterwards filled with its own sediment. This sedimentary formation is described under the head of Bluff Deposit.

2. ALTERED DRIFT.

It has already been shown that the drift as originally deposited was a heterogeneous accumulation of various materials, without any arrangement of them into strata, or any regular separation of them from each other. The greater part of it remains to this day in apparently the same condition in which it was left by the glaciers; but the waters resulting from the latter as they receded by aggressive melting along their southern borders, together with such as constantly fell and still falls upon the surface, have produced a certain degree of modification in a part of it. This modification consists in the production of more or less horizontal arrangement of its materials, or a more or less complete separation of them from each other.

The materials thus modified we designate as Altered Drift; restricting the use of the term, so as to apply only to such materials as have been re-arranged but not transported to any considerable distance since their accumulation as drift. This restriction seems necessary, because reference is here had only to the Altered Drift as it appears in the valleys, and where it is sometimes difficult to define the limit between it and the unaltered drift on the one hand, and between it and the alluvium on the other. The truth is, in the valleys these surface deposits are all composed of or derived from the same materials and differ from each other only in the degree to which their materials have been disturbed, separated, or re-arranged since their original accumulation.*

Some good examples of the Altered Drift may be seen along the base of the bluffs which border the flood-plain

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*It will be observed that little reference is here made to the alteration of the drift that must have taken place upon the surface immediately upon the close of the Glacial epoch, and before the river valleys were excavated. There seems to be some evidence that this modification was almost co-extensive with the deposit itself, and that those cases of indistinct stratification upon the high prairies before mentioned, are a part of the same wide-spread modification which the original deposit may be supposed to have received. Prof. St. John reports observations in central and western Iowa which led him to some such conclusion. Much further observation is necessary before a complete knowledge of this subject can be obtained.

of the Missouri river. The stratification there is sometimes very distinct, and in some instances the limy water that issues upon it from the Bluff Deposit has so cemented the sand and gravel together that it has thereby produced real, although worthless, sandstone and conglomerate, the beds of which are so regular as to have caused many persons to mistake them for outcrops of regular ledges of rock. These examples of Altered Drift along the bluffs of the Missouri river are unusually distinct.

Other examples of the more slightly Altered Drift may be seen in the valleys of almost any of the rivers of the State that have attained considerable size. They are particularly observable in those valleys that have been eroded out of the drift alone, such as those of Rock river and the upper part of the Little Sioux; those of the upper branches of the Des Moines, etc., the bottoms of which to a great extent do not consist of Alluvium, properly so-called, but of Altered Drift, often only slightly modified.

Another phase of the Altered Drift, as included in these descriptions, may be seen near the mouths and confluence of rivers. Here the alteration is greater, and approaches the alluvium in character. Sometimes upon the sides of valleys the Altered Drift assumes somewhat the form of river terraces, but they are really quite different in composition. The river terraces are always composed of finer materials, and are always free from boulders, while the others may contain both gravel and boulders in comparative abundance.

3. ALLUVIUM.

The deposit here designated as Alluvium is that which has accumulated in the valleys of rivers by the action of their own currents. The materials composing it are all derived from the rocks or deposits out of which the rivers have eroded their valleys, and consequently it has all been transported to a greater or less distance by their waters. It is this deposit that always constitutes the flood-plains and deltas of our rivers, as well as some of the terraces of their valleys. Some of these terraces, particularly those occupying comparatively high levels in the valleys, have been deposited in stiller waters than those of the rivers as they now flow. The material of these latter terraces is fine and silt-like, and will be more particularly referred to on a subsequent page. The Alluvium proper is largely composed of sand and other coarse materials, but some of the best and most productive soils in the State are upon that deposit. Besides being an inseparable feature of our river valleys, the Alluvium has a certain degree of interest as being the latest of all the deposits, and is even now in process of deposition.

4. THE BLUFF DEPOSIT.

The bluffs which border the broad flood-plain or bottom land of the Missouri river, along all that part of its course which forms the western boundary of Iowa, are so peculiar in character and appearance that they cannot fail to attract the attention of every one who sees them for the first time. Their strangely and beautifully rounded summits, occasionally mingled with sharply cut ridges, smooth and abruptly retreating slopes, and the entire absence of rocky ledges, except in rare instances when they appear only at their base, cause them to present a marked contrast with those of the Mississippi and other rivers of the eastern part of the State where rocky ledges support and compose the greater part of their bulk.

From the mouth of Big Sioux river to the southern boundary of the State, these bluffs present a continuous, serrated and buttressed front to the flood-plain of the great river, from which they rise abruptly to a maximum height in different parts of the line, varying from one hundred to little less than three hundred feet. Although the front they present is so definite and continuous, it is nevertheless frequently and deeply cleft, not only by the tributaries of the great river, but also by small creeks and short ravines that drain the surface-water from the uplands beyond, in which the bluffy character is soon lost.

Sometimes the bluff-range, departing a little from the general direct line, presents a full crescentic front to the plain with an arc of several miles in length. Such, for example, are seen at the town of Crescent, and again about seven miles southward from Council Bluffs. At these places, their peculiar outlines are shown in an interesting manner, and the form and arrangement of the numerous rounded prominences present views of impressive beauty as they stretch away in the distance or form bold curves in the line of hills; while the broad flood-plain of the Missouri river, level as a floor, stretches miles away to the westward to meet the turbid stream near the line of bluffs which borders the western, as those of Iowa do the eastern side. Trees often fill the sides of their deeper ravines or skirt their bases, but usually their only covering is a growth of wild grasses and annual plants; and, as the mound-like peaks and rounded ridges jut above each other, or diverge in various directions while they recede upward to the upland, the setting sun throws strange and weird shadows across them, producing a scene quite in keeping with that wonderful history of the past of which they form a part.

The accompanying sketch of a smaller one of these curves in the line of hills known as Sergeant's bluff, is taken from a point about two miles below Sioux City.*

General Characters. Upon near approach to these bluffs, we find that their peculiar features are due to the no less peculiar character of the material of which they are composed, either wholly or in part. When not wholly, that material which differs from the great bulk appears only at the base and does not modify their outlines. It is very distinct in character from any other formation or deposit in the State; but is very similar to that deposit in the valley of the Rhine, known there by the provincial name of "loess." It was called "silicious marl" by Dr. Owen, in his geological report to the

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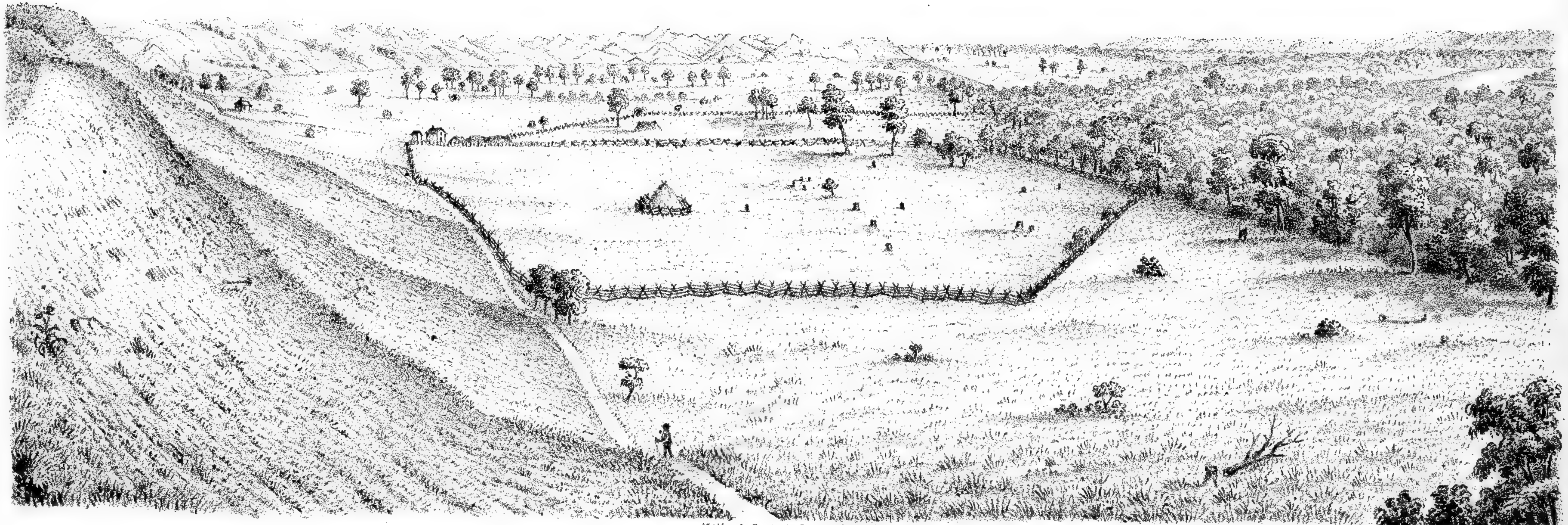
*The plain between the two extremes of the crescentic line of hills as shown in the picture is a part of the Missouri river flood-plain, and has some historic interest as the death-place of Sergeant Floyd, a member of the famous Lewis and Clark Exploring Expedition.



Mills & Co. Lith. Desmoines, Iowa.

VIEW OF SARGENTS BLUFFS_FROM THOMPSON'S BLUFF, LOOKING SOUTHWARD.

1868

general government; and its origin rightly referred by him to an accumulation of sediment in an ancient lake which was afterward drained when its accumulated sediment became dry land. By Professor Swallow, State Geologist of Missouri, who examined the deposit in that State, where it is continuous with the same in Iowa, it was given the name of "bluff." This term, as a specific name for the deposit, is not unobjectionable, but it is not easy to find one that every person would consider to be better. Neither is it often expedient to change established names, therefore, that of Professor Swallow is used in this report; although it is thought that the term *Lacustral Deposit* would have been better, as it is expressive of the mode of its origin, and would accord with such accepted terms as *Alluvial*, *Diluvial*, *&c.*

The material of this deposit is perfectly homogeneous in composition and uniform in color throughout, even where it is two hundred feet thick. Specimens taken from the bluffs at Sioux City, and compared with specimens from the bluffs upon the southern boundary of the State, although nearly a hundred and fifty miles apart, are not distinguishable from each other. It is of a slightly yellowish ash color, except where darkened by decaying vegetation; very fine and silicious but not sandy, strictly speaking, for by the unassisted eye one can hardly discover it in particles of granular silicious matter, so coarse as to deserve the name of grains of sand. At the surface it forms excellent soil, and if taken from a depth of two hundred feet from the surface it proves to be equally fertile. Although the material is so finely comminuted, it is not very cohesive and not at all plastic, and the soil composed of it does not "bake" or crack in drying, nearly so much as that which contains an appreciable amount of clay in its composition.

The following is in part the result of Prof. Emery's analysis of a sample from Sioux City—a full account of which will be found in his report on another page.

Silica	82.15
Iron	3.89
Alumina	.67
Carbonate of lime	9.66

The silica is in the form of clean, white microscopic grains of sand, which, as will be seen, constitute the greater part of the deposit.

That it contains much lime is also apparent from the presence of numerous calcareous, concretionary lumps, somewhat resembling pebbles in shape and size, which are generally distributed throughout the mass. It is also shown in the abundant accumulation of calcareous tufa, around the springs which issue in considerable numbers at the base of the bluffs just where this deposit rests upon the drift. The water of these springs has fallen upon the surface, and percolated through the whole thickness of the Bluff Deposit, and escapes laterally in the form of springs upon the less pervious drift. Rain water always contains at least a minute quantity of carbonic acid dissolved in it, and after it has penetrated the air cavities of porous earth, much more. This renders some of the carbonate of lime which the deposit contains slightly soluble. When the water, holding this excess of carbonate of lime in solution, reaches the atmosphere it becomes precipitated there in the form of the tufa before referred to. It is the lime thus precipitated which cements the sand and gravel of the Altered Drift in those localities, which have been mentioned on a previous page. Except the limy concretions before mentioned, not a stone or pebble of any kind is to be found in the whole deposit, but all is uniformly fine and homogeneous.

Physical Properties. Some of the physical properties of this deposit are so unusual that they merit especial mention. When it is known that there is no rocky support to these Missouri river bluffs, although they are frequently so steep that a man cannot climb them, it is very apparent that the material composing them is different from the earth ordinarily met with, and which it resembles upon its ordinary surfaces. Its peculiar property, however, of standing securely with a precipitous front, is best shown in artificial excavations. For all practical purposes of building-foundations, even of the most massive structures, and for roads, etc., the ground it composes is as secure as any other, yet it is everywhere easily excavated with the spade alone. Notwithstanding this fact it remains so unchanged by the atmosphere and frost, that wells dug in it require to be walled only to a point just above the water line; while the remainder stands so securely without support of any kind, that the spade-marks remain visible upon it for many years. Embankments also, upon the sides of roads or other excavations, although they may be quite perpendicular, stand for many years without change, and show the names of ambitious carvers long after an ordinary bank of earth would have softened and fallen away to a gentle slope. Lime kilns, fashioned entirely out of this material, even including the fire-arch, have been carved in the side of a hill by the spade, and used for burning lime during a whole season or longer, without any interior or exterior wall or other support of any kind. Even potters' kilns have been thus constructed and successfully used. For such purposes a place is selected which is unusually dry, such as a narrow ridge from which all water falling upon the surface is rapidly drained away. In some instances small, temporary stables, or cattle-shelters have been excavated in the side of steep banks, and used for a few years, the roof standing with considerable security in the form of an arch. Indeed so securely does the material of this strange deposit remain when excavations are made in it, and so easily is it excavated that subterranean passages of many miles in length might readily be constructed in it without meeting any impediment. Any fortifications built upon these hills, which form a continuous line along the greater part of the western border of Iowa, if future emergencies should ever require them, might be readily undermined by digging such subterranean passages; and if there were any cause or use for such works, catacombs might be successfully constructed in any of them that would rival those of ancient Rome. Beyond the influence of the atmosphere, they would probably endure as long as they.

The peculiar property possessed by this material, of standing unchanged in form when exposed to the weather, is doubtless due to the slight cementation of the minute grains of silica which constitutes so large a part of it. This is effected by the partial solution of its carbonate of lime by the carbonated waters which fall upon and percolate it as before mentioned, and the reprecipitation of the same in those parts nearest the exposed surfaces, whether artificial or natural. The cementing material thus formed, is never sufficient in amount to interfere with its porosity, for this is another of its peculiarities. The cause of its being so pervious to water is no doubt due to the distinct granular form of its silex although so minute, and the fact that the minute grains are not compacted and rendered coherent by impalpable clayey matter. Thus water passes through it just as effectually as though ordinary sand, but not so quickly.

That the deposit is very pervious to water may be readily seen by observing the line of springs that issue at its base near the foot of the bluffs, and nowhere above that line. That it is so pervious, also appears from the fact that wells dug in it, so far as has yet been ascertained, have never afforded a supply of water until the base, or very near the base of the deposit was reached. Often the whole thickness of the deposit must be passed through in digging the well, and the water when found, is obtained in the sandy or gravelly drift which everywhere underlies the Bluff Deposit.

It will thus be seen that this strange deposit, although it is compact, has the property of being very porous, so that the water which falls upon its surface never collects there in ponds, nor does it accumulate within its mass as it is known to do upon the surface of and within the drift and the stratified formations. Consequently, there is great risk that wells dug in its deepest parts must necessarily be dug to an impracticable depth before reaching water, for a well two hundred feet deep would hardly be practically useful. Where the deposit is thinner, however, it may be entirely pierced, and water obtained at little if any more than the ordinary depth required in the drift deposit alone, which forms the surface of the greater part of the State. Although water does not accumulate in the Bluff Deposit, it should not be inferred that it is not always moist, for it always contains sufficient moisture to give it the ordinary coherence of common soil even at the surface; and crops growing upon it suffer no more from drought than they do upon any other soil. As a soil, it has the additional advantage of being constantly and completely underdrained.

Physical Features of the Region. Hitherto the Bluff Deposit has been spoken of in relation to the character and aspect it exhibits in and near the range of bluffs that border the flood-plain of the Missouri river. It now remains to speak of the physical features of the region occupied by the deposit, in a more general way.

In this connection it will be necessary to give some account of the geographical extent of the region it occupies, together with its known thickness, when that has been ascertained. The limits of this area have nowhere been ascertained with absolute accuracy, but these may doubtless be defined with as much precision as we can define the exact limits of any of the formations which underlie the drift. The difficulty of defining its limits arises from its gradual passage into the fine top soil of the drift, or rather from the fact that the finely comminuted, humus-stained soils of both deposits are so nearly alike in aspect when unbroken by natural or artificial excavation, that it is difficult to say where one ends and the other begins. However, the following outlines are assumed to be not far from its eastern and northern limits in Iowa:

Commencing at the southeast corner of Fremont county, follow up the watershed between the East Nishnabotany and the west Tarkeo rivers to the southern boundary of Cass county, thence to the centre of Audubon county, thence to Tip-Top station on the Chicago and Northwestern railway, thence by a broad curve westward to the northwestern corner of Plymouth county. The last named point is probably very near the most northerly one to which the deposit anywhere reaches, certainly the most northerly one to which it reaches in Iowa. Less is known of its nothern limits in

Dakota and Nebraska, and of its western limits in the latter State and Kansas. It is known, however, to extend as far west as the valley of the Elkhorn in Washington county, Nebraska, some twenty-five or thirty miles west of the Missouri river. There is reason to believe also that it occupies a continuous region of an equal average width, bordering that great river, and extending as far south as Kansas river. In Missouri, it occupies a large area adjoining that of Iowa, the whole having been, originally, an united and continuous deposit before the Missouri river had eroded its valley out of and through it. What its southern limits are is not known, but it is reported by Prof. Swallow, of Missouri, to extend far down into that State.

The Bluff Deposit is thus known to occupy a region through which the Missouri river runs almost centrally, and measures as far as is now known, more than two hundred miles in length and nearly a hundred miles wide.

The thickest part of the deposit yet known is in Fremont county, where it reaches a thickness of at least two hundred feet above the drift. There is reason to believe that its thickest part is in the immediate vicinity of the valley of the great river, because it occupies almost equal areas on each side, and thins out in all directions from it to the outer margins of the deposit. The whole height of the bluffs in Fremont county, is at one or more points about three hundred feet above the flood-plain of the Missouri river; but in that case one hundred feet of it is made up of the Upper coal-measure strata and drift which supports the Bluff Deposit. Going northward from that county along the line of the bluffs, the Upper coal-measure strata are seen for the last time, in that direction, at their base a few miles north of Council Bluffs. The next stratified rocks to be found by continuing northward, are of Cretaceous age. These are found occupying the base of the bluffs in Woodbury county, first appearing at the town of Woodbury, seven miles below Sioux City. The distance between the most southerly point in the line of bluffs at which the Cretaceous strata are exposed, and the most-northerly point at which the strata of the Upper coal-measures are found, is fully seventy-five miles. Along this entire distance no rock is to be seen, and only occasionly can the presence of the drift be detected. Beyond these two points in either direction, the strata appear so seldom, and so near the base of the bluffs, and the exposures are so small that they never modify the peculiar aspect which the Bluff Deposit imparts to the bluffs everywhere.

Sometimes the presence of the drift may be detected at the base of the bluffs by an indistinct terrace, but usually its presence is known only by the appearance of clay, sand, or gravel upon the surface, and by the issuance of springs. Along a great part of the whole line, the drift is evidently beneath the level of the great flood-plain, because nothing but the material of the Bluff Deposit appears to view from base to summit of the bluffs.

The drift is evidently very thin where the Bluff Deposit is thickest, and the latter has been deposited in a broad depression hollowed out of the general surface, principally in the drift alone. The topmost strata of the Upper coal-measures are, however, occasionally found scored by glaciers, which indicates that the hollowing process extended into the stratified rocks also. Indeed the drift is nowhere known to be very thick in the vicinity of the Missouri river, and in a couple of instances at least the Bluff Deposit was found resting directly upon the limestone. Within twenty-five miles east of the eastern border of the Bluff Deposit there is evidence that the drift reaches a thickness of about two hundred feet.

The valleys of all the streams of western Iowa, which reach the flood-plain of the Missouri river within the State, traverse the region occupied by the Bluff Deposit. The streams and their branches not being very far apart, the surface is often much broken; but it nowhere presents those peculiar outlines that are so striking a feature of the bluffs of the Missouri river. The valleys being of considerable depth, and not far apart, the aggregate slope from the watersheds to the streams is greater than it is elsewhere in the State. This is well shown in the profiles which illustrates the topography of the State opposite a previous page, and has made railroad building a difficult matter in some parts of western Iowa. This difficulty has usually been avoided by running the roads down some one of the smaller valleys to reach that of the Missouri river.

The banks and beds of the streams which traverse this deposit receive from it quite peculiar characters. The beds are of soft, fine, dark-colored homogeneous mud, and the banks are composed of the same material in a dryer condition. The banks are often, even upon the small streams, from five to ten feet or more in height, quite perpendicular, so that they make the streams almost everywhere unfordable, rendering them in consequence a great impediment to travel across the open country, where there are no bridges.

The value of the material of this deposit as soil will be discussed further on, but it may be remarked here that it is unsurpassed by any soil in Iowa for real value. It is true, also, that forest trees grow as triftily upon it as upon any other soil, even where there is no other kind of soil within many miles of them, nor within a hundred feet beneath their deepest rootlets. A thrifty growth of young forest trees is now spontaneously springing up everywhere upon this deposit, and rapidly encroaching upon its hill-sides and prairies whenever they are by any means protected from the annual prairie fires. This is at present more apparent upon the hill-sides than upon the flatter prairies, and as one passes along the road which traverses the length of the Missouri river flood-plain, in view of the ever-varying and ever-interesting bluffs, he can hardly avoid a feeling of regret that the primitive beauty of their nakedness is so soon to receive a forest-mantle of nature's own weaving, by which their graceful outlines, now cut so clearly against the sky, are to be forever lost; so rapidly are the hitherto fire-stunted trees assuming forest proportions and multiplying their numbers.

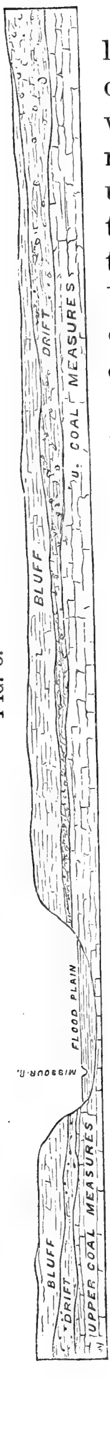


Fig. 3.

Origin and Geological Age. As to the real geological age of the Bluff Deposit there can be no question; any difference of opinion upon the subject would amount only to a difference of terms. It is of more recent origin than the drift because it rests upon that deposit, and it is not of later origin than the earliest part of the Terrace epoch, because river terraces are formed in itself as well as in the drift. While fully recognizing the correctness of the views entertained by those who refer certain post-glacial changes along the Atlantic border of the continent, and elsewhere, to a distinct epoch, subsequent to the drift and previous to the Terrace epochs, called the Champlain, the existence of any phenomena in the valleys of the Mississippi and Missouri rivers, in and adjacent to Iowa, which indicate post-Tertiary changes that require more than two epochal subdivisions, is not recognized.

These two are the Drift and Terrace epochs, and the Bluff Deposit is referred to the earliest part of the Terrace epoch, because the material of which it is composed originated as such by fluvatile erosion, which occurred immediately upon the close of the Glacial epoch. The material was at the same time deposited as lacustral sediment in a broad depression in the surface of the drift which was left there by the retreating glaciers.

The accompanying diagram, figure 3, shows the relative position of the Bluff and Drift Deposits, as well as the relation of the river valley and the Upper coal-measures to each.

This broad depression formed a lake-like expansion in the Missouri river, which was then, as now, one of the muddiest streams upon the globe, and became rapidly filled by its own sediment, which its waters gave up as soon as their impetuous current was checked by the stiller waters of the lake. The filling of the depression with sediment must have been completed very early after the recedence of the glaciers, because, as shown by the present height of the surface of the deposit, it reached as high a level as that of the highest surrounding land, before the Missouri river, which emptied into and flowed from the lake, had deepened its channel below it sufficiently to commence its drainage.*

From that time until the deepening of the Missouri river valley had well progressed, the surface of the deposit no doubt existed as a broad, undrained marsh. As the deepening of the valley below the then filled lake progressed during the remainder of the Terrace epoch, the river readily swept out enough of the soft material which its own waters had previously deposited to form its valley in that also, and at the same time caused the deepening of those of the tributary streams. The cutting out of the great valley in this deposit was accomplished, as in the deepening of all valleys, by the vibration from side to side of the stream, alternately occupying every square foot of its flood-plain, and at times hugging the sides until the bluffs were left as steep as they would stand. Cross-cutting by tributary drainage gave the bluffs their serrations, and rains and frosts completed the rounding of their summits and slopes so that they now appear, as they really are, like miniature mountain ranges of dried mud.

During the deepening of the valley of the great river, few real terraces seem to have been formed in the Bluff Deposit, compared with the number usually found in the valleys of those streams, which have been eroded out of other

*This deposit now extends a little to the eastward in some places, of what is now the Great Watershed in Iowa, and appears upon some of the upper branches of Raccoon river. This may have resulted however, by the gradual extension upward, even beyond the border of the ancient lake bed, of those branches necessitated by the deepening of the principal valleys which took place during the Terrace epoch. It is shown also by the levelings of the Chicago and Northwestern Railway, that at some points the surface of the Bluff Deposit is a few feet higher than the surface of the drift is where that railway crosses the Great Watershed. Further investigations are needed to ascertain what the actual relative level of the surface now is there, and what changes have taken place since the Bluff Deposit was all accumulated,

Mills & Co. Lith. Des Moines.

VIEW LOOKING UP THE VALLEY OF SOLDIER RIVER, JACKSON TOWNSHIP, HARRISON CO. IOWA,

Terraces of the Bluff formation.

material. But such terraces do sometimes appear in this deposit, and are of the same character as those observed in the drift and alluvium of other valleys. The accompanying sketch of the valley of Soldier river, just where it joins the great flood-plain of the Missouri river, shows the remains of several successive terraces that were formed while the two valleys were in process of deepening.

These terraces in the Bluff Deposit, notwithstanding the fact that it is newer than any other deposit except its own alluvium, are certainly of the same age as the other terraces of the same river that have been formed in the drift or any other formation, for they all originated from the same cause, and nearly or quite simultaneously.

The evidence that this deposit was formed as sediment in a fresh water lake may be summed up thus: The material is very fine and homogeneous, such only as could have been deposited in comparatively still waters. It contains a few shells of fresh water and land mollusks, and no other.* Neither does it contain any marine remains. It is therefore not of marine origin; besides which, no inland deposit of marine origin is known, that has, like this, occurred subsequent to the drift. The material of the deposit is essentially the same as the sediment of the Missouri river at the present time, as will be seen by referring to the analysis of both in Prof. Emery's report on other pages. This sediment is so abundant now in that river, that if it were possible to throw an obstruction across its valley as high as its bluffs it would become rapidly filled with essentially the same material that it originally deposited and subsequently in part swept out. This is constantly illustrated in the reservoirs of the St. Louis water-works, which become filled with the sediment of the water taken from the river, so that they must be periodically re-excavated.

The proportion of sediment contained in the water of the river in its earliest history, was probably somewhat greater

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* No true branchiate shells have been found in the deposit except a few Unios, the greater part being pulmonate gasteropods.

than it is now, and any lake-like expansion that may have existed in it at that time must have become so quickly filled as to have occupied an insignificant part of the time-history of its valley, although the act was an important one in that history. It seems not improbable that the broad lake that occupied a part of what is now Western Iowa, was mainly filled with sediment while yet the glaciers hovered around the upper course of the Missouri river, and were there grinding the material which served for the filling.

That there were formerly other similar lake-like expansions of the Missouri and lower Mississippi rivers, and that they were filled with the same kind of sediment, is not improbable, for it was then in the condition that Carl Ritter aptly terms an "unfinished river." Indeed, it is certain that there were such, for Professor Hilgard, State Geologist of Mississippi, speaks, in his report on the geology of that State, of a similar deposit there, occupying a similar relative position to the Mississippi river that ours does to the Missouri. It is not thought possible that our Bluff Deposit, and that of the State of Mississippi, could have ever been continuously connected as the same deposit, although they were, doubtless, exactly contemporaneous; but it is quite probable that other lake-like expansions besides these two existed between them in the course of the river, their deposits being all alike because all were formed from the same sediment and furnished by the same river from the same sources.

Such remains of lakes or lake-like expansions in the courses of rivers are common in all parts of the world, and as each river system became "finished," to use Ritter's term, by the deepening of their valleys, the sedimentary filling became dry land. The filling was, of course, most rapid in the case or the muddiest rivers, and those which flowed over formations that are not readily disintegrated, could contain but little sediment. Therefore, their lakes are not filled. If such a river as the Missouri had emptied into the great northern chain of lakes, they would have become so completely filled with its sediment that they would never have been known as lakes to civilized man, but tributaries of the St. Lawrence river would have traversed the regions they now occupy.

Primary Origin of the Bluff Material. Ascending the Missouri river, we find in Nebraska, Dakota, and even in northwestern Iowa, the source from which the material of the Bluff Deposit was derived. Stretching from here far away towards the Rocky mountains, and bordering the great river on either side, is an immense region occupied by the most friable formations on the continent—those of Cretaceous and Tertiary ages. Seeing these we at once cease to wonder that the waters of the Missouri are muddy, because it is so evident that they could not be otherwise. The Tertiary strata are largely silicious, and the Cretaceous are scarcely less so, but a part of the latter are not only calcareous, but much of it is very nearly pure chalk. It is from the last named strata that the Bluff Deposit has derived its nearly ten per cent of carbonate of lime. All these friable strata are even now furnishing abundant sediment to the streams that flow into the Missouri river, but at the close of the Glacial epoch, the fine sediment was, if possible, still more abundant, because then the whole region was strewn with the grindings fresh from those "mills of the gods"—the glaciers.

5. OTHER ANCIENT LACUSTRAL AND MARSH DEPOSITS.

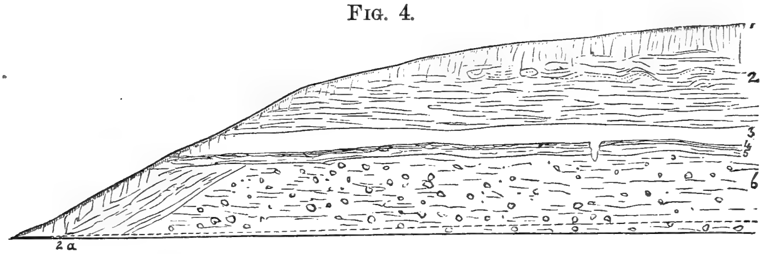
Besides the Bluff Deposit just described, there are other post-glacial deposits found along the borders of the valleys of the Mississippi, and some of the rivers of the eastern part of the State. So far as yet observed, these are confined within the river valleys or to their immediate vicinity, and evidently originated at different periods in the history of their erosion from the general level that existed at the close of the Glacial epoch, because they are found occupying different levels, varying from almost as high as the general level of the uplands down to a level only a few feet above the highest floods of the rivers at the present time. Some of them are similar in character to the Bluff Deposit, but having been derived from different materials, they are never precisely like it. They always contain a considerable amount of clay, which the Bluff Deposit contains almost none at all of. Others are remains of marshes and not lakes, or at least of marshes which may have existed upon the borders of lakes; for the waters in which these deposits took place, are believed in every case to have been lake-like expansions, or comparatively still portions of the rivers upon the borders of whose valleys these deposits are now found.

Those that are more distinctively lacustral in their character are composed, in varying proportions of fine silicious and clayey silt, such as would be deposited in comparatively still waters. They are found upon the sides of the valleys, where they show indistinct traces of stratification when they are freshly excavated. Those of this character thus far observed, have been found almost alone upon the valley sides of the Mississippi, and almost always near its lower part, or not far above the level of the present flood-plain.

Traces of such terraces are to be found in almost all cases where the valley of a creek or small tributary comes into the flood-plain of the great river. These, however, can hardly be said to be parts of the proper river terraces which they very much resemble, the latter being abandoned flood-plains, and the former a deposit of fine silt in waters stiller than those which brought it down from the uplands. An interesting example of such a silt-like deposit exists within the city of Burlington, having been produced by Hawkeye creek when the Mississippi occupied a level higher by forty feet than it now does. Much of the deposit was removed by the deepening valley of the creek, and much has lately been removed for railroad purposes from the vicinity of Fifth and Market streets, where it was once finely exposed by the artificial excavation and seen to rest upon the drift.

Such of these deposits as partake more of the character of marsh accumulations are found in somewhat similar positions, but all seem to have taken place at an earlier period in the process of deepening the river valleys. For example, one of these deposits occurs almost upon the very brow of the bluffs that border the valley of the Mississippi, near Davenport. This example is one of unusual interest, in consequence of the existence there of an extensive bed of ancient peat which is covered to the depth of several feet beneath the prairie soil, and the discovery in the clay above the peat of the remains of a Mammoth. The accompanying diagram, fig. 4, and the following explanation by W. H. Pratt, Esq., Secretary of the Davenport Academy of Science, shows the position of the deposit in relation to the drift.

FIG. 4.



The exposure was made by the excavation for the Chicago, Rock Island, and Pacific Railroad Company, previous to which there was no appearance at the surface to indicate the presence there of any thing more than the ordinary Drift Deposit. Mr. Pratt's notes and references to the diagram were obtained while the excavation was fresh.

"No. 1. The ordinary prairie soil, one foot. The prairie here extends to the edge of the bluff, gently sloping backward towards the north.

"No. 2. The "yellow clay" or loam, twenty feet thick, iron-stained, frequently distinctly laminated; laminæ curved and have their layers of sand interstratified in some places. It contains small calcareous nodules and shells of the genera *Succinea, Helicina, and Pupa.* This clay makes good brick.

"No. 3. Bluish-gray clay, three to five feet thick, not stratified; contains a few shells like those of No. 2. A tusk, several teeth, and some other portions of *Elephas primigenius* (?) were found just at the junction between Nos. 2 and 3.

"No. 4. A bed of brown peat one foot thick, which burns tolerably well. In some places the peat-moss, *Hypnum aduncum,* was so well preserved as to be recognized. Quantities of much decomposed coniferous wood are distributed throughout this bed.

"No. 5. Ancient soil, two foot thick, very dark brown, resembling the peat but more decomposed. Contains no shells or other fossil remains.

"No. 6. Blue clay, very tenacious, containing sand, gravel, and small boulders. Pebbles and boulders all water-worn and many of them distinctly glacier scratched. Thickness unknown.

"The dotted line represents the railroad grade. The point represented by the top of the diagram is 167 above low-water mark in the Mississippi river at the railroad bridge."

This deposit is quite remarkable in many respects; in none more so perhaps than in the fact that the bed of peat rests upon a bed of clayey silt, and is in turn covered by a similar but much deeper one, these varying conditions evidently having been produced by the shiftings of the adjacent and then sluggish river, in that very early period of its post-glacial history. The extent of this peat bed beneath the surface is not known, as there is nothing in the surrounding surface to indicate it. It was exposed by the railroad excavation for a distance of thirty or forty rods.

Another deposit of ancient peat has been found in digging a well a couple of miles southward from Iowa City. It was found at a depth of thirty feet beneath the surface, and that surface is fifty feet or more below the general level of the uplands in the vicinity, The locality is upon the gentle slope of the valley-side of the Iowa river, and about a mile from it. The position of the peat, although so far beneath the surface, is yet much above the level to which the highest floods of the river now reach. The peat was evidently formed where it is now found, and in what was then a marsh upon the borders of the river-valley as it then existed, but during the process of the deepening of the valley, and by the shiftings of the stream, it became covered by the sandy deposit which we find now resting upon it, having mostly the general character of Altered Drift.

Neither this deposit of peat, nor the one near Davenport, are fit for fuel, as they are not nearly so combustible as recent peat, and if they were, they contain too much impurity to be practically useful. Both the deposits contain numerous pieces of wood and twigs, all of which, so far as yet examined, prove to possess the structure peculiar to conifers. It is worthy of remark in this connection, that no conifers having a wet habitat as these evidently had, are now to be found living within the State.

Several fragments of the elytra of a coleopterous insect were found in the ancient peat of both Davenport and Iowa City; but their specific and generic relations have not been determined.

The peat of both these localities is referred to the age of the Terrace epoch, although at one time it was thought the one near Iowa City might prove to be of pre-glacial origin.

A small deposit of similar ancient peat was also discovered in Adair county, and will be found mentioned in the description of the geology of that county in another part of this report.

It will be observed that in the foregoing discussion of all that pertains to the post-tertiary geology of Iowa, it is assumed that no appreciable changes in the elevation of the surface above the sea, have taken place during that time. It seems unmistakably evident that all our rivers have eroded their own valleys, and produced their own terraces without the aid of any elevation or depression of the surface. It is for this reason that no reference is made to the Champlain epoch in discussing Iowa geology. We date the Terrace epoch from the recedence of the glaciers to the present time.

CHAPTER III.

SOILS, ETC.

The soil of Iowa has become justly famous for its fertility, and it may well be doubted whether there is an equal area of the earth's surface that contains proportionably so little untillable land, or whose soil has so high a degree of average fertility. After careful consideration of the results of my examinations, I do not hesitate to thus publicly announce my estimate that ninety-five per cent of the surface of Iowa is tillable land. The State being, as previously explained, without ranges of mountains or hills, or other barren surfaces, and everywhere covered with a soil of such fertility and depth, its agricultural capabilities are almost beyond computation, and agriculture must ever remain the principal element in the prosperity of our Commonwealth.

The desirableness of giving to the public all possible information concerning our soil is fully appreciated, but being convinced that little really practical good can result from a series of quantitative analysis of them, these have been omitted and discussions of the subject are confined to the physical examination and general description of its varieties.*

The soils of the State may be separated into three general divisions which not only possess different physical characters,

*For views upon the subject of soil-analysis which are eminently correct and well expressed, the reader is referred to an article in the American Journal of Science, Vol. XXXII, II Series, by Prof S. W. Johnson, of Yale College, and non-resident Professor in the Iowa State Agricultural College. See also later publications by the same author.

but also differ in the mode of their origin. These are the Drift, Bluff, and Alluvial soils, and belong respectively to the deposits bearing the same names. The drift soil occupies a much greater part of the surface of the State than both the others; the bluff soil has the next greatest area of surface and the alluvial least.

1. DRIFT SOIL.

All soil is disintegrated rock, and its excellence or sterility depends both upon the composition of the rocks from which it is derived and the degree of comminution to which they have been subjected. A soil composed of material that has been suspended in and thus transported by the waters of a stream and then deposited, as the bluff soil has, always possesses a sufficient degree of fineness, while both the drift and alluvial soils may, and sometimes do, contain too great a proportion of coarse materials for good soil. This, however, is very seldom the case with the drift soil of Iowa, for upon the greater part of it not a pebble or boulder is to be seen. This character of the drift soil of Iowa arises primarily from the character of the rocks from which its drift material was originally derived.

If the rocks from which a drift deposit has been derived were hard and unyielding, the accumulation of drift from them would have been comparatively slight, although they may have been subjected to violent glacial action during the whole Glacial epoch. The soil of such a slight accumulation of drift would also be light and poor, because the materials of it would lack, for the same reason, that degree of fineness necessary to the formation of good soil, although both they and the rocks from which they were derived may contain all the elements necessary for it. These facts are believed to afford sufficient explanation of the cause of the sterility of much of the soil of New England, and of the remarkable fertility of the drift soil of Iowa.

As stated in the preceding pages, the drift deposit of Iowa was derived to a considerable extent from the rocks of

Minnesota, but the greater part of Iowa drift was evidently derived from its own rocks, much of which has been transported but a very short distance, if any, from the place where it originated. Many of the strata of Iowa rocks are soft or friable, and nearly all of them are sufficiently yielding to have been comminuted with facility by the glaciers. This is also true even of many of the granite rocks of Minnesota. We found the greater part of the granite exposed in the valley of the Minnesota river to be too soft and easily disintegrated to be useful even for good common building stone; and at the mouth of the Redwood, a tributary of the Minnesota, we found a cliff of decomposed granite, upward of one hundred feet in height, so soft from top to bottom that it could be crushed to the condition of fine soil in the hand alone. Indeed, it graded imperceptibly into the fertile soil which covered it, but with this exception, the deposit had never been disturbed from its original position. In southwestern Minnesota this friable granite is overlaid by what remains from glacial action of the Cretaceous rocks which were once continuous with those of western Iowa. These Cretaceous rocks are all so soft and friable as to have yielded readily to glacial action, and have evidently contributed largely to the fine materials of the drift. It will be seen then, that the supply of material here for transportation as drift into Iowa was abundant, and well adapted for the production of good soil for our State as well as for the region where it originated.

The Drift Deposit of Iowa is so thick and the proportions of its component materials so nearly uniform throughout the State; the soil of that deposit has also a great degree of uniformity. But still it may not unfrequently be observed that an underlying formation has impressed its character upon the soil. We may, perhaps, say in general terms that the *constant* component element of the drift soil is that portion which was transported from the north, while the *inconstant* elements are those portions which were derived from the adjacent or underlying strata. For example, in western Iowa, wherever that Cretaceous formation, known as the

Nishnabotany sandstone exists, close observation shows the soil to contain more sand in its composition than elsewhere; yet it is never sufficient in amount, even there, to cause it to approach barrenness. On the contrary, it adds a warmth and mellowness to the soil which are beneficial. The same may be said of the soil of some parts of the State occupied by the Lower coal-measures, the sandstones and sandy shales of that formation furnishing the sand.

In northern and northwestern Iowa the drift contains a greater portion of sand and gravel than elsewhere; consequently the soil also partakes of the same composition, but yet even there the barren spots are rare exceptions to the general fertility, because the proportion of coarse material is greater beneath than upon the surface. The sand and gravel of this region was doubtless derived from the Cretaceous rocks, that now does or formerly did exist there, and also in part from the conglomerate and pudding-stone beds of the Sioux quartzite.

Again, in some parts, as for example, in southern Iowa, the soil is frequently stiff and clayey, but very fertile. The subsoil, together with the whole thickness of the drift, is also clayey. This preponderating clay is doubtless derived from the clayey and shaly beds which alternate with the limestones of that region. It must not be understood, however, that clay is anywhere absent from the drift soil, not even from that of those parts where the underlying rocks contain only a minute proportion of clay; for, as before stated, much of the fine material of the drift, and consequently of its soil also, had its origin to the northward—some of it being derived from the granitic rocks there which contain, in large proportion, the necessary material for the production of clay.

The origin of clay and of soil from such rocks, when decomposed, may be finely illustrated by taking a handful of the decomposed granite from the valley of the Redwood before referred to, and stirring it up thoroughly in a vessel of water. The fine grains of quartz it contains disseminated throughout the mass become at once precipitated to the bottom of the vessel as a layer of sand, while the feldspar, hornblende, and mica also, if present, are suspended for a time in the water and are then deposited as a layer of common clay upon the sand.* Mixing the whole together again we have a handful of common soil in a condition fit for the growth of vegetation.

To constitute a proper fertile soil the mineral ingredients must of course have an addition of humus, derived from decayed vegetation. This has been abundantly supplied to Iowa soil by the growth of prairie grasses and other vegetation which has flourished upon it during the unnumbered years that have passed before civilized man disturbed its virgin repose. This accumulated fertility of the past now constitutes our great agricultural wealth; for it is a fact not to be disguised that our present agricultural prosperity is due to the primitive fertility of our soil, and although it is now of almost marvelous fertility, yet the time is soon to come when we must enquire with an earnestness, excited by necessity, into our resources for its fertilization and restoration.

The materials of the drift are so nearly uniform from top to bottom, and so great a proportion of these are finely comminuted, that almost any part of it, after proper exposure to the atmosphere and frosts, may be brought to the condition of good soil; so that the depth of any given soil, as the term is generally understood, is indefinite, but it may be said to have the depth to which the fibrous roots of the primitive vegetation has reached, and thus added humus to the mineral constituents. This depth is usually from two to four feet, but no Iowa farmer has any fear of plowing so deep as to reach through his soil. It will thus be seen that the subsoil does not differ materially from the soil proper. Hence no possible objection can be urged against subsoil plowing, while the nature of the subsoil itself suggests its great value.

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*This also well illustrates how stratified rocks are formed and how they derive their materials from the crystaline or unstratified rocks.

Although the greater part of the drift of Iowa is composed of materials that are fitted to produce good soil, it should be stated that the portion which now occupies the first few feet beneath the surface is in much the best condition for it, and that the surface is almost everywhere free from the coarse drift materials, being usually occupied by the finer portion alone. Consequently the soil is almost everywhere fine and excellent, even when the drift beneath, as is sometimes the case, contains much sand and boulders, and in other cases stiff clay. It should be also borne in mind that even where the boulders are most abundant, they are not sufficiently so as to interfere with agricultural operations, nor to impair the value of the land for agricultural purposes.

2. BLUFF SOIL.

The bluff soil, as its name denotes, is that which rests upon and constitutes a part of the Bluff Deposit before described. The description of that deposit is really a description also of the soil, for with the exception of the accumulation of humus in it at the surface; it is perfectly homogeneous from top to bottom, even where it is more than two hundred feet thick. Neither does it vary materially in composition with geographical extension, as will be seen by Prof. Emery's analysis of specimens of it obtained from different localities; there is, therefore, no proper distinction between the soil and subsoil of the region it occupies. The area occupied by this soil is the same as that occupied by the Bluff Deposit, described on previous pages. In Iowa, it is found only in the western part of the State and adjacent to the Missouri river, and may be said to contain a superficial area within the State amounting in round numbers to about five thousand square miles. This bluff soil grades imperceptibly into the somewhat similar drift soil to the eastward of it, but as a whole it presents a marked contrast with all the other soils of the State, and occupying as it does, so large an area, its peculiarities are well known and easily recognized. Although, as shown in Prof. Emery's report, it contains less than one per cent of clay in its composition, it is in no respect inferior to the best drift soil, and many of those who occupy it claim that it is superior to any other.

Its fertility is unquestionably as great as that of any, while the advantage claimed for it is that it is perfectly underdrained in consequence of the porosity and depth of the deposit of which it constitutes a part, and containing no clay, it never becomes heavy and "sticky," and never "bakes" in times of drought. There being not a stone or pebble to be found in it there are no obstructions to its perfect cultivation.

3. ALLUVIAL SOILS.

These are the soils of the Alluvial flood-plains of the river valleys, or as they are popularly called in Iowa, "bottom lands." They vary much in character and fertility, but the best of them are the most fertile soils in the State, from the fact that they contain the washings of the other soils, in addition to a large amount of decayed vegetable matter derived through the agency of former floods from the luxurious growth along the borders of the streams.

Those flood-plains, or portions of them, which are periodically flooded by their rivers are, of course, of little value for agricultural purposes, but a large part of them are entirely above the reach of the highest floods, while others are reached only by extraordinary floods at intervals of several years. Such as those last named are frequently cultivated, the farmer estimating this occasional loss of a year's crop to be comsated for by the great productiveness of such soils in other years. The lower portions of the flood-plains, even if they were not annually reached by the floods of the streams, are almost always too sandy for cultivation; but the higher ones are usually covered with a fine silt which forms the soil, and is often many feet in depth. The silt is almost always underlaid by layers of sand and gravel, formerly deposited there by the stream, so that the alluvial soils are usually well underdrained by that means, although they are, as a rule, quite flat.

The alluvial lands of the valleys of the two great rivers are the most important, but all the valleys of their principal tributaries contain valuable areas of alluvial soil. That of the Missouri river flood-plains partakes largely of the character of the peculiar bluff soil which borders it; and that of the flood-plains of those smaller rivers which traverse the region occupied by the Bluff Deposit, is scarcely different in character from the adjacent upland soil from which it was derived.

All varieties of Iowa soil are suited to the production of any crop to which our climate is adapted, with perhaps the only exception that winter wheat succeeds best upon alluvial soils, and those which have been reclaimed from the woodlands.

4. ADAPTABILITY OF IOWA SOILS FOR THE GROWTH OF FOREST TREES.

Notwithstanding the fact that the distance from the northern to the southern limits of the State is more than three degrees of latitude, in consequence of the slight difference in surface elevation, and the great degree of uniformity in the character of the soil, there is a striking uniformity in the character of the native vegetation; for the same reasons also, there is an equal uniformity in the adaptability of the soil and climate to the production of cultivated crops. There are indeed many species of indigenous plants that are restricted to certain parts of the State, and others that are found only in habitats, rendered congenial by moisture, dryness, barrenness, unusual fertility, etc., as the case may be; yet these are only exceptions to the general uniformity throughout the State, of all indigenous vegetation, including the forest trees.

The subject of the distribution of indigenous vegetation is a very suggestive and interesting one in all its bearings,* but

* Nature gives earnest and hopeful promises of future harvests of cultivated fruits in the wonderful profusion of wild grapes, apples, plums, cherries, etc., which every year load the indigenous trees and vines. These promises are now being redeemed in full to those who demand their fulfillment in proper form.

especially when applied to the growth of forest trees, it becomes one of unusual practical importance to every citizen of Iowa. The great importance which attaches to this part of the subject is apparent from the fact that the wood of forest trees for fuel, no less than for other purposes, is an indispensable element in the prosperity, and even the inhabitation of any country; not to mention the beneficial effects of forests upon the climate, the beautifying and adornment of its landscapes, and the shading and sheltering of its homes.

When the State was first settled, preference was always given to those parts where woodland and prairies joined. The open prairie was always avoided by the early settlers, among whom the belief was general that those portions of the State could never be occupied for want of timber. Time has proved the groundlessness of those views; but even now there is not woodland enough in Iowa to meet the necessities of a population that its fertile soil is capable of supporting in the greatest plenty.

It is a matter of regret that so distinguished a man as Prof. Whitney, and one whose accuracy of observation is usually beyond question, should have entertained and published views so erroneous in relation to the growth of forest trees in Iowa, as he did in the former geological report,* where he expressed the opinion that "the nature of the soil is the prime cause of the absence of trees upon the prairies." If the Professor could now revisit those regions he had examined at the time he wrote those views, we are confident he would at once retract them. Duty to the State demands that we should deny the correctness of those views in the most positive manner, and it is for this cause alone that this personal reference is made. If there is really an unfitness of prairie soil for the growth of forest trees, then at least one-third of our State is worthless indeed. But this is not the case, for personal observation in all parts of the State, extending through a period of thirty years, has established a

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*See Geology of Iowa, 1858, Vol. I. part I., page 24, *et seq.*

knowledge of the fact that *all varieties of our indigenous forest trees will grow thriftily upon all varieties of our soil; even those whose most congenial habitat is upon the alluvial soil of our river valleys, or upon the rugged slopes of the valley-sides.*

This fact is now well understood by every farmer in the State, and they also know that it requires positive exertion on their part to prevent the natural encroachment of forest growth upon their prairie farms as soon as the bordering wood-land is protected from the annual prairie fires. This encroachment of forest growth is equally marked upon the alluvial or bottom prairies, the ordinary drift prairies, and those in western Iowa whose soil is composed entirely of that fine silt-like material before described under the head of Bluff Deposit.

The rapidity with which all kinds of our forest trees will grow upon all varieties of our soil is quite astonishing, for the superiority of these soils is as strikingly shown in the growth of trees as it is in the production of the staple crops of corn and wheat. So rapid indeed is the growth of trees, both by natural and artificial propagation, that not only is there a gradually increasing area occupied by them, but there seems to be sufficient evidence that there is more wood-fuel now existing in Iowa than there was at the time of its first settlement, notwithstanding the constant consumption of it by the inhabitants since then.

In many parts of the State the supplies of fuel are derived almost exclusively from trees that have grown from the seed since its settlement. Not only has the new growth reached a size that will answer for fuel, but hundreds of farms have been re-fenced with rails that grew in adjoining wood-land since they were first cultivated.

These facts are certainly sufficient to show that there is no unfitness of any of the soil of Iowa for the growth of its forest trees, and their original healthful growth, in all parts of the State, even in the smallest numbers, is sufficient evidence that their absence upon the remainder of the surface was not due to any unfavorable condition of climate. More especial reference has here been made to the *natural* growth and encroachment upon the prairies of the forest trees, but it is proper to state here that the planting of these trees has become a recognized branch of the agriculture of the State, and every Iowa farmer knows that he may plant and grow a crop of wood with the same certainty that he can grow a crop of corn.

4. ORIGIN OF THE PRAIRIES.

The question of the origin of the prairies has become more hackneyed perhaps, than any other of the speculative questions which North American geology affords; and yet it seems to be no nearer a solution, satisfactory to all, than it was when it first began to be discussed. It is not now proposed to discuss this question at length, nor even to present the different views that have been published by different authors, but only to state a few facts, offer a few suggestions, and perhaps leave the subject as unsettled in the minds of others as it was before.

By the word prairie we mean any considerable surface that is free from forest trees and shrubbery, and which is covered more or less thickly with grass and annual plants. This is also the popular understanding of the term. It is estimated that about seven-eighths of the surface of Iowa is prairie or was so when the State was first settled. They are not confined to the level surfaces, but are sometimes even quite hilly and broken; and it has just been shown that they are not confined to any particular variety of soil, for they prevail equally upon Alluvial, Drift, and Lacustral soils. Indeed, we sometimes find a single prairie whose surface includes all these varieties, portions of which may be respectively sandy, gravelly, clayey, or loamy. Neither are they confined to the region of, nor does their character seem at all dependent upon the formations which underlie them, for within the State of Iowa they rest upon all formations, from those of Azoic to those of Cretaceous age inclusive, which embrace almost all kinds of rock, such as quartzite, friable sandstone, magnesian limestone, common limestone, impure chalk, clay, clayey, and sandy shales, &c. Southwestern Minnesota is almost one continuous prairie upon the drift which rests directly upon, not only the hard Sioux quartzite but also directly upon the granite.

Thus, whatever the *origin* of the prairies may have been, we have the positive assurance that their present existence in Iowa and its immediate vicinity is not due to the influence of climate, the character or composition of the soil, nor to the character of any of the underlying formations. It now remains to say without the least hesitation, that *the real cause of the present existence of the prairies in Iowa is the prevalence of the annual fires.* If these had been prevented fifty years ago Iowa would now be a timbered instead of a prairie State.

Thus far we have stated facts and what are deemed to be legitimate deductions from them. The following are offered only as suggestions. We have no evidence to show or suggest that any of the prairies ever had a growth of trees upon them; notwithstanding the fact that those at least of the eastern part of the great prairie region will support an abundant growth of trees after they are introduced, if protected from the fires. There seems to be no good reason why we should regard the forest as any more a natural or normal condition of the surface than the prairies are. Indeed, it seems the more natural inference that the occupation of the surface by the forests has taken place by dispersion from original centres, and that they encroached upon the unoccupied surface until met and checked by the destructive power of the fires.

Then arise questions like the following, not easily answered, and for which no answers are at present proposed: When was fire first introduced upon the prairies, and how? Could any but human agency have introduced annual fires upon them? If they could have been introduced only by the agency of man why did the forests not occupy the prairies before man came to introduce his fires, since we see their great tendency to encroach upon the prairies as soon as the fires are made to cease? The prairies, doubtless, existed as such almost immediately after the close of the Glacial epoch. Did man then exist and possess the use of fire that he might have annually burnt the prairies of so large a part of the continent, and thus have constantly prevented the encroachment of the forests? It may be that these questions will never be satisfactorily answered; but nothing is more evident than that the forests would soon occupy a very large proportion of the prairie region of North America if the prairie fires were made to cease, and no artificial efforts were made to prevent their growth and encroachment.

5. FOREST TREES.

Although the subject of the growth of wood is not, strictly speaking, a geological one, yet it is proper to consider it in this report in addition to coal and peat, as a part of the fuel resources of the State; and it is introduced here as having also a natural connection with the subjects discussed in the pages immediately preceding.

Wood is, and always has been, the principal and preferred fuel of the inhabitants of the State for domestic use, and were it everywhere in sufficient quantity, they would probably never care to change their established habits in the use of fuel by discarding it for any other. It has been feared by many, that the amount of fuel which Iowa could be made to produce; would not be sufficient to meet the wants of the prospective inhabitants that her fertile soil is capable of supporting in plenty; but it is believed that an examination of the subsequent pages upon the subjects of coal and peat, will show the groundlessness of such fears, even if no other sources of supply are considered. In addition to that, it is proposed to show in this place that a sufficient amount of fuel, at least for domestic use, for all the present and prospective inhabitants of the State may be produced from the soil alone by the growth of forest trees.

It has before been stated that forest trees can be cultivated as successfully as a crop of corn upon all varieties of our soil, and this question being settled in the minds of those interested in the subject, it becomes necessary to consider the time within which the result may be practically accomplished; because to meet the wants of the rapidly increasing population, it is necessary that some almost immediate supply be provided in the case of the broad prairie districts. Some such districts are upon, or adjacent to the coal-fields. Some are adjacent to considerable bodies of woodland, and others have important deposits of peat; from all of which sources immediate supplies of fuel may be obtained. But besides these, there are other broad and fertile tracts that have none of the advantages just named, and those who occupy them must rely for their supplies of fuel upon distant sources or upon its production from the soil. Railroads are being rapidly constructed which will carry coal from our coal-field to a large part of these prairie regions, but a large proportion of the inhabitants of Iowa must depend alone for their ordinary fuel upon the growth of trees.

By first planting those trees which have the most rapid growth, to be followed immediately by those of slower growth and greater density of wood, one not acquainted with the subject would be surprised to see how quickly a sufficient supply of fuel may be obtained, and how a future supply of the best kinds of wood can be established. The principal kinds of trees indigenous to the State, which are or may be used as fuel, are the following given in the order of their estimated relative abundance by natural growth at present in the State at large: Oaks—several species—cottonwood, elm, white maple, linden, hickory, sugar maple, black walnut.

The oaks form the greater part of the firewood now used in the State. In some parts cottonwood is scarcely used at all for fuel, but in others, better wood being scarce, it constitutes the greater part of the fuel used by the inhabitants. Other trees, such as hackberry, ash, honey-locust, slippery-elm, butternut, etc., are occasionally used as fuel, but they are comparatively so few in number that they hardly deserve mention as varieties of fuel. In the new natural growth of these trees the relative abundance is somewhat changed, the black oak, hickory, and black walnut increasing. The following named trees are those which will probably be most used for cultivation. They are given in the order of their estimated rapidity of growth: Cottonwood, white maple, black walnut, oaks, sugar maple, and hickory.

The relative value of each of these kinds of wood for fuel is estimated to be in the same order, cottonwood being the poorest and hickory the best; or, in other words, the slower the growth of the tree, the more valuable it is for fuel. But taking into account the necessity that exists for immediate supplies of fuel in many parts of Iowa, the cottonwood becomes one of our most valuable trees because of its rapid growth. As soon as it has performed this valuable pioneer service, it should be laid aside to give place to more solid and useful varieties.

The most congenial habitat of the cottonwood is upon the sandy alluvial soils of the river-valleys; but it grows with astonishing rapidity upon all varieties of soil in the State, and flourishes as well upon the prairies as in the valleys. Instances are numerous of the growth of this tree from the seed, or from a riding stick stuck into the prairie soil, to the size of from twelve to fifteen inches in diameter, a foot above the earth, within the space of ten or twelve years. So rapid is its growth that those well acquainted with it estimate that ten acres planted with the seeds or young shoots, will, at the end of five years, supply a large family continually with all necessary fuel. Indeed a large number of persons have practically proved the correctness of these estimates.

Cottonwood may be propagated either from the seed, cuttings, or by transplanting the young trees. The seed, which is very light, is sometimes scraped up from the sandy surfaces along the streams where it has fallen from the trees, the seed and sand mixed together and sown broadcast upon ground prepared for it, as small grain is sown. Sometimes the slender poles are cut from the dense growth that often springs up along the streams, trimmed of their branches, and then notched with the ax at intervals of a few feet along their entire length, then placed end to end in furrows at proper intervals, and covered with soil by the plow. Sprouts quickly start from the sides of the notches and rapidly become thrifty trees.

The most congenial habitat of the white maple is also upon the low-lands, but it thrives well upon the prairies. For rapidity of growth it ranks next to the cottonwood and makes better and more durable fuel. It succeeds well upon all varities of soil and may be readily propagated from the seed, or by transplanting the young trees from the places of their natural growth.

The black walnut has been proven to succeed well upon the prairies by artificial propagation. It is propagated from the seed with certainty and little labor.

These three kinds of trees are those now most commonly used for the production of artificial groves and woodlands by the people of the State, since the failure of the black locust, in consequence of its destruction by the borers. It is well known that all the other indigenous trees may be artificially cultivated, but these seem to have been wisely chosen for the rapidity of their growth and the small amount of labor required in their propagation and cultivation. These tests which the people have made extensively throughout the State, prove beyond the possibility of doubt that a sufficient amount of fuel and fencing material may be produced from the soil alone in any part of Iowa.

People have hitherto been in the habit of regarding the great proportion of prairie surface in our State as a calamity; but with a knowledge of the facts just stated it is evident that views directly opposite should be taken, because the labor and expense of procuring all necessary fuel by the means just explained, is but a tithe of what would be necessary to prepare the land for cultivation if it had originally been covered with forests, such as formerly prevailed over a large part of the States of Ohio and Indiana.

In a prairie region like ours the farmer selects the finest lands for cultivation, every acre of which is ready for the plow, and sets aside the more broken and less tillable portions for his future woodlands. Thus he may not only choose the location of his fields and woodlands, but also the kinds of crops, whether of grain or trees, that shall be grown upon each.

A CATALOGUE OF THE INDIGENOUS FOREST TREES OF IOWA.

Acer Dasycarpum—White maple.
Acer saccharinum.—Sugar maple.
Æsculus glabra.—Buckeye.
Betula nigra.—Water birch.
Carya alba.—Hickory.
Carya amara.—Pig-nut hickory.
Carya olivaeformis.—Pecan.
Celtis occide talis.—Hackberry.
Cerasus serotina.—Black wild cherry.
Fraxinus Americana.—White ash.
Gleditschia triacanthus.—Honey locust.
Gymnocladus Canadensis.—Kentucky Coffee bean.
Juglans cinerea.—Butternut, White walnut.
Juglans nigra—Black walnut.
Negundo aceroides.—Box-elder.
Platanus occidentalis.—Button, Sycamore.
Populus monilifera.—Cotton-wood.
Populus tremuloides.—Aspen.
Quercus alba.—White oak.
Quercus imbricaria.—Laurel oak.
Quercus macrocarpa.—Bur oak.
Quercus tinctoria.—Black oak.
Tilia Americana.—Linden, Bass wood.
Ulmus Americana.—Common elm.
Ulmus fulva.—Slippery elm.

Some of the trees enumerated in this catalogue can hardly be said with strict propriety to be a part of our forest trees on account of their scarcity. A few others might also be mentioned that occur in small numbers within the State, besides several species of the smaller class of trees; but the object of this catalogue is only to give a general view of the arboreous flora of the State to those who are not acquainted with it.

CHAPTER IV.

CLIMATE.*

The climatology of the State can only be properly ascertained from a careful comparison of a long series of observations made at different points in various parts of the State. Yet much of great value, to the agriculturist and others, may be learned from a study of the observations made at a single point, and their value enhanced as they extend over a longer period of time. The observations upon which this chapter is based, prepared at the request of C. A. White, M. D., State Geologist, to accompany his report upon the Geology of the State, were made by the writer at Muscatine, (Bloomington, until 1837) and Iowa City, commencing January, 1839, and continued until the present time. Those at Bloomington, 1839–1847, were furnished the Government through Prof. Espy, of the Treasury Department, until the organization of the "Smithsonian Institution," where, at the request of Prof. Henry, Secretary thereof, they were continued at Muscatine from 1847 to 1860 and at Iowa City from 1860 to 1869. The difference in latitude is about one-tenth degrees, and longitude about five-tenths degrees. I have calculated the means of the observations at Muscatine for twenty years and at Iowa City for ten years, and find that the difference is so very slight that I have not hesitated to

* Professor THEODORE S. PARVIN, of the State University, has generously contributed the entire contents of this chapter.—C. A. WHITE.

regard the observations as taken at one point and used them accordingly.

The instruments used are a barometer, thermometers, psychometer, wind-vane, pluviameter, (rain gauge,) all of the best quality, and manufactured by James Green, of New York. Accompanying these observations are records of the frost; flowering of fruit trees; times of the opening and closing of the Mississippi river, etc., etc., presenting facts in regard to the seasons of great value to the farmer, stock and fruit raiser, as well as shipper.

The observations were made at the hours of 7 A. M., 2 P. M., and 9 P. M. In their collection and reduction, I have, in order to make them of comprehension to the unscientific reader and observer, avoided as far as possible the use of either scientific terms or formula.

The array of facts here presented will, it is hoped, prove of interest not only for the residents of this State and the Mississippi valley, but also for the dwellers upon the sea-board, as furnishing data from which a comparison may be drawn as to the difference in the temperature, amount of rain-fall, the source thereof, &c., &c., as also their distribution through the several seasons of the year. Eastern meteorologists have been greatly surprised at the large amount of precipitation of vapor in the valley, overlooking the fact that *there* the rain winds are N.E., *here*, S.W. The amount precipitated has not diminished since the first settlement of the country, and probably will not, as the area covered by timber has not decreased with the settlements of the State and is not likely to in the future; on the contrary, is increasing and will continue to increase with the growth of settlements, in age and extent. The peculiarities of our soil and climate are such that the past three decades have demonstrated that our State can endure an extreme of drought or rain with as little or less loss than any other cultivated region of our country.

No use has been made in this report of the barometrical observations taken in connection with the others used, nor of the relative humidity, &c., deduced from the observations of the psychometer, the latter of which especially bear so strongly upon the problem of health. It did not come particularly within the limit assigned me and has more of a scientific than practical relation to my work and object. It may here be stated, however, that the atmospheric conditions of our climate are, in the highest degree, favorable to general health, and no people enjoy this boon in a higher degree than ours.

TABLE I. (1.)

MONTHLY AND ANNUAL MEAN TEMPERATURES AT THE THREE HOURS OF DAILY OBSERVATIONS.

YEAR.	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
	7 A. M.	2 P. M	9 P. M.	7 A. M	2 P. M.	9 P. M.	7 A. M	2 P. M.	9 P. M.	7 A. M.	2 P. M	9 P. M.	7 A. M	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.
1839	27.4	36.5	32.2	....	....	....	35.8	48.8	45.1	51.1	71.2	63.1	53.5	68.4	59.4	57.0	73.7	65.0
1840	16.9	22.1	17.8	22.8	36.2	31.1	31.4	44.5	37.8	41.3	60.7	52.7	53.5	71.1	61.5	63.6	77.2	69.5
1841	12.9	24.3	20.3	14.7	33.8	23.6	29.8	46.4	37.8	37.2	56.8	48.8	49.3	69.1	58.5	64.3	82.4	66.9
1842	18.4	33.6	26.9	18.9	35.5	26.8	34.6	57.9	35.8	44.9	66.3	56.9	47.9	66.6	56.8	55.2	76.3	63.5
1843	18.1	32.6	26.3	7.0	23.1	13.2	5.2	25.2	16.7	36.3	57.7	48.1	45.8	71.0	57.8	56.2	76.1	67.2
1844	19.5	26.6	21.2	22.4	38.2	26.5	31.7	48.4	39.2	50.3	70.5	57.0	52.3	67.2	58.2	60.3	70.3	69.9
1845	22.1	35.0	32.1	25.7	41.1	31.9	30.9	48.1	40.4	43.4	65.6	54.8	47.0	65.7	58.1	56.2	77.6	62.0
1846	24.8	38.6	30.4	16.9	30.8	24.2	27.4	37.4	31.4	45.6	59.6	51.1	58.0	72.3	68.5	60.1	70.6	66.1
1847	5.3	19.3	12.1	21.1	31.7	25.1	20.4	38.0	31.0	36.1	62.2	49.8	47.4	67.1	56.4	54.1	72.7	59.6
1848	21.3	33.2	29.0	29.4	34.8	31.2	22.3	43.6	36.0	35.0	58.5	44.0	51.6	72.3	56.5	55.0	74.0	62.9
1849	7.3	19.9	16.6	10.6	23.5	20.0	29.5	42.3	38.6	37.3	50.1	43.1	46.9	63.2	55.1	66.0	75.9	66.4
1850	20.0	30.0	23.5	19.0	35.8	26.0	25.6	40.4	31.5	35.1	48.9	38.2	42.3	64.2	50.6	58.6	80.2	67.2
1851	18.9	30.4	24.2	29.2	34.3	26.4	30.4	50.1	34.5	34.9	51.8	40.8	50.0	67.0	59.2	57.7	70.8	61.9
1852	16.2	25.0	17.6	23.3	36.2	27.8	29.8	42.7	35.3	35.4	50.1	41.3	51.4	72.6	57.6	58.0	75.0	63.5
1853	21.2	36.6	26.0	16.5	30.1	22.7	26.5	43.3	32.3	40.0	56.0	45.2	48.9	61.3	50.8	61.7	83.6	65.3
1854	10.3	21.8	16.4	22.5	36.5	26.5	36.1	47.3	36.2	41.6	63.9	47.9	50.9	69.6	59.6	61.6	79.6	65.7
1855	21.1	29.6	23.6	11.6	20.2	15.0	24.2	38.0	29.2	44.5	66.2	50.9	53.7	70.0	57.4	62.7	75.3	64.0
1856	2.1	14.8	5.8	10.1	22.2	12.8	19.8	34.2	24.9	43.9	59.8	48.6	54.5	70.2	59.1	65.1	79.8	66.4
1857	1.2	12.5	4.9	24.4	34.1	27.7	22.9	37.7	27.7	29.4	44.7	35.5	44.2	62.8	52.6	57.0	76.1	62.9
1858	24.7	38.1	28.3	10.8	22.1	15.1	31.5	47.5	36.1	41.3	52.6	41.4	56.0	57.4	55.4	67.4	75.3	66.1
1859	19.3	29.3	22.8	19.4	33.2	24.7	34.5	45.9	40.1	36.5	52.8	41.9	56.9	69.6	59.6	60.3	72.0	63.1
1860	18.7	28.7	20.3	19.2	31.8	27.3	30.2	54.1	41.9	39.9	61.6	48.7	55.3	75.0	61.0	60.8	80.4	66.7
1861	8.4	21.2	11.5	16.8	31.8	22.8	25.2	40.0	33.0	40.0	56.0	46.7	42.7	62.4	55.1	61.3	78.2	64.6
1862	7.8	18.9	13.4	6.3	21.9	12.3	23.2	36.0	29.3	37.4	49.7	42.3	49.4	68.7	55.7	54.1	72.9	62.1
1863	21.2	33.8	24.2	18.4	29.6	22.7	25.6	40.1	30.7	38.9	59.5	44.7	54.9	65.7	55.9	56.0	75.4	60.3
1864	8.6	23.7	15.2	21.4	34.6	26.0	26.2	40.1	31.4	40.1	52.5	45.8	51.4	73.4	60.3	62.6	84.7	68.3
1865	12.9	28.8	20.3	25.0	38.2	30.1	26.0	42.1	34.2	41.0	55.1	48.9	53.3	70.1	60.5	47.8	76.6	67.0
1866	16.2	26.6	19.6	11.8	27.7	18.8	25.4	38.7	30.9	39.0	60.6	49.9	48.6	70.1	58.2	63.1	76.6	65.6
1867	11.2	25.0	16.8	19.1	35.1	27.4	16.8	32.0	22.9	39.2	56.1	46.2	43.0	60.2	50.7	64.3	75.3	66.6
1868	6.4	24.4	13.3	14.6	32.1	21.1	33.3	48.4	43.0	26.0	52.2	44.0	54.7	71.0	61.7	63.8	78.5	69.5
1869	18.9	34.1	24.9	19.9	34.7	27.4	22.3	39.2	29.7	39.4	55.6	45.3	52.8	69.8	62.3	60.3	75.2	65.1
1870	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Greatest	27.4	38.1	32.2	29.4	41.1	31.1	36.1	54.1	45.1	51.1	71.2	63.1	58.0	72.3	68.5	67.7	84.7	69.9
Least	1.2	12.5	4.9	6.3	20.2	12.3	5.2	25.2	16.7	34.9	44.7	35.5	42.3	61.3	50.6	54.1	70.3	59.6
Means	15.1	27.6	20.5	18.1	31.8	23.8	26.8	42.8	23.7	40.1	58.1	47.8	50.6	67.9	57.8	59.5	76.3	65.1

TABLE I (1)—*Continued.*

MONTHLY AND ANNUAL MEAN TEMPERATURES AT THE THREE HOURS OF DAILY OBSERVATIONS.

YEAR.	JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.			FOR THE YEAR.		
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.
1839..........	64.9	82.9	76.1	63.3	81.3	71.6	53.1	69.5	59.4	52.7	64.7	59.3	32.1	38.5	35.4	20.9	27.5	23.8	46.3	59.9	55.0
1840..........	67.0	75.4	73.0	64.2	77.4	72.9	53.1	70.9	63.7	45.7	58.7	56.9	33.5	46.8	42.3	20.6	34.9	27.9	42.8	56.3	50.5
1841..........	65.3	84.8	69.1	59.2	81.3	66.3	50.2	68.6	55.3	38.7	57.2	47.6	30.9	44.3	39.5	23.2	34.2	27.1	39.6	56.9	45.9
1842..........	59.6	83.3	68.6	57.3	82.7	68.6	51.6	76.4	62.6	40.8	68.3	27.8	23.5	36.5	29.2	15.2	28.9	21.7	38.9	59.4	43.7
1843..........	64.4	86.5	70.4	61.3	83.6	67.4	58.2	72.9	62.8	34.1	51.4	44.9	28.6	35.5	34.7	23.2	35.0	30.9	36.4	54.2	45.0
1844..........	68.2	82.5	71.6	62.3	79.4	66.6	50.1	70.1	55.0	37.3	57.2	50.3	29.2	42.0	34.1	17.2	31.3	25.7	41.7	56.9	47.9
1845..........	65.9	84.6	70.8	62.1	82.0	68.4	53.0	70.2	53.4	37.5	56.4	42.0	25.6	40.4	33.6	11.7	22.5	17.4	40.4	57.4	47.2
1846..........	64.1	85.4	69.5	64.3	79.9	70.8	56.9	70.2	65.5	38.3	56.0	47.4	32.7	40.1	38.0	30.9	37.9	31.0	43.3	56.9	49.5
1847..........	59.9	82.0	67.8	55.1	76.2	63.7	50.1	67.7	57.7	37.0	58.6	46.1	27.2	39.6	33.5	19.3	34.2	24.9	36.1	54.1	45.6
1848..........	56.5	73.1	64.1	60.0	75.7	65.9	46.5	65.0	56.0	38.1	56.2	47.0	25.0	36.0	30.5	14.0	25.7	19.6	37.9	54.0	44.4
1849..........	59.2	79.0	67.4	53.7	73.3	62.8	54.0	70.1	60.1	39.0	51.2	46.6	36.0	50.1	40.1	12.9	23.2	19.3	37.3	51.7	44.8
1850..........	65.5	84.0	69.3	64.3	83.8	70.0	51.9	68.4	58.6	39.1	58.1	45.4	31.9	44.8	36.4	13.3	26.3	19.6	38.8	55.4	44.7
1851..........	64.5	81.4	69.3	61.5	79.0	66.4	59.9	77.1	65.2	42.9	58.5	50.1	28.8	40.0	33.6	17.4	25.9	21.8	41.2	55.5	46.1
1852..........	63.5	82.7	67.8	59.1	78.0	65.7	51.3	68.4	57.9	47.6	60.2	50.3	27.7	33.8	28.1	19.5	26.0	21.3	40.2	50.4	44.2
1853..........	59.2	78.3	64.8	62.9	80.8	66.0	54.1	70.0	60.2	35.3	58.3	49.4	36.6	45.0	37.9	22.3	33.8	25.6	40.4	56.2	45.5
1854..........	68.3	87.3	73.0	65.4	84.8	69.8	58.6	80.0	66.1	47.6	62.7	52.8	30.2	44.8	35.5	20.0	34.4	25.9	42.7	59.4	47.9
1855..........	68.4	81.7	68.8	66.6	78.9	65.8	64.4	73.7	64.5	38.1	59.0	44.4	33.4	44.8	35.3	17.5	26.9	22.8	41.3	55.4	45.1
1856..........	67.7	81.1	69.9	57.3	77.9	60.9	50.1	70.1	56.5	44.4	61.5	51.7	28.1	38.8	32.1	11.5	20.0	14.2	37.7	52.5	41.9
1857..........	64.8	85.3	68.1	62.6	81.0	68.5	57.1	72.8	62.2	41.4	55.8	46.4	26.7	35.6	32.1	27.3	36.6	30.7	38.2	52.9	43.2
1858..........	67.8	84.8	72.0	65.2	81.3	72.3	55.7	72.9	62.0	46.9	56.6	50.7	29.6	37.2	31.6	20.1	31.2	22.2	43.8	54.7	46.1
1859..........	63.5	85.0	68.8	62.4	80.8	65.7	53.0	69.5	58.9	40.5	56.2	43.4	33.7	46.7	38.2	9.6	21.4	13.8	40.8	55.2	43.4
1860	65.2	82.8	69.8	60.0	77.8	66.3	54.3	70.2	61.1	45.4	65.5	49.0	28.4	42.9	32.2	12.4	26.0	17.8	40.8	58.9	46.8
1861..........	61.3	79.9	65.5	65.9	85.0	75.6	55.1	72.0	60.4	42.2	59.3	48.4	29.2	44.4	35.0	18.8	34.9	24.2	38.1	55.4	45.2
1862..........	66.4	83.3	76.9	64.1	78.9	64.7	55.4	69.5	60.8	43.1	57.9	47.7	29.3	39.4	33.3	32.6	34.9	28.1	38.4	52.6	43.9
1863..........	62.9	85.0	67.0	63.5	80.1	68.8	54.5	70.7	58.7	34.0	47.8	38.8	28.0	41.9	31.3	24.2	31.7	23.9	40.1	55.1	43.9
1864..........	70.0	81.8	74.4	66.9	80.8	72.4	58.0	75.4	65.5	39.9	55.3	46.6	30.2	39.4	34.3	13.8	25.2	17.6	40.9	55.5	46.5
1865..........	64.3	76.6	67.9	68.5	79.5	71.5	68.5	78.9	71.5	44.8	62.1	52.5	32.6	50.7	40.9	11.2	27.7	19.7	42.9	57.1	48.7
1866..........	70.7	85.3	75.2	62.2	76.4	68.1	51.9	67.3	57.4	45.5	63.3	50.7	34.4	47.0	40.6	19.5	28.2	23.3	40.7	55.6	46.5
1867..........	63.5	81.3	71.5	67.3	84.9	72.9	60.8	76.6	67.3	43.9	65.3	53.6	34.4	50.6	39.6	19.8	30.4	23.1	40.3	56.9	46.5
1868..........	75.6	89.1	79.5	60.9	78.7	68.4	52.2	66.2	57.2	42.9	58.4	48.3	33.2	43.9	36.6	15.1	28.2	20.9	40.7	56.1	46.9
1869..........	64.7	78.3	70.0	68.8	80.6	74.9	56.1	72.7	62.3	34.7	53.1	40.8	27.5	38.3	30.6	....	....	....	....	....	....
1870..........	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Greatest ..	75.6	89.1	79.5	68.8	85.0	75.6	64.4	80.0	71.5	52.7	65.5	59.3	36.0	50.7	42.3	30.9	37.9	31.0	46.3	59.9	55.0
Least.....	56.5	73.1	68.1	53.7	73.3	60.9	46.5	65.0	55.3	34.1	47.8	27.8	25.6	35.5	28.1	11.5	23.2	13.8	36.1	50.4	41.9
Means....	64.9	82.4	69.7	62.5	79.9	68.3	54.7	71.1	60.9	41.2	58.7	47.8	30.4	42.7	35.1	18.9	29.5	22.8	40.6	55.9	40.5

TABLE I. (2.)

MONTHLY AND ANNUAL MAXIMUM, MINIMUM, AND MEAN TEMPERATURES.

YEAR.	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
1839	60	0	32.16	63	4.	31.80	80	4	40.50	86	38	62.70	84	38	68.90	89	48	70.60
1840	39	17	19.50	71	25.	28.20	63	12	38.30	86	27	52.94	85	37	63.13	88	57	72.38
1841	52	23	20.87	62	14.	26.10	68	18	37.07	77	27	51.00	90	33	58.10	96	49	71.10
1842	52	10	26.29	56	13.	28.05	84	13	45.82	84	28	53.30	86	33	57.88	92	43	65.61
1843	50	15	24.97	45	19.	13.38	38	10	15.51	78	5	47.71	88	27	58.22	90	40	67.75
1844	41	6	22.09	56	0.	30.34	66	6	38.30	72	30	60.54	85	36	55.86	90	48	65.81
1845	58	6	30.03	66	6.	29.91	77	8	40.38	86	16	55.10	82	34	55.47	88	54	64.27
1846	56	12	31.22	50	8.	24.19	72	20	40.57	82	28	52.70	86	38	64.09	82	54	66.14
1847	40	23	12.26	56	10.	25.28	66	0	29.43	86	13	49.13	87	30	55.84	86	40	62.45
1848	50	8	28.00	50	4.	28.39	70	8	35.16	80	22	45.08	84	25	62.00	88	33	64.31
1849	46	24	14.26	48	22.	18.12	68	10	37.55	74	22	44.32	80	30	54.83	86	44	67.62
1850	46	10	24.40	55	14.	28.85	64	10	32.60	78	18	41.22	86	24	53.30	88	40	70.17
1851	46	16	23.97	52	0.	27.73	78	12	38.22	70	24	43.52	82	22	58.19	85	44	64.64
1852	53	23	19.60	52	0.	29.00	80	3	36.15	64	20	42.17	82	29	59.96	90	40	66.80
1853	54	9	27.05	55	11.	23.36	66	5	33.24	71	27	47.81	81	34	55.65	91	49	71.22
1854	55	14	16.16	60	13.	28.50	70	14	39.86	88	12	51.13	76	35	60.03	92	45	68.96
1855	64	23	24.77	40	11.	15.64	63	2	30.31	87	24	53.99	86	27	60.42	91	35	67.02
1856	32	26	7.52	42	29.	15.03	56	17	25.80	77	27	49.51	90	40	61.38	97	50	71.79
1857	41	30	6 16	57	12.	28.76	58	5	29.87	65	13	38.29	83	29	53.91	89	38	65.11
1858	52	8	29.96	46	17.	15.98	70	1	38 71	78	24	46.12	81	39	54.31	96	52	70.62
1859	50	13	24.10	51	13.	25.77	67	23	40.09	72	22	43.27	82	45	62.13	85	40	69.06
1860	48	26	21.32	58	20.	26.62	72	16	42.69	84	18	49.62	89	28	64.33	92	48	69.32
1861	39	18	13.85	56	15.	27.10	64	8	33.99	73	28	47.59	78	35	58.67	89	51	68.28
1862	38	23	13.48	42	25.	13.16	64	5	29.55	67	25	42.85	84	39	59.37	89	42	71.79
1863	59	0	25.97	44	17.	23.40	57	12	31.89	82	38	47.25	80	36	58.69	93	42	62.49
1864	55	26	15.89	56	15.	27.37	60	0	32.61	74	32	46.11	90	32	62.15	92	47	70.60
1865	46	10	20.45	48	10.	31.48	70	5	34 28	75	20	48.09	86	37	61.40	88	54	74.89
1866	47	14	20.67	55	20.	19.57	60	4	51.28	86	22	51.22	84	35	59.18	90	48	67.92
1867	45	18	17.86	52	18	26.31	47	13	25.66	70	27	47.14	79	31	51.87	90	52	70.47
1868	50	16	13.37	55	26.	25.29	75	3	42.69	78	18	44.69	84	46	61.69	92	47	70.75
1869	48	14	26.02	62	8.	27.00	72	12	30.26	80	20	47.09	82	40	60.01	85	44	66.07
1870	..	..	.....	..	...	.....	..	..	.....	..	..	.....	..	..	.....	..	..	.....
Greatest	64	12	32.16	71	11	31.80	80	23	45.82	88.	38.	62.70	90.	46.	68.90	97.	54.	74.89
Least	32	30	6.16	42	29	13.10	38	17	15.51	64.	5.	38.29	76.	22.	51.87	85.	33.	62.45
Means	49 4	13.8	21.75	53.5	11.9	24.81	66.6	5.0	34.75	79.0	23.4	48.50	84.1	34.4	59.06	89.1	44.2	67.92

TABLE I. (2.)—*Continued.*

MONTHLY AND ANNUAL MAXIMUM, MINIMUM, AND MEAN TEMPERATURES.

YEARS.	JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.			FOR YEAR		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
1839	95	58	75.70	92	49	73.10	84	38	61.10	80	31	60.70	60	2	35.10	48	5	23.90	76	23	52.02
1840	87	58	73.92	86	54	72.13	76	44	63.09	77	25	52.57	66	19	41.89	55	2	29.55	73	24	50.63
1841	96	56	70.40	96	48	65.50	96	36	58.50	72	18	55.00	66	4	38.20	47	8	28.80	76	19	48.39
1842	94	50	68.36	96	42	68.72	92	35	64.48	80	23	55.45	69	11	30.20	48	21	21.63	78	17	52.14
1843	95	55	70.44	94	46	70.60	92	45	64.58	84	12	42.15	56	10	34.08	44	8	31.90	71	17	45.07
1844	94	56	74.87	92	46	70.00	93	33	61.43	74	16	46.10	63	7	36.06	38	6	25.25	72	22	47.30
1845	98	50	76.05	93	48	70.80	92	30	62.89	72	16	48.48	60	11	33.32	42	12	18.16	76	20	48.74
1846	94	44	72.97	94	54	71.98	92	42	65.85	80	16	42.99	62	2	39.12	54	6	28.89	75	25	50.06
1847	92	42	69.52	86	42	65.26	84	36	59.82	86	8	47.77	74	7	33.54	63	10	25.26	76	15	44.63
1848	85	48	63.98	86	48	66.65	84	33	56.31	72	27	43.92	50	5	30.82	44	6	19.14	70	19	45.32
1849	89	42	66.48	86	36	65.26	84	37	61.70	70	28	48.96	72	20	42.87	44	12	18.36	71	19	45.01
1850	94	50	74.22	94	50	72.22	84	30	59.83	80	22	44.15	66	16	37.55	44	6	19.77	73	19	46.52
1851	97	44	71.62	85	52	69.09	91	30	68.34	79	18	50.35	51	14	34.50	56	18	21.42	72	19	47.63
1852	94	45	72.36	92	44	68.98	84	35	59.76	76	30	53.18	50	7	30.00	52	0	22.18	69	19	46.68
1853	87	46	68.82	92	41	71.08	89	37	62.21	75	10	45.46	60	15	39.73	48	1	26.67	71	20	47.71
1854	98	46	76.16	99	46	73.00	96	37	68.23	82	27	54.36	69	7	36.82	50	4	27.76	78	19	49.99
1855	95	55	73.01	96	53	70.35	92	35	67.92	84	15	47.19	67	10	37.82	60	19	21.67	77	19	47.51
1856	93	55	73.51	91	40	65.40	91	28	59.00	82	25	52.38	54	4	32.79	42	13	15.63	70	15	44.18
1857	97	45	71.21	92	47	70.85	88	36	63.77	74	22	47.92	60	0	31.19	52	13	31.41	71	16	44.87
1858	89	52	78.80	93	46	79.89	87	42	66.93	85	30	51.99	52	4	32.61	48	15	25.53	73	23	49.62
1859	97	46	72.33	92	42	69.22	87	34	60.25	82	15	47.47	75	12	39.61	46	22	15.11	74	21	47.37
1860	94	50	71.68	95	45	68.75	89	40	54.25	87	24	61.30	69	4	35.73	43	22	17.48	77	16	47.76
1861	97	47	69.00	99	47	70.07	88	40	62.57	74	28	50.13	65	5	37.01	62	5	26.00	74	21	47.02
1862	95	56	73.36	99	55	69.23	82	41	63.44	86	17	48.58	64	15	35.22	52	3	29.30	72	20	45.77
1863	94	49	71.45	94	36	70.43	90	36	61.24	66	18	40.02	61	8	33.77	53	23	27.00	72	18	46.22
1864	94	55	75.97	91	50	72.98	92	36	66.85	68	26	47.81	59	0	35.79	54	14	19.27	74	18	47.80
1865	91	55	69.33	99	55	72.43	90	44	72.56	82	30	53.91	66	20	42.63	50	17	21.03	73	24	50.20
1866	94	60	77.12	85	43	68.80	85	33	59.12	82	20	53.12	72	16	40.16	53	2	23.59	74	20	47.65
1867	92	55	73.32	95	50	74.74	87	43	66.82	80	32	54.51	72	0	41.58	42	2	24.29	71	20	47.96
1868	96	53	80.79	92	48	69.12	81	32	58.76	73	30	49.84	63	18	37.97	50	18	21.69	74	19	48.01
1869	86	52	70.86	93	57	74.36	88	33	63.23	78	16	42.72	70	5	32.12	..	..	.....	..	..	.....
1870	...	...	.....	...	...	.....	...	...	.....	..	..	.....	..	..	.....	..	..	.....	..	..	.....
Greatest	97	60	76.16	99	57	79.89	96	45	72.56	85	32	60.70	75	20	42.87	62	13	31.90	78	24	52.14
Least	85	42	63.98	85	36	65.26	76	28	58.50	66	8	40.22	50	11	30.20	38	21	15.63	69	15	44.18
Mean	93.3	50.9	72.51	89.6	47.2	70.70	87.6	37.3	63.37	78.1	22.0	49.58	63.7	6.9	36.28	49.5	8.4	23.55	73	19	47.57

In Table I. (1) is presented the monthly mean *Temperatures* for the three observations taken, viz: 7 A. M., 2 P. M., and 9 P. M., for a period of thirty-one years, extending from 1839 to 1869, inclusive; together with the annual means for the same period. At the bottom of the table may be found the greatest and least of these means, with the mean for the whole.

An examination of the results here given, will show a great range in many of these means of many observations, an inequality far greater than might have been anticipated.

In table I (2), the monthly and annual maximum (greatest) and minimum (least), and mean temperatures are given. In the column for the year the maximum and minimum are the means of these results. An inspection of this table will show that in this region—round about Iowa City—November and March are essentially *winter* months, their mean temperatures rising but a little above the freezing point. September, much more than May, has a summer temperature; the mean temperature of the latter month being 69.06 degrees; of the former it is 63.37 degrees. The mean temperature of October is 49.58 degrees, falling as low as 40.02 in 1863, and again in 1869 to 42.72.

In order to show at a glance more plainly the variation in the annual mean temperature, we present the same in the form of a diagram (A), table I (3). The *o* in the left marginal column, represents the mean annual temperature for the period of thirty-one years, viz: 47.57 degrees—the range being three below 44.18 and five below 52.14, or, 7.96 degrees in all, as may readily be seen upon an examination of table I (2).

Diagram B, table I (4), shows the extreme means of the monthly temperatures; the upper dotted line, the greatest (maximum), the lower dotted line, the least (minimum), while the full central curved line shows the annual monthly fluctuations of temperature—all of which are deduced from the results presented in table I (2).

TABLE I. (5.)

TEMPERATURE OF THE SEASONS.—1850-69.

SEASONS.	TEMPERATURE.	MONTHS NEAREST SEASONS.	
Spring.......... ..	47° 44′	April...	48° 50′
Summer...	70° 37′	August....	70° 70′
Autumn...	44° 52′	October	49° 50′
Winter.......	23° 37′	December.........	23° 25′
Year	47° 57′	....	....

RANGE OF TEMPERATURE.

Highest...........	99° 00°	August 31st,1854.... ....
Lowest.......... ..	30° 00′	January 18th, 1857.............. ....
Range.........	129° 00′	....

Table I (5) shows the temperature of the seasons, being the mean results for the years 1839–69 aforesaid. To this table is added the mean temperature of the months nearest thereto.

The month of December is here joined to those of January and February of the same legal year.

Following this is the range of temperature with the dates corresponding. The highest temperature here occurs in August, while July is the hottest month of the year by nearly two degrees, and January the coldest by three degrees. During a residence of more than thirty years in central eastern Iowa, I have never seen the mercury rise to 100 degrees nor fall below 30 degrees.

The mean temperatures of April and October most nearly correspond to the mean temperature of the year, as well as their seasons of Spring and Fall; while that of the Summer and Winter is best represented in that of August and December.

TABLE I. (6.)

TEMPERATURE, TIMES OF HIGHEST AND LOWEST, AND DATES NEAREST.

YEAR.	HIGHEST.	LOWEST.	DAYS NEAREST ANNUAL MEAN.	
1850	July 26	February 3	April 1	October 12
1851	July 27	December 16	April 23	October 13
1852	July 28	January 19	April 23	October 31
1853	August 11	February 8	April 16	October 17
1854	August 31	January 24	April 12	October 17
1855	August 3	January 23	April 14	October 2
1856	June 24	February 4	April 12	October 18
1857	July 18	January 18	April 3	October 23
1858	June 22	February 10	April 20	October 18
1859	July 18	December 31	April 19	October 21
1860	August 6	January 1	April 10	October 19
1861	August 4	January 30	April 10	October 25
1862	August 8	February 14	April 27	October 10
1863	August 8	December 31	April 20	October 17
1864	July 17	January 1	April 20	October 13
1865	July 5	December 21	April 20	October 20
1866	July 12	February 15	April 14	November 2
1867	August 18	January 29	April 30	October 23
1868	July 14	February 10	April 18	October 13
1869	August 24	January 11	April 16	October —
Earliest	June 22	December 16	April 1	October 2
Latest	August 31	February 15	April 30	November 2
Mean	July 27	January 20		

We add in Table I (6) the times or dates of the highest and lowest temperatures of each year for a period of twenty years, 1850–1869 inclusive; also the days of the months most nearly corresponding to that of the annual mean temperature.

We learn from an inspection of this table that the period of greatest heat ranges from June 22nd to August 31st; the mean time being July 27th. That of the lowest temperature extends from December 16th to February 15th; the average being January 20th. The range in each case being two full months. These mean times, it will be seen, fall in those months whose mean temperatures show them to be the extreme ones of the year.

TABLE II. (1.)

NUMBER OF DAYS IN EACH MONTH IN WHICH THE PREVAILING WINDS CAME FROM EACH OF THE FOUR QUARTERS OF THE HORIZON.

The figures 1, 2, 3, and 4 indicate the quarters, as follows:—1. N. N. E.; 2. E. S. E.; 3. S. S. E.; 4. W. N. N.W.

YEARS.	JANUARY.				FEBRUARY.				MARCH.				APRIL.				MAY.				JUNE.			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1850........	4	4	12	11	8	3	5	12	8	5	4	14	9	5	7	9	7	7	6	11	8	5	14	3
1851........	3	2	8	18	14	2	11	2	3	5	9	14	13	2	5	10	6	12	8	5	8	10	5	7
1852........	7	2	8	14	6	2	5	16	5	9	3	14	7	9	2	12	6	11	8	6	8	3	11	8
1853........	7	5	7	10	3	4	8	13	4	8	3	16	12	5	4	9	8	3	6	12	2	12	11	5
1854........	4	2	8	17	8	1	7	12	4	4	5	18	10	8	10	2	5	16	5	5	5	11	9	5
1855........	3	5	10	13	6	4	2	16	3	3	13	12	9	6	8	7	8	17	6	0	3	6	15	6
1856........	3	6	6	16	6	1	11	11	2	2	11	16	3	10	11	6	6	9	8	8	5	8	12	5
1857........	3	3	10	15	4	7	10	7	8	10	5	8	6	8	7	9	9	12	5	5	6	9	12	3
1858........	1	2	14	14	4	4	4	16	2	11	7	11	5	9	5	11	6	9	6	10	3	8	15	4
1859........	0	0	12	19	0	5	11	12	3	9	8	11	2	11	7	10	6	10	10	5	1	14	5	10
1860........	3	0	11	17	1	5	9	14	3	3	14	11	5	9	6	10	2	12	10	7	5	9	9	7
1861........	4	4	8	15	4	6	9	9	8	3	13	7	8	6	10	6	5	2	15	9	4	6	11	9
1862........	13	2	6	10	9	2	7	10	11	5	8	7	16	2	6	6	14	6	7	4	4	7	13	6
1863........	8	4	12	7	8	4	7	9	10	4	7	10	15	4	4	7	5	4	10	12	5	14	0	11
1864........	5	3	11	12	4	0	6	19	8	3	7	13	14	3	3	10	8	0	12	11	12	4	8	6
1865........	6	2	7	16	8	7	7	6	4	4	11	12	5	5	9	11	9	6	10	6	2	10	14	5
1866........	9	3	9	10	6	4	5	13	6	5	5	15	4	9	6	11	8	2	10	11	2	4	11	13
1867........	7	6	5	13	6	3	12	7	5	6	4	17	6	7	4	13	11	10	5	5	6	12	9	3
1868........	8	4	4	15	8	2	10	9	7	5	15	4	4	8	7	11	7	10	5	9	3	13	8	6
1869........	6	4	11	10	5	6	4	13	5	0	12	14	2	3	6	19	12	5	8	6	5	5	10	10
Means..	5.2	3.1	9.0	13.6	5.9	3.6	7.5	11.3	3.9	5.5	8.2	11.7	7.7	6.3	6.1	9.3	7.4	8.1	7.9	7.3	4.8	8.6	10.1	6.6
Least...	0	0	4	7	0	0	2	2	2	0	3	4	2	2	2	2	2	0	5	0	1	3	0	3
Greatest.	13	6	14	19	14	7	12	19	11	11	15	18	16	11	11	19	14	17	15	12	12	14	15	13

TABLE II. (1.)—*Continued.*

NUMBER OF DAYS IN EACH MONTH IN WHICH THE PREVAILING WINDS CAME FROM EACH OF THE FOUR QUARTERS OF THE HORIZON.

The figures 1, 2, 3, and 4 indicate the quarters, as follows:—1. N. N. E.; 2. E. S. E.; 3. S. S. W.; 4. W. N. N. W.

YEARS.	JULY.				AUGUST.				SEPTEMBER.				OCTOBER.				NOVEMBER.				DECEMBER.				FOR THE YEAR.			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1850..........	2	5	20	4	9	13	7	2	8	7	7	8	9	3	7	12	8	3	10	9	12	2	5	12	92	62	104	107
1851..........	7	6	13	5	20	1	7	3	11	8	8	3	9	4	8	10	4	6	8	12	7	3	3	18	105	61	93	107
1852..........	10	6	11	4	7	15	4	5	10	9	5	6	8	5	8	10	7	4	8	11	1	8	9	13	82	83	82	119
1853..........	6	8	8	9	3	9	13	6	7	10	8	5	3	10	7	11	9	4	9	8	4	4	10	13	68	83	96	117
1854..........	4	6	13	8	4	13	11	3	6	10	10	4	3	13	6	9	1	1	8	20	4	4	8	15	58	89	98	118
1855..........	9	9	10	3	3	14	12	2	8	10	9	3	6	5	12	8	4	11	5	10	4	5	8	14	66	95	110	97
1856..........	3	10	9	9	4	6	12	9	1	6	12	11	3	13	10	5	3	6	7	14	7	6	2	16	46	83	113	126
1857..........	6	7	13	5	6	8	12	5	5	12	10	3	5	11	8	7	5	7	7	11	4	5	13	9	67	97	114	91
1858..........	6	11	9	5	10	5	10	6	3	2	17	8	2	9	11	9	11	2	3	14	2	1	18	10	55	73	119	118
1859..........	5	6	14	6	7	6	9	9	6	5	6	13	5	5	7	14	5	8	9	8	5	4	8	14	45	84	102	131
1860..........	1	10	10	10	4	14	4	9	7	10	4	9	7	8	9	7	3	8	5	14	9	2	3	17	47	80	95	129
1861..........	6	13	7	5	5	8	12	6	6	12	12	8	13	11	3	4	5	3	5	17	6	0	14	11	74	74	118	106
1862..........	2	13	12	4	1	6	20	4	2	7	11	10	4	4	13	10	10	1	4	15	8	4	7	12	94	59	114	98
1863..........	18	6	4	3	1	9	11	10	7	4	13	6	5	2	9	15	7	2	5	16	7	9	7	8	96	64	89	114
1864..........	3	8	11	9	3	11	11	6	5	8	12	5	9	2	7	13	4	6	10	10	2	8	7	14	77	56	105	128
1865..........	7	5	10	9	4	5	14	8	4	4	16	6	9	3	8	11	3	12	8	7	10	5	3	13	71	68	116	110
1866..........	0	6	20	5	2	10	9	10	7	10	3	10	4	11	4	12	7	9	6	8	9	8	4	14	63	78	93	132
1867..........	3	10	16	2	3	5	17	6	7	3	14	5	6	6	9	10	5	5	10	10	4	8	9	10	69	80	114	102
1868..........	2	12	15	2	4	8	14	5	3	5	12	10	8	7	6	10	3	3	8	16	8	5	7	11	65	82	111	108
1869..........	2	10	15	4	8	8	11	4	2	7	11	10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Means.......	5.1	5.8	12.0	5.5	5.4	8.7	11.0	5.9	5.7	6.9	10.0	7.2	6.2	6.9	8.0	9.8	5.4	5.7	7.1	12.2	5.9	4.7	7.6	12.9	70	76	105	114
Least.......	0	5	4	2	1	1	4	2	1	2	4	3	2	2	4	5	1	1	3	8	2	0	2	8	46	56	82	91
Greatest.....	18	13	20	10	20	15	17	10	11	12	16	11	13	13	13	15	11	12	10	20	12	9	18	18	105	97	119	132

In this Table II. (1), are given the number of days in each month in which the prevailing *Winds* came from each of the four principal points of the compass. The first column (1), including the winds from the N. and N. E.; the second (2), those from the E. and S. E.; the third (3), the S. and S.W. winds; and the fourth (4), the W. and N. N.W. winds. At the bottom of the columns is shown the greatest, least, and mean number, and the last right hand column the *total* number of days for the year. Of the direction of the wind for the year they blew seventy days from the N. N. E.; seventy-six from the E. S. E.; one hundred and five from the S. S. W., and one hundred and fourteen from the W. N. N.W., or one hundred and forty-six days from an easterly direction, and two hundred and nineteen days from a westerly direction.

TABLE II. (2.)

WINDS OF THE SEASONS.—(1850-69.)

SEASONS.	DIRECTION OF THE WIND.				MONTH NEAREST MEAN OF SEASONS.			
	1.	2.	3.	4.	1.	2.	3.	4
Spring..........	19.0	19.9	22.2	28.8	April	April	March	April
Summer.........	15.3	23.1	33.1	18.0	July	July	August	June
Autumn.........	17.3	19.5	25.1	29.2	September	September	October	October
Winter..........	17.0	11.4	24.1	37.8	December	December	December	December
Year.........	17.5	19.0	26.2	28.5				

Table II (2) gives the winds for the seasons, the average number of days in which they blew from the four quarters of the horizon, with the month furnishing the number from the same direction nearest corresponding thereto.

In the Spring, the winds of April correspond with nearly to those of each of the quarters of the horizon; for the Summer, June; for the Autumn, October, and for the Winter, those of December.

The same results are herewith plainly exhibited in Diagrams C and D, of Table II (3), the former showing the relative frequency for the year; the latter for the Summer, (June, July and August) in the full curve; and for Winter, (December, January and February, of the same year, in the dotted curve.

TABLE III. (1.)

NUMBER OF DAYS OF RAIN AND SNOW FOR EACH OF THE MONTHS.

YEARS.	JAN.		FEB.		MAR.		APRIL.		MAY.		JUNE.		JULY.		AUG.		SEPT.		OCT.		NOV.		DEC.		FOR THE YEAR.	
	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.
1839	4	4	3	1	8	2	9	0	10	...	11	...	6	...	8	...	5	...	14	0	3	2	2	9	83	18
1840	3	7	3	4	4	3	9	0	13	...	13	...	11	...	11	...	10	...	5	0	2	1	0	1	84	17
1841	2	1	1	6	8	1	8	1	8	...	10	...	10	...	8	...	10	...	7	1	5	4	5	3	82	17
1842	2	3	4	4	6	1	7	0	6	...	8	...	8	...	3	...	7	...	2	0	3	7	1	5	57	20
1843	2	2	1	4	0	6	7	2	9	...	7	...	6	...	7	...	11	...	3	4	3	6	5	1	61	25
1844	7	5	3	1	9	3	9	0	9	...	15	...	9	...	7	...	6	...	5	1	4	2	2	2	84	14
1845	2	2	5	2	4	2	8	0	3	...	6	...	8	...	4	...	8	...	3	0	1	2	1	5	53	13
1846	1	4	1	2	6	2	11	0	9	...	7	...	9	...	5	...	8	...	6	3	5	2	4	4	72	17
1847	0	5	2	5	4	2	5	1	8	...	6	...	5	...	8	...	2	...	6	1	6	4	2	3	54	21
1848	4	1	3	2	4	2	2	0	10	...	7	...	14	...	15	...	4	...	9	0	1	7	1	6	74	12
1849	3	4	2	2	5	1	11	0	12	...	9	...	5	...	11	...	5	...	5	0	7	0	2	7	77	14
1850	5	3	2	0	4	3	7	2	4	...	7	...	9	...	11	...	9	...	4	0	8	2	2	3	72	13
1851	1	1	6	4	4	3	8	2	17	...	21	...	15	...	8	...	6	...	7	0	3	6	5	4	101	20
1852	3	5	2	0	11	3	11	0	7	...	6	...	6	...	4	...	8	...	9	0	3	6	3	7	73	21
1853	2	2	2	3	2	1	10	0	10	...	9	...	11	...	5	...	7	...	1	1	6	3	0	3	65	13
1854	0	3	3	4	6	1	6	0	13	...	2	...	10	...	7	...	8	...	11	0	3	2	2	2	71	12
1855	2	2	0	5	5	4	4	0	5	...	10	...	8	...	6	...	13	...	6	1	9	2	6	5	74	20
1856	0	4	1	7	1	6	4	0	12	...	4	...	9	...	4	...	3	...	7	0	10	2	8	5	66	21
1857	0	6	9	2	3	4	5	2	9	...	7	...	4	...	11	...	8	...	7	0	10	3	7	2	80	19
1858	6	0	0	3	6	0	11	1	21	...	6	...	16	...	8	...	7	...	13	0	11	8	5	3	111	15
1859	4	2	2	7	11	5	12	4	10	...	13	...	7	...	4	...	7	...	4	1	9	1	3	6	80	26
1860	1	4	4	4	5	2	8	0	9	...	6	...	11	...	8	...	10	...	4	0	2	4	1	7	69	21
1861	1	5	3	7	6	3	7	0	11	...	2	...	3	...	6	...	14	...	6	0	4	4	3	3	66	22
1862	1	14	1	5	6	4	12	1	6	...	4	...	4	...	7	...	8	...	8	0	2	5	6	2	65	31
1863	9	3	11	5	3	2	7	0	10	...	3	...	2	...	7	...	6	...	8	2	5	3	2	6	74	21
1864	3	2	2	1	9	7	15	0	9	...	9	...	6	...	8	...	10	...	9	1	8	2	4	7	92	20
1865	0	3	8	5	3	7	13	1	7	...	12	...	13	...	5	...	11	...	11	3	2	0	1	5	68	24
1866	3	8	1	7	3	5	7	1	7	...	12	...	7	...	11	...	13	...	8	0	3	1	4	4	79	26
1867	0	6	2	5	2	10	7	0	13	...	12	...	9	...	6	...	6	...	5	1	3	1	1	5	66	28
1868	2	4	1	2	9	2	9	2	15	...	5	...	6	...	6	...	13	...	3	0	6	3	1	8	76	21
1869	3	3	5	10	5	7	8	2	7	...	15	...	14	...	15	...	6	...	2	0	4	8	...	...	...	...
Greatest	9	14	11	10	11	10	12	4	17	...	21	...	15	...	15	...	14	...	14	3	11	8	8	9	111	28
Least	0	0	0	0	0	0	2	0	3	...	2	...	2	...	3	...	2	...	1	0	1	0	0	1	54	12
Mean	2.4	3.8	3.0	3.8	5.2	3.3	7.3	0.7	9.6	...	8.5	...	8.5	...	7.5	...	7.9	...	6.5	0.7	4.9	3.1	2.6	4.4	74.3	19.4

DIAGRAM A.

Showing variation in the annual mean temperature during 31 years 1839–1868.

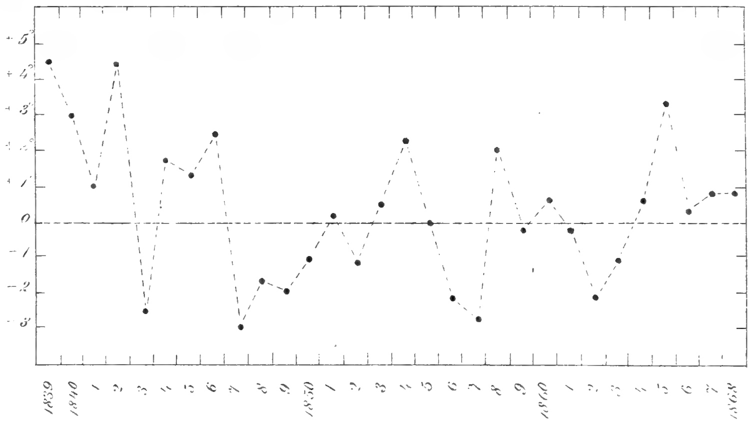


DIAGRAM B.

Showing the extreme means of Monthly temperature.
The full (central) curve shows the annual (monthly) fluctuation of temperature.

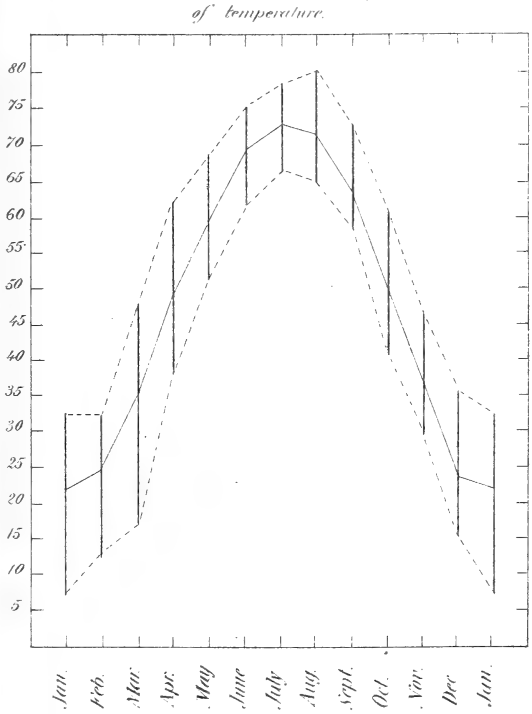


DIAGRAM C.

Showing the relative frequency of each Wind throughout the year.
1850 1869

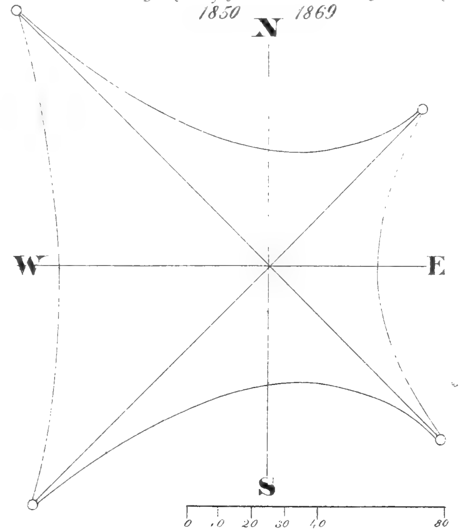
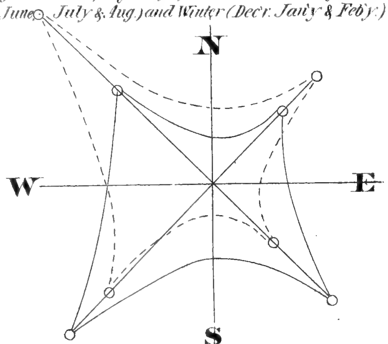


DIAGRAM D.

Showing the relative frequency of each Wind *during Summer (June, July & Aug.) and Winter (Dec'r. Jan'y & Feb'y.)*



The full line for Summer, the dotted one for Winter.

DIAGRAM E.

Showing the relation of Rain *to the direction of the* Wind *throughout the year.*

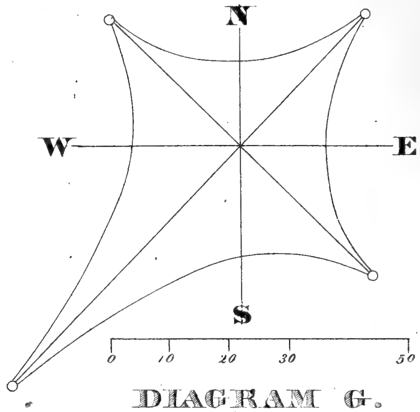


DIAGRAM F.

Showing the relation of Rain *to the direction of the* Wind *during the Summer (Mar–Aug) & Winter (Sept–Feb'y)*
(Dotted lines for Winter & full lines for Summer.)

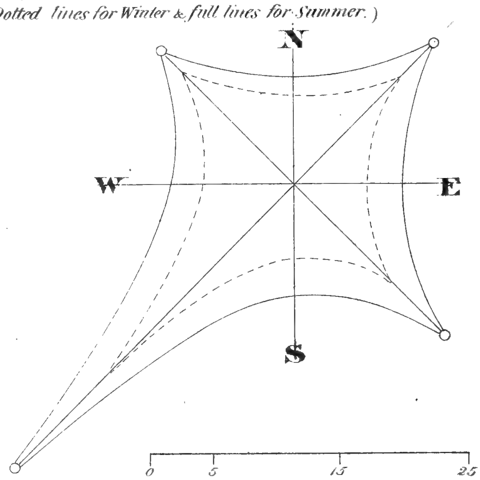


DIAGRAM G.

Showing the distribution of Rain *throughout the* Season

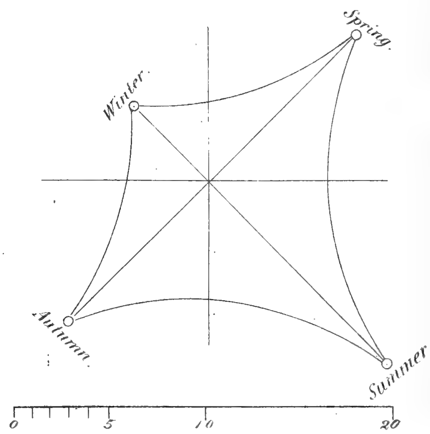


DIAGRAM H.

Showing the relation of Clear Weather *to the direction of the wind throughout the year (1850 – 1869)*

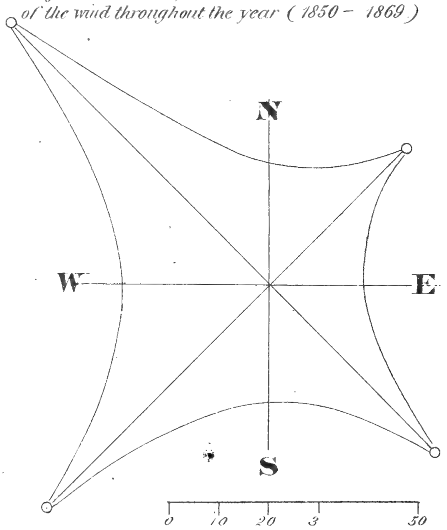
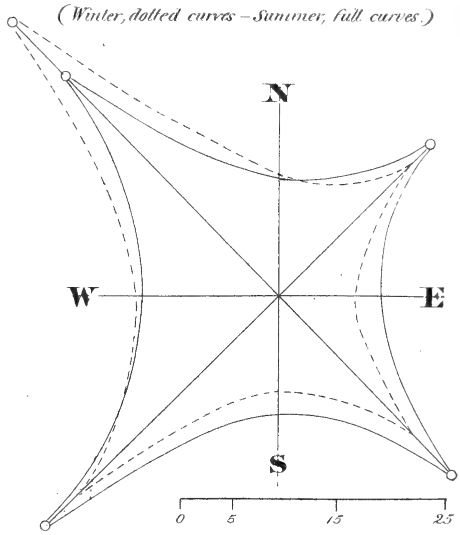


DIAGRAM I.

Showing the relation of Clear Weather *to the direction of the wind during Summer (Mar.–Aug.) and Winter (Sept. – Feb'y.)*
(Winter, dotted curves – Summer, full curves.)



The *Rain* and *Snow*, number of days each falling in each month, is given in Table III (1) for the same period as first given—31 years—to which is added the same for the year, as also the greatest, least, and average number of days upon which each fell during each month of the year.

No snow has fallen in either of the months of May, June, July, August, and September, while there is generally less or more rain in each month of the year.

TABLE III. (2.)

MONTHLY AND ANNUAL QUANTITY OF RAIN AND SNOW, REDUCED TO WATER IN INCHES.

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	For year.
1848	1.20	1.60	2.10	.70	3 40	2.50	5.70	9.10	3.00	4.30	1 40	1.29	26.29
1849	2.82	1.30	2.41	4.70	4.70	12.20	1.40	12.20	5.00	4.80	6 60	1.14	59.27
1850	4.62	.80	2.08	3.30	3.70	3.50	5.00	13 00	3.90	2.70	3.59	2.87	49.06
1851	1.55	5.34	3.03	3 60	12.60	14.30	8.60	14.00	3 50	1.40	3.63	2.95	74.49
1852	2.52	1 00	8.60	5.30	6 50	2.20	3.70	2.80	8.30	7.60	5.76	5.11	59.49
1853	.43	.90	.70	11.80	4.60	6.40	6.60	1.70	6.20	.21	4.92	.32	45.78
1854	.40	1.80	1.22	1.76	6.21	.66	2.22	3.33	1.13	4.22	.19	.51	23.35
1855	1.68	.70	1.87	2.55	1.94	4.75	2.35	3.51	1.84	2.86	2.18	2.15	28 38
1856	.12	4.46	.51	3.44	4.39	2.86	2.74	1.36	2.45	5 21	4.35	6.25	38.17
1857	.61	5.80	3.33	5.09	2.75	.90	4.67	6.00	1.80	1.95	4.77	1.85	39.52
1858	1.60	2.00	2.20	2.00	8.40	6.70	7.30	4.12	6.10	4.90	4.54	1.82	51.28
1859	.94	1.72	5.01	1.05	7.49	5.82	2.93	1.70	1.80	.85	1.53	1.81	32.65
1860	1.17	.43	.55	1.67	1.42	3.66	4.03	2.30	2.76	1.00	2.09	4.02	25.10
1861	.28	3.91	2.30	4.40	2.95	.40	2.70	4.07	9.92	9.16	2.93	2.87	47.89
1862	.29	.38	4.06	5.30	3.65	6.07	3 10	7.30	6.10	2.49	3.29	2.75	44.78
1863	3.40	3.02	2.58	.55	4.56	.21	.80	2.44	4.44	4.10	4.11	3.55	33.75
1864	2.30	.67	5.64	3.97	3.60	5.70	5.00	7.60	2.12	4.55	4.82	1.60	51.57
1865	.30	3.15	3.57	9.31	2.72	6.96	7.30	1.35	3.75	6.35	.25	.33	45.34
1866	4.19	.79	.83	2 92	1.59	4.76	6.55	6.85	6.53	4 61	1.41	2 34	43.37
1867	1.26	4.76	1.90	.95	10.60	3.94	3 94	4.45	4 62	3.06	1.97	.73	42.18
1868	.17	1.51	6.31	4.92	7.20	1.28	6.15	4.67	5.17	.33	4.38	.81	46.00
1869	1.56	2.65	.43	3.16	4.06	7.42	7.42	11.43	3.09	2.07	3.42	....	.....
Mean	1.52	2.21	2.78	3.79	4.95	4.59	4.68	5.69	4.24	3.65	3.27	2.34	44.27
Least	.12	.38	.43	.55	1.42	.21	.80	1.36	1.13	.21	.19	.32	23.35
Greatest	4.19	5.80	8.60	11.80	12.60	14.30	8.60	14.00	9.92	9.16	5.76	6.25	74.49

Table III, (2) shows the quantity of rain and snow, reduced to inches, which has fallen during each of the months and years—from 1848 to 1869—a period of 22 years. The greatest, least, and mean amounts are also given.

The mean amount, 44.27 inches, is greater than meteorologists on the seaboard have been led to expect. The greatest fall 74.49 inches in 1851, and the least, 23.35 inches in 1854, furnish a range of upward of fifty inches. August is the month in which the greatest amount falls, and January the least.

TABLE III. (3.)

MONTHLY AND ANNUAL QUANTITIES OF SNOW IN INCHES.

YEARS.	JAN.	FEB.	MAR.	APR.	OCT.	NOV.	DEC.	FOR THE YEAR.
1848	1.10	.10	2 10	.00	.00	3.51	29.52	36.33
1849	3.22	.32	1.12	.00	.00	.00	4.75	9.41
1850	2.22	.00	.81	.20	.00	.92	3.71	7.90
1851	.50	8.41	.30	6.00	.00	1.30	1.50	18.00
1852	3.20	.00	5.50	.00	.00	30.00	11.40	50.10
1853	1.00	2.00	2.00	.00	.11	8.00	3 .20	16.30
1854	4.00	5.50	1.00	.00	.00	1.00	1.00	12.50
1855	17.50	7.00	6.50	.00	.50	1.50	13.00	46.10
1856	12.20	12.00	.51	.00	.00	5.20	19.00	54.40
1857	6.11	3.00	8.97	5.03	.00	8.50	3.50	35.10
1858	.00	18.00	.00	2.02	.00	5.40	12.01	37.40
1859	.40	4.10	4.00	1.05	.10	2.00	8.10	34.82
1860	17.65	30	.10	.00	.00	6.00	28.00	52.05
1861	18.05	16.75	1.10	.00	.00	3.30	6.25	45.45
1862	24.25	2.75	16.15	.10	.00	5.30	.10	48.65
1863	2.92	8.70	2.34	.00	4.10	2.40	25.00	45.46
1864	3.15	1.10	6.67	.00	1 00	2.10	4.25	18.27
1865	3.15	5.90	3.57	1.00	3.00	.00	2.11	18.73
1866	5.75	5.59	5 20	.10	.00	1.00	12.00	29.64
1867	12.63	27.00	16.00	.00	.11	.13	6.10	61.97
1868	1.12	7.00	1.00	1.00	.00	1.10	8.99	19.33
1869	6.30	12.55	1.60	.20	.00	10.66		... .
Means	6.70	6.73	3.93	.76	.40	4.73	9.21	33.23
Least	.00	.00	.00	.00	.00	.00	.10	7.90
Greatest	24.25	27.00	16.15	6.00	4.10	30.00	29.52	61.97

The monthly and annual quantity of snow is given in table III (3). The greatest fall for a month was December, 1848, 29.52 inches; for the year 1868, 61.97 inches. The least in any year, 1850, when only 7.90 inches fell. The most generally falls in December.

TABLE III. (4.)

RAIN—TOTAL QUANTITY FOR EACH OF THE SEASONS.

YEARS.	SPRING.	SUMMER.	AUTUMN.	WINTER.
1850	9.08	21.50	10.19	8.29
1851	19.23	36.90	8.53	9.84
1852	20.40	8.70	21.66	8 63
1853	16 10	14.70	11.33	1.66
1854	9.14	6.21	5.54	2.71
1855	6.36	10.61	6.88	4.53
1856	8.34	6.96	12.01	10.83
1857	11.17	11.57	8.52	8.26
1858	12.60	18.12	15.34	5.42
1859	13.55	10.45	4.18	3.47
1860	3.64	9.99	5.85	5.62
1861	9.65	7.17	22.01	7.06
1862	13.01	16 47	11.88	3.42
1863	7.69	3.45	12.65	9.97
1864	13.21	18.30	11.49	5.57
1865	15.60	15.61	10.35	3.78
1866	5.34	18.16	12.55	7.32
1867	13.45	12.43	9.65	6.75
1868	18.43	12.10	9 88	2.49
1869	7.65	26.27	8.59	....
Greatest	19.23	36.90	22.01	10.83
Least	6.36	3.45	4.18	1.65
Mean	11.39	14.93	11.22	5.62

The total amount of rain for each of the seasons for twenty years—1850–69—is given in table III (4). Much the largest amount being in the summer, as may be seen from the amounts greatest, least, and means, at the bottom of the table; spring and autumn having the same mean—eleven and one-third inches—while summer is nearly one-third more, and three times as much as during winter.

Illustrating table III (5), we give diagram G, exhibiting the same results in a more visible form.

TABLE III. (5.)

DISTRIBUTION OF RAIN THROUGHOUT THE SEASONS, WINTER, SPRING, SUMMER, AND FALL, 1850-69, A PERIOD OF TWENTY YEARS.

Winter, total, 117.29 inches ; mean, 5.86 inches.
Spring, total, 237.11 inches ; mean, 11.85 inches.
Summer, total, 278.06 inches ; mean, 13.90 inches.
Fall, total, 216.73 inches ; mean, 10.83 inches.

Winter taken as unit, as 1.00, 2.02, 2.38, 1.88.

TABLE III. (6.)

RELATION OF RAIN TO THE DIRECTION OF THE WIND.

YEARS.	SPRING.				SUMMER.				AUTUMN.				WINTER.				FOR THE YEAR.			
	1.	2.	3.	4.	1.	2.	3.	4.	1.	2.	3.	4.	1.	2.	3.	4.	1.	2.	3.	4.
1850 ..	2	1	2	..	4	6	11	1	3	3	8	6	2	2	2	..	11	12	23	7
1851 ..	10	5	5	5	7	2	10	1	2	2	..	3	2	2	3	..	21	11	18	9
1852 ..	5	5	6	..	1	..	5	1	3	3	5	3	1	..	..	..	10	8	15	4
1853 ..	4	3	1	1	2	3	4	..	4	2	3	1	..	..	..	..	10	8	9	2
1854 ..	2	4	2	1	4	4	2	3	2	3	6	2	..	..	..	..	8	21	23	6
1855 ..	4	1	4	1	1	4	11	2	7	7	4	6	..	..	4	1	12	12	23	10
1856 ..	3	2	3	3	1	3	10	1	4	2	9	4	7	3	4	3	15	10	26	11
1857 ..	4	8	6	5	1	6	5	1	2	6	10	2	3	4	10	2	10	24	31	10
1858 ..	6	8	14	7	4	7	17	5	8	6	11	10	2	2	8	..	20	23	50	22
1859 ..	3	12	8	..	3	6	9	6	2	4	14	4	..	2	2	7	8	4	23	17
1860 ..	2	6	11	2	..	10	8	5	3	8	3	3	4	1	4	3	9	25	26	13
1861 ..	5	6	8	4	2	2	3	4	5	5	2	13	1	3	2	..	13	16	15	21
1862 ..	9	2	6	4	3	3	6	3	4	3	5	6	3	2	2	.	19	10	19	13
1863 ..	6	..	8	4	5	1	2	5	2	1	8	6	2	4	7	2	15	6	25	17
1864 ..	11	1	10	5	5	3	11	1	5	6	10	14	2	..	2	2	22	10	33	22
1865 ..	6	5	9	3	3	4	10	10	7	3	8	5	3	3	3	..	19	15	30	18
1866 .	2	7	3	4	..	6	13	7	6	3	6	6	4	..	..	2	12	16	23	19
1867 ..	5	5	8	5	3	5	15	3	3	..	8	3	..	..	3	..	11	10	34	11
1868 ..	7	4	15	7	1	2	10	2	1	2	14	8	3	..	..	..	12	8	39	17
1869 ..	4	5	7	2	5	9	20	5	..	..	..	..	..	..	..	..	...	...	...	...
Mean	5.0	4.5	6.8	3.1	2.7	4.3	9.1	3.3	2.6	3.4	6.7	5.2	1.9	1.4	2.8	1.1	12.8	11.4	26.3	12.4

The relation of rain to the direction of the wind for the year, and also for the seasons from 1850 to 1869, is here given, table III (6). In this table we have sought to enter only the days when any considerable quantity of rain fell, and not all the rainy days. The figures 1, 2, 3, 4, at the head of the column refer, as before, to the principal points of the compass, 1 being N. N. E., etc.

The same results for the seasons and the year arc much more conspicuously seen in the diagrams E and F, table III (7). The former gives the results for the year, the latter for the seasons: Summer, March and August inclusive; and Winter, September and February inclusive of same year—the dotted curve for winter and full curve for summer.

These diagrams show very interesting results. The rains curve during the seasons and during the year accompanied with southwest winds, or, in other words; the rain-winds are from the southwest, the very opposite to the rain-winds of the Atlantic States.

Twenty per cent of the rainy days are accompanied with N. N. E. winds; 18 per cent by E. S. E. winds; 42 per cent by S. S. W. winds, and 19 per cent by W. N. W. winds; or, to sum up, 62 per cent occur in connection with winds from a westerly course.

TABLE III. (8.)

RAIN.

Greatest fall of rain, 10.71 inches, August 10th, 1851—11 P. M., 10th, to 3 A. M., the 11th, 4 hours. Wind N. E. both days.

SNOW.

Earliest—October 17th, 1859.
Latest—April 29th, 1851.
Greatest—December 21st, 1848, 20.50 inches.
December 28th, 1863, 15.10 inches in twelve hours.

Table III (8), furnish brief statistics of rain and snow, the greatest fall of the former, and the earliest, latest, and greatest of the latter.

TABLE IV. (1.)

MONTHLY AND ANNUAL NUMBER OF DAYS IN WHICH THE WEATHER WAS CLEAR, VARIABLE, OR CLOUDY.

YEARS.	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
	Clear.	Variable.	Cloudy.	Clear.	Variable.	Cloudy.	Clear.	Variable.	Cloudy.	Clear.	Variable.	Cloudy.	Clear.	Variable.	Cloudy.	Clear.	Variable.	Cloudy.
1850	4	18	9	8	20	0	6	19	6	3	22	5	7	20	4	6	22	2
1851	3	23	5	6	17	5	11	18	2	7	19	4	8	20	3	4	20	6
1852	6	18	7	10	15	4	5	17	9	5	16	9	10	20	0	9	21	0
1853	11	18	2	6	16	6	14	11	6	9	12	9	10	16	5	12	16	2
1854	12	14	5	9	12	7	8	15	8	9	16	5	9	16	6	9	20	1
1855	15	6	10	20	4	4	8	16	7	9	17	4	12	15	4	8	18	4
1856	10	8	7	5	20	4	9	20	2	4	20	6	9	16	6	10	18	2
1857	13	12	6	3	12	13	8	16	7	5	21	4	12	13	6	11	15	4
1858	19	7	5	18	7	3	15	10	6	7	16	7	6	6	19	11	10	9
1859	12	17	2	10	10	8	5	16	10	8	13	9	12	13	6	8	16	6
1860	14	13	4	18	7	4	20	8	3	11	13	6	8	18	5	15	12	3
1861	11	10	10	8	13	7	8	15	8	8	14	8	11	15	5	12	15	3
1862	3	14	14	10	11	7	4	14	13	5	7	18	12	10	9	13	9	8
1863	7	14	10	5	12	11	11	14	6	13	9	8	9	15	7	11	15	4
1864	12	12	7	15	11	3	8	14	9	3	18	9	15	11	5	7	20	3
1865	6	21	4	6	11	11	9	12	10	7	14	9	7	19	5	5	20	5
1866	11	11	9	9	9	10	3	20	8	8	14	8	8	17	6	7	18	5
1867	8	14	9	8	12	8	8	10	13	13	10	7	7	15	9	7	16	7
1868	10	15	6	8	14	7	10	10	11	3	19	8	5	20	6	15	12	3
1869	9	7	15	6	7	15	6	15	10	3	19	8	8	14	9	5	15	10
Means	9.8	13.6	7.3	9.4	12.0	6.8	8.5	14.6	7.7	7.0	15.3	7.3	9.2	15.3	6.4	9.2	16.4	4.2
Least	3	6	2	3	4	0	3	8	2	3	7	4	5	6	0	4	9	0
Greatest	19	23	15	20	20	15	20	20	13	13	22	18	15	20	19	15	22	10

TABLE IV. (1.)—*Continued.*

MONTHLY AND ANNUAL NUMBER OF DAYS IN WHICH THE WEATHER WAS CLEAR, VARIABLE, OR CLOUDY.

YEARS.	JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.			FOR THE YEAR.		
	Clear.	Variable.	Cloudy.	Clear.	Variable.	Cloudy.	Clear.	Variable.	Cloudy.	Clear.	Variable.	Cloudy.	Clear.	Variable.	Cloudy.	Clear.	Variable.	Cloudy.	Clear.	Variable.	Cloudy.
1850	7	24	0	3	23	5	5	23	2	6	23	2	5	19	6	1	23	7	61	256	48
1851	12	15	4	6	20	5	10	13	7	12	12	7	3	18	9	6	17	8	88	213	61
1852	14	16	1	11	16	4	17	12	7	7	13	11	1	10	19	0	13	18	89	187	89
1853	11	17	3	15	16	0	13	11	6	14	13	4	5	16	9	11	13	7	131	172	59
1854	9	18	4	14	13	4	12	13	5	9	17	5	10	16	4	13	12	6	121	182	63
1855	10	18	3	7	19	5	4	17	9	9	13	9	8	13	9	7	15	9	117	171	77
1856	15	14	2	12	14	5	13	12	5	8	15	8	6	13	11	6	14	11	115	184	69
1857	18	10	3	6	22	3	10	15	5	12	11	8	8	15	7	12	10	9	118	172	75
1858	6	6	19	15	10	6	20	6	4	9	8	14	4	7	19	14	7	10	144	91	130
1859	12	15	4	15	12	4	14	11	5	19	7	5	10	13	7	14	9	8	139	152	74
1860	10	15	1	15	11	5	7	18	5	12	15	4	8	18	4	10	16	5	148	164	54
1861	11	15	5	9	17	5	8	8	14	13	10	8	4	15	11	10	13	8	113	160	92
1862	15	11	5	10	15	6	13	7	10	15	10	6	9	10	7	12	7	12	121	125	119
1863	16	10	5	13	11	7	15	9	6	5	16	10	8	17	5	5	11	15	118	153	94
1864	16	11	4	10	14	7	9	15	6	8	12	11	7	14	9	7	16	8	117	168	81
1865	12	13	6	8	10	3	7	19	4	9	10	12	16	11	3	16	10	5	118	170	77
1866	14	12	5	9	15	7	10	10	10	11	15	5	6	15	9	12	11	8	108	167	90
1867	10	18	3	16	12	3	12	12	6	12	13	6	12	13	5	7	14	10	120	159	86
1868	12	15	4	13	13	5	10	10	10	10	13	8	10	5	15	9	13	9	115	159	92
1869	10	11	10	7	15	9	10	14	6	14	14	3	6	15	9	....	....	....	....	....	....
Mean	12.3	14.2	4.5	10.7	14.9	4.7	10.7	13.3	6.6	10.5	12.9	7.5	7.3	13.5	8.8	9.0	12.9	91	116	169	80
Least	6	6	0	3	10	0	5	6	2	5	7	2	1	7	3	0	7	5	61	91	48
Greatest	11	24	19	16	23	7	20	23	14	19	23	14	16	19	19	16	23	18	148	256	130

TABLE IV. (2.)

RELATION OF CLEAR WEATHER TO THE DIRECTION OF THE WIND.

YRS.	SPRING.				SUMMER.				AUTUMN.				WINTER.				FOR THE YEAR.			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1850	11	5	3	5	4	7	4	..	2	9	6	9	5	5	5	5	22	26	18	19
1851	5	5	2	1	10	6	1	3	6	7	4	3	6	8	7	2	27	26	14	9
1852	2	7	3	3	5	5	2	..	11	10	9	7	8	7	6	9	26	28	19	19
1853	9	8	5	2	2	3	4	1	9	4	6	1	7	4	8	2	26	20	23	6
1854	8	8	4	8	2	12	13	3	4	10	4	11	5	4	3	15	16	34	24	37
1855	9	11	6	4	7	9	9	4	4	7	8	3	4	3	8	22	24	30	31	29
1856	4	9	6	8	5	12	14	12	2	9	11	4	..	4	4	20	11	34	35	44
1857	1	1	11	16	7	5	4	10	8	5	17	6	3	7	12	7	19	18	44	39
1858	4	8	15	18	5	7	12	4	5	2	15	13	2	3	23	27	16	30	75	62
1859	1	5	11	8	6	12	10	7	10	4	10	16	1	1	13	20	8	22	44	51
1860	2	7	11	20	4	13	3	12	3	7	5	6	4	4	15	19	13	31	39	57
1861	6	..	11	6	4	5	13	7	6	7	7	5	2	2	10	15	18	14	41	33
1862	7	6	5	3	..	11	19	7	3	7	10	20	6	..	6	13	16	24	40	43
1863	8	6	6	16	8	14	10	8	6	4	6	10	1	3	5	5	25	27	27	39
1864	7	1	7	11	5	9	10	10	6	3	6	10	2	..	15	20	20	13	38	51
1865	2	2	10	13	5	7	15	11	4	7	12	13	6	2	6	16	17	18	43	53
1866	5	2	4	7	..	8	8	12	3	12	1	8	5	2	5	16	13	24	18	47
1867	5	9	10	25	4	6	14	4	4	2	14	11	3	2	8	10	16	19	46	50
1868	5	3	4	3	3	10	17	3	2	5	4	15	4	2	5	15	14	20	30	36
1869	3	1	4	12	9	6	5	2	..	..	..	..	..	..	..	...	..	..	..	..
Mean	5.1	5.2	6.4	9.3	4.7	8.3	9.5	5.9	4.9	6.0	7.7	8.5	2.7	2.1	8.0	13.1	17.5	22.9	32.3	364

The *Weather*, as to its character of Clear, Variable, and Cloudy Days is given in Table IV (2), for each month and also the year.

This Table is introduced that it may be seen which relation the Clear and Cloudy Days bear to the whole number. The Clear Days are 32 per cent; Variable, 46 per cent; and the Cloudy, 22 per cent of the whole number.

The relation of clear weather to the direction of the wind for the seasons and the year, is given in Table IV. (2.)

For the year, the mean number of clear days in twenty years are distributed as follows:

17.5 occurs where the wind is N. N. E.
22.9 occurs when the wind is E. S. E.
32.3 occurs when the wind is S. S. W. and
26.4 occurs when the wind is W. N.W.

By comparing this table with that exhibiting the relation of rainy days to the direction of the wind, we shall see that the greatest number of rainy days occur when the wind is S. S.W., while the clear days occur when it is W. N W.

In the diagrams H and I, we have the same results in the more visible form. That of H for the year, and I for the seasons, the full curve for summer and dotted curve for winter, including the months of September and February; while summer includes those of March and August. The greater number of clear days are accompanied by winds from the W. and N. W., while the S. and S. W. winds furnish the next greatest division notwithstanding this is the quarter from whence comes the rains.

TABLE V.

FROST AND ICE—EARLIEST AND LATEST OF THE SEASON, DISAPPEARANCE FROM THE GROUND, ETC., ETC.

YEARS.	FROST.				ICE.		
	Latest.	Earliest.	Disap-pe'rance.	Depth—inches.	Latest.	Earliest.	Inches thick.
1839	April 17	Sept. 12	....	....	Mar'h 25	Nov. 7	....
1840	April 27	Sept. 28	....	....	April 18	Oct. 3	....
1841	April 12	Sept. 11	....	....	April 14	Oct. 17	....
1842	May 4	Sept. 17	....	....	April 28	Oct. 19	....
1843	May 2	Oct. 8	....	....	May 1	Oct. 8	....
1844	May 21	Oct. 10	....	....	Mar'h 30	Oct. 16	....
1845	May 25	Sept. 21	....	.	April 8	Oct. 5	....
1846	April 15	Oct. 2	....	....	April 13	Oct. 18	....
1847	May 26	Oct. 9	....	....	May 4	Oct. 14	....
1848	May 10	Sept. 23	....	....	April 26	Oct. 1	....
1849	May 1	Oct. 8	....	....	April 20	Oct. 13	....
1850	April 23	Sept. 7	....	....	April 23	Sept. 29	....
1851	May 5	Sept. 28	....	....	May 1	Oct. 15	....
1852	May 20	Sept. 26	....	....	April 22	Sept. 26	...
1853	May 25	Sept. 10	....	...	May 13	Oct. 2	....
1854	May 2	Oct. 15	....	...	May 2	Oct. 15	....
1855	May 6	Sept. 27	....	....	May 6	Oct. 25	....
1856	April 19	Sept. 24	April 10	29	April 19	Sept. 24	27
1857	May 20	Oct. 14	May 5	14	May 12	Oct. 20	12
1858	April 26	Sept. 12	April 1	12	April 16	Oct. 7	10
1859	April 23	Sept. 2	April 1	11	April 23	Oct. 6	10
1860	May 1	Sept. 11	Mar'h 20	11	April 2	Oct. 24	11
1861	May 4	Oct. 23	Mar'h 12	20	April 16	Sept. 24	21
1862	April 24	Oct. 11	April 1	20	April 6	Oct. 25	20
1863	*Aug. 25	Aug. 29	April 2	18	April 8	Oct. 7	20
1864	May 11	Sept. 19	April 17	18	April 14	Oct. 18	20
1865	May 11	Oct. 2	April 10	20	April 6	Oct. 15	18
1866	May 2	Sept. 21	May 7	20	April 6	Oct. 31	24
1867	May 6	Oct. 23	May 23	18	April 6	Nov. 4	18
1868	April 5	Sept. 17	April 15	20	April 8	Nov. 1	22
1869	May 19	Sept. 26	April 7	21	April 13	Oct. 13	20
Latest	May 26	Oct. 23	May 23	29	May 13	Nov. 7	27
Earliest	April 5	Aug. 29	Mar'h 12	11	April 2	Sept. 24	10
Mean	May 4	Sept. 24	April 10	18	April 18	Oct. 15	18

*1863—Frost every month in the year; the last hard frost, April 13th.

The year 1863 was a peculiarly cold year. Frost occurred each month, and for comfort as well as health, it was necessary to keep up fire occasional each month, July not accepted. October was very cold, more so than this month of 1869. The mean time for late frost is May 4th; early in the fall, September 24th. The latest in the spring was May 26th, 1847, the earliest, August 29th, 1863.

It has happened but once or twice in the last thirty years that the frost has, over a great extent, seriously injured the corn crop. When the spring is late, the fall is either quite hot or lengthened so as to afford the crop to mature.

TABLE VI.

FLOWERING OF FRUIT TREES—1848-69.

YEARS.	APPLE.	PEACH.	CHERRY.	PLUM.	PEAR.	QUINCE.
1848	April 23	April 16	April 18	April 21	....	....
1849	May 3	May 5	May 2	May 4	....	....
1850	May 3	May 1	May 1	May 4	....	....
1851	May 3	May 1	May 1	April 29	....	....
1852	May 10	May 10	May 5	May 1	May 5	....
1853	May 4	April 30	May 1	May 3	May 3	May 5
1854	April 24	April 20	April 22	April 21	April 20	April 24
1855	April 29	May 1	May 1	May 10	May 1	May 10
1856	May 12	May 10	May 9	May 12	May 15	....
1857	....	....	....	....	....	....
1858	....	....	....	....	....	....
1859	May 4	May 2	April 30	April 30	May 2	May 8
1860	....	....	....	....	....	....
1861	May 1	April 25	....	April 23	April 24	....
1862	May 12	....	....	May 6	May 9	....
1863	May 3	May 1	April 27	April 30	May 1	May 10
1864	May 10	May 8	May 4	May 7	May 8	May 17
1865	May 3	May 1	April 27	May 1	May 1	May 10
1866	May 24	May 20	May 17	May 14	May 16	May 25
1867	May 18	May 13	May 14	May 12	May 15	....
1868	May 10	May 7	May 6	May 4	May 9	....
1869	May 5	....	April 30	May 3	May 4	....
Mean	May 6	May 3	May 2	May 2	May 5	May 10
Earliest	April 23	April 16	April 18	April 21	April 20	April 24
Latest	May 24	May 20	May 17	May 14	May 16	May 25

The foregoing table may prove of interest and value to the horticulturist. The peach is winter-killed to such an extent as to prove valueless. The mean time for late frosts being May 4th, and the mean time of the flowering of fruit trees being May 5th, it will be seen that the young buds are often injured in the spring and a partial loss occurs. Nevertheless, experience has proved that in many localities, with many varieties of fruits, Iowa is fast becoming a fruit-growing State.

TABLE VII.

MISSISSIPPI RIVER AT MUSCATINE—TIMES OF OPENING AND CLOSING AND NUMBER OF DAYS CLOSED.

YEARS.	OPENED.	CLOSED.	NUMBER OF DAYS CLOSED CONSECUTIVELY DURING YEAR.	
1838....	March 24..................	January 30................	53	......
		December 4	......	80
1839....	February 20.............	....	78	51
1840....	February 29..............	January 15................	45	......
		December 31	......	45
1841....	March 1..................	December 27	60	63
1842....	February 28	November 27.............	62	93
1843....	April 8	....	*133	99
1844....	February 23..............	January 24................	31	......
		December 27	......	35
1845....	February 18	December 1................	52	79
1846....	January 29	....	60	29
1847....	March 19..................	January 6.................	72	......
		December 15	......	88
1848....	February 16..............	December 15	63	63
1849....	March 13..........	December 17	88	86
1850....	February 19..............	....	64	50
1851....	February 21.............	January 30................	22	......
		December 16...............	......	37
1852....	February 24..............	November 18..............	70	98
1853....	February 25..............	December 31..............	99	56
1854....	March 1..................	....	60	60
1855....	March 7......	January 22................	44	......
		December 25...............	......	50
1856....	March 29..................	December 6................	94	113
1857....	February 27..............	November 25..............	83	......
	November 30	....	*5	63
1858*...				
1859....	February 21..............	January 7......	45	......
		December 8................	......	68
1860....	February 28..............	December 15	82	75
1861....	March 2..................	December 28	77	64
1862....	March 25..................	....	87	......
	December 13	December 7................	6	90
1863....	February 18..............	February 6................	12	......
		December 18...............	......	25
1864....	March 4..................	December 7................	77	87
1865....	March 1..................	December 13...............	83	77

* The river did not close over.—Open.

TABLE VII—*Continued.*

MISSISSIPPI RIVER AT MUSCATINE—TIMES OF OPENING AND CLOSING AND NUMBER OF DAYS CLOSED.

YEARS.	OPENED.	CLOSED.	NUMBER OF DAYS CLOSED CONSECUTIVELY DURING YEAR.	
1866....	March 9..................	December 18..............	85	81
1867....	April 1....................	December 18..............	103	103
1868....	March 9..................	December 25..............	81	74
1869....	February 15..............	March 8..................	52	......
	March 23.................	....	15	......
Latest..	April 8....................	February 6...............	133	113
Earliest	November 30.............	November 18..............	5	25
Mean...	February 26..............	December 23..............	67	67

This Table of the time of opening and closing of the Mississippi river, is introduced both to show the length of the winter; and also to afford useful information to the shipper, as this river must continue to become, more and more, the great outlet for the surplus produce of the State.

Boats generally continue to run till near the time of closing, and always commence as soon as opened.

The average time of closing is December 23d, of opening, February 26th; and the mean number of days closed is 67, or but little over two months.

PART II.

GENERAL GEOLOGY.

EXPLANATORY REMARKS.

The outline of surface occupied by each formation or group is indicated upon a geological map accompanying this report, with as much precision as it has been practicable to attain, and to illustrate upon so small a map. The Drift Deposit of Iowa is so deep, especially in its northern and northwestern parts, and has there so completely hidden the underlying strata from view, that it has been found impossible to lay down upon the map the exact boundaries of each formation or group which exists in that part of the State. Therefore, in the preparation of this map, those boundaries alone are indicated concerning the correctness of which little or no doubt is felt, while the large stoneless region referred to in Part I, is left uncolored.

Three general sections, constructed upon lines, traversing the State in different directions, also accompany the map. That part of those sections which traverses the stoneless region is given in dotted lines, to show that doubt exists as to the real position of the formations there.

In the preparation of the map-model which accompanies Part I, and which is intended for purposes of general illustration only, the sheets are cut for the northern and northwestern part of the State as, after considering all the evidence it has been possible to obtain, the formations are believed to exist there.

The original plan for parts II and III, contemplated a careful identification and record of every species of fossils found in each stratum of every section made in the prosecution of the field-work, to be embodied in the text. For want of time this work was carried no farther than to leave no doubt in the mind of the writer as to the correctness of the deductions drawn from the observations made and here presented.

CHAPTER I.

AZOIC, LOWER SILURIAN, UPPER SILURIAN, AND DEVONIAN SYSTEMS.

Although the labors of the Geological Survey, since its present organization, have been principally confined to the western half of the State, a general examination has also been made of the formations of the eastern half. Therefore, a general review of all the formations in the State will be given in this and following chapters; but more especial attention will be paid to those which belong to or overlie the Carboniferous system.

The stratified rocks of Iowa range from the Azoic to the Mesozoic inclusive, but the greater portion of the surface of the State is occupied by those of Palæozoic age. The accompanying section of the rocks of Iowa, show each of these formations in their order, together with the method of their classification adopted in this report.

1. AZOIC SYSTEM.

HURONIAN (?) GROUP.

THE SIOUX QUARTZITE.

Area and General Characters. This formation is found exposed in natural ledges only upon a few acres in the extreme northwest corner of the State. Its area being so small in Iowa, it could not be conveniently represented on the map-model in another part of this volume, but its position is shown on the larger geological map. The exposures in Iowa are found principally upon the banks of the Big Sioux river, for which reason the specific name of Sioux Quartzite has been given to it.

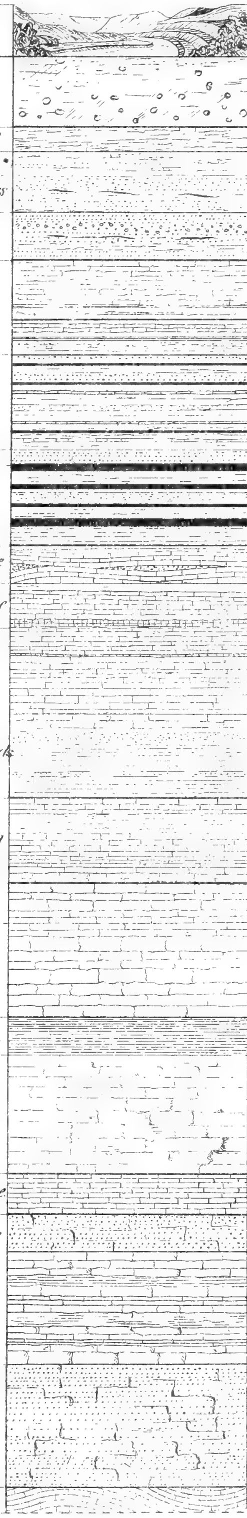
It is an intensely hard rock, breaking with a splintery fracture, and a color varying in different localities from a bright to deep red. Although it is so compact and hard the grains of sand of which it was originally composed are yet distinctly to be seen, and even the ripple marks upon its bedding surfaces are sometimes found as distinct as they were when the rock was a mass of incoherent sand in the shallow waters in which it was accumulated. The lines of stratification are also quite distinct, but they are not usually sufficiently definite to cause the mass to divide into numerous layers. It has, however, a great tendency to break up by vertical cracks and fissures into small angular blocks. The process of metamorphism has been so complete throughout the whole formation that the rock is almost everywhere of uniform texture, and its color also being so nearly uniform there is no difficulty in identifying it wherever it may be seen.

The exposures of this rock, at the localities named, occupy the surface over a number of acres. It also forms some bold fronts by the side of the stream, and causes a slight fall in the river just where the northern boundary line of the State meets it. The dip is distinctly perceptible to the eye, being some four or five degrees to the northward, and the trend of the outcrop is eastward and westward. Although no other kind of rocks, in place, are seen within many miles of this locality, there is little doubt that the friable rocks of Cretaceous age, which appear farther down the Big Sioux in the bluffs which border its valley there, really rest unconformably upon the quartzite near where the latter rock appears at the surface. If the Cretaceous rocks do really exist in the uplands of the extreme northwestern part of the State as they seem to do, we have the interesting fact of the newest stratified rocks of the State resting directly

GEOLOGICAL SURVEY of IOWA.

General Section of Iowa Strata.

Systems AGES	Groups PERIODS	Formations EPOCHS	Thickness in FEET.
	Post Tertiary	*Drift.*	10 to 200
CRETACEOUS	Lower Cretaceous	*Inoceramus bed*	50
		Woodbury Sandstone and Shales	130
		Nishnabotany Sandstone	100
CARBONIFEROUS.	Coal Measures	*Upper Coal Measures.*	200
		Middle Coal Measures.	200
		Lower Coal Measures	200
	Sub.Carboniferous	*St. Louis Limestone*	75
		Keokuk Limestone	90
		Burlington Limestone	190
		Kinderhook beds	175
DEVONIAN.	Hamilton	*Hamilton Limestone and Shales.*	200
U.SILURIAN	Niagara	*Niagara Limestone.*	350
LOWER SILURIAN.	Cincinnati	*Maquoketa Shales.*	80
	Trenton	*Galena Limestone.*	250
		Trenton Limestone	200
	Primordial	*St. Peters Sandstone*	80
		Lower Magnesian Limestone.	250
		Potsdam Sandstone.	300
Azoic	Huronian?	*Sioux Quartzite.*	50



upon the oldest, even when there are within its limits more than two thousand feet in thickness of strata, which properly intervene between them in the geological scale.

Although the dip of the strata at this locality is to the northward, nothing more is seen of the formation to the southward of that point, from which it is inferred that it also dips immediately to the southward again and is lost beneath the Cretaceous and other formations in that direction.

Going northward, up the river valley from this point, the strata entirely disappear by their northerly dip within half a mile of the southern limit of the exposure; but within five or six miles still further to the northward, they rise again and are seen at intervals along the valley, between there and Sioux Falls, in Dakota territory. The falls are about ten miles in a direct line northwestward from the northwest corner of the State of Iowa. The Big Sioux river, which, by an abrupt bend, has here a northward course, passes over a bold outcrop of the quartzite, causing a series of falls, sixty feet in aggregate height, within the distance of half a mile. The trend of this outcrop is also eastward and westward, but the dip is to the southward, at an angle of six or eight degrees, being in an opposite direction from that of the current of the stream, and in opposite direction also from that of the dip of the same strata at the northwest corner of Iowa. By estimating from the angle of the dip and actual measurement of the height of the falls, we find the formation to have a thickness here of three hundred feet, and yet we saw neither the base nor the well-defined top of it.

In Rock county, Minnesota, which joins the northern boundary of Iowa and the eastern boundary of Dakota, are other large exposures of the Sioux quartzite. In Pipe-stone county also, which lies immediately north of Rock county, are still other large exposures. The most important of these exposures of quartzite, encloses the famous pipe-stone layer, from which the Indians have manufactured their pipes from time immemorial. This pipe-stone is a bed of metamorphic clay, known among mineralogists as Catlinite, about a foot in thickness, intercalated between layers of the quartzite. The formation was originally an accumulation of sand with a layer of clay, and the same metamorphic action which changed the sand to a quartzite also converted the clay into pipe-stone. The pipe-stone, containing a considerable amount of per-oxide of iron, has a red color similar to that of the quartzite which encloses it.

At New Ulm, in the valley of Minnesota river, other large exposures of the same formation are found. This is the most easterly point at which it has yet been recognized. It appears only at the northern side of the valley there, having a strong dip to the eastward, and an estimated thickness of strata, that are more or less exposed, amounting to near four hundred feet. A large portion of one of the exposures here has the character of pudding-stone or coarse conglomerate. It is also frequently exposed in Dakota Territory, west of the Big Sioux river, where also some portions of it are in the condition of metamorphic conglomerate.

These exposures beyond the limits of the State are referred to for the purpose of giving a fuller description of the formation than could be made from those within it, and for the purpose of pointing out the original localities of those red quartzite boulders that are so profusely scattered in the drift of western Iowa.

Economic Value. In a few rare cases this rock may be quarried readily, as the layers are easily separated, but usually it is so compact throughout that it is quarried with the greatest difficulty into any forms except those into which it naturally cracks. It has a great tendency, however, upon its natural exposures, to break up by vertical fissures and cracks into angular blocks of convenient size for handling. Except this tendency to crack into angular pieces, which is not very great in those already reduced to proper size for building purposes, the rock is absolutely indestructible. The process of metamorphism has been so complete that the rock is almost everywhere of uniform texture, and the smoothness of its fracture is sometimes such that mortar, unless the lime it contains is fresh and pure, does not adhere with sufficient firmness to make a solid wall. It is however the only kind of stone to be had in all the region where it occurs, and although not the best, it is still very valuable.

Geological Age. No traces of fossil remains of any kind have yet been found in the Sioux Quartzite, or in its associated pipe-stone. Therefore we have no other than stratigraphical and lithological evidences of its geological age. The following is a summary of the reasons which induce its reference to Azoic age:

1. Its complete metamorphic character; while the other stratified rocks, at least in Iowa, down to and including the Potsdam sandstone, are free from true metamorphism.

2. Its disturbed condition; while all the other formations just named are at most but slightly inclined, and are all nearly or quite conformable to each other up to the close of the Carboniferous age at least. No formation has been found resting conformably upon the quartzite. In other words we know of no such disturbance of strata as the quartzite has suffered, having taken place in this part of North America, between the commencement and the close of the Palæozoic time.

3. It is known to be older at least than the Lower magnesian limestone, because that formation, near New Ulm, rests without perceptible disturbance, and of course unconformably upon the disturbed quartzite; and because the Lower magnesian limestone has never been found to be unconformable with the Potsdam sandstone, it is inferred that the Sioux Quartzite is older than the latter also.

2. LOWER SILURIAN SYSTEM.

PRIMORDIAL GROUP.

THE POTSDAM SANDSTONE.

Area and General Characters. Although the Potsdam sandstone has a geographical range extending throughout a large part of the northern portion of the United States and of Canada, and reaches a known thickness in Iowa of about three hundred feet, it nevertheless forms rather an inconspicuous feature in the geology of Iowa. It is exposed only in a small portion of the northeastern part of the State, and has been brought to view there by the erosion of the river valleys. Consequently, it is only to be seen in the bases of the bluffs, and steep valley sides which border the rivers there, while in the same steep valley sides the Lower Magnesian limestone, St. Peter's sandstone, and Trenton limestone, are all frequently seen to overlie it in their regular order. In this position it is to be seen along the bluffs of the Mississippi from the northern boundary of the State as far south as the town of Guttenburg, along those of the Upper Iowa river for the distance of about twenty miles from its mouth, and in the bottoms of a few other small valleys whose streams empty into the Mississippi within Allamakee county.

The base of this formation does not appear anywhere in Iowa, consequently its full thickness here is not known, nor is it certainly known what it rests upon. It is probable that it rests upon the Sioux Quartzite, but of this we have no direct proof.

The rock is everywhere soft; usually a very friable sandstone, but sometimes containing some clayey material and approaching in character a sandy shale.

Economic Value. The Potsdam sandstone in Iowa is nearly valueless for any economic purpose. It is almost nowhere of sufficient hardness to serve even the commonest purposes of masonry. It is sometimes, however, so incoherent as to be serviceable as building sand.

Fossils. No fossils have yet been discovered in this formation in Iowa, but they are found in it quite abundantly in some parts of Wisconsin.

LOWER MAGNESIAN LIMESTONE.

Area and General Character. This formation has but very little greater geographical extent in Iowa than the Potsdam sandstone has; because, like that formation, it appears only in the bluffs and valley-sides of the same streams. It is, however, a more conspicuous formation than the Potsdam sandstone, because, being a firm rock, it presents bold and often picturesque fronts along the valleys. If it were not for the erosion of the river-valleys, the Lower magnesian limestone, like the Potsdam sandstone, would never have been seen in Iowa, and the succeeding formations now cover them up to the very verges of those valleys.

Its thickness is about two hundred and fifty-four feet, and is quite uniform in composition, being a nearly pure, buff-colored dolomite. It lacks a uniformity of texture and stratification, which causes it to weather into rough and sometimes grotesque shapes, as it stands out in bold relief upon the valley-sides.

Economic Value. Owing to this lack of uniformity in texture and bedding, the rock is not generally valuable for building purposes. Some parts of it, however, may be selected which serve an excellent purpose for such uses, and the cities of Lansing and McGregor are supplied largely from this source. Near each of these places, some beds afford very good material for dressing into caps, sills, etc., for buildings. It has also been used to some extent for making lime, but thus far, that made from the Trenton limestone near Dubuque is preferred.

Some years ago small quantities of lead ore were discovered in this formation in the bluffs that border the valley of the Upper Iowa in Allamakee county, which excited great hopes of profitable mining, and the town of New Galena was consequently founded there. The amount of lead ore obtained there, however, proved too small for profitable working and the mines were soon abandoned. From these experiences, and from other information which has been accumulating during many years, it is evident that there is no hope of profitable lead-mining in the Lower Magnesian limestone.

Fossils. The only fossils that have been found in this formation in Iowa are, so far as known, a few traces of the stems of Crinoids found near McGregor. Of course, no specific identification of them could be made. Some traces were also observed there which are doubtfully referred to fucoids.

ST. PETER'S SANDSTONE.

Area and General Characters. This formation is remarkably uniform in thickness throughout its known geographical extent, and also in lithological characters. It is a clean grit, light colored, very friable rock; so pure in its silicious composition that it is probable some portions of it may be found suitable for the manufacture of glass. Usually, however, it is more or less colored with oxide of iron, and a couple of miles below McGregor it is much colored by various shades of red and yellow, where it takes the local name of "Pictured Rocks." It has been exposed principally by the same fluvatile erosion that brought the Lower Magnesian limestone and Potsdam sandstone to view; but it is evident that it occupies the surface of a large part of the northern half of Allamakee county, immediately beneath the drift.

It is very seldom hard enough to be used as stone, and unless it should prove suitable for glass in some places, it is probably of no economic value whatever. It contains no fossils, and is referred to the Primordial group upon lithological and stratigraphical grounds.

TRENTON GROUP.

THE TRENTON LIMESTONE.

Area and General Characters. With the exception of this, all the limestones of both Upper and Lower Silurian age in Iowa, are magnesian limestones—nearly pure dolomites. The rocks of this formation also contain much magnesia, but a large part of it is composed of bluish compact common limestone. The surface occupied by the Trenton limestone is equal in area to about one-third of the whole of that occupied by all the other Lower Silurian formations in the State. It occupies large portions of both Winneshiek and Allamakee counties, together with a portion of Clayton; and although its southwesterly dip has carried it beneath the Galena limestone there, yet it is again found, after passing out of sight for a distance of about ten miles, in the bottom of Turkey river valley, where it is seen along the greater part of its entire length, having been exposed by the cutting through of the Galena limestone by Turkey river in the erosion of its valley. From this valley, the southwesterly dip of the formation has carried it so deeply beneath the surface that it is seen no more in Iowa.

The thickness of this formation as seen along the bluffs of the Mississippi is about eighty feet, but in Winneshiek county we find the thickness increased to upwards of two hundred feet.

Economic Value. The greater part of the bulk of this formation is worthless for economical purposes, but a considerable portion, quite enough to meet the wants of the inhabitants, affords excellent material for building purposes and also for the production of common lime of excellent quality. There is no lack of common building stone wherever it is exposed, and in some places there are compact and evenly bedded layers which afford fine material for dressing into all desirable forms for use as caps, sills, etc. The best quarries of this rock that have been examined are those just above Dubuque, and those in and near the town of Decorah. The worthless portion of the formation consists of clayey shales and shaly limestone. The latter is very prevalent in Winneshiek county, as seen along the valley of the Upper Iowa, where the formation is also thickest. There are also some beds of tolerably pure clay associated with the calcareous portions which promise to be valuable. One of these occurs near the town of Clermont, in Fayette county, where Mr. Dibble has been manufacturing from it the light-colored variety of brick, known as "Milwaukee brick."

The State collections contain some specimens of these brick, which show that the clay is excellent for that purpose. An analysis of the clay will be found in the report of Prof. Emery in volume two.

Fossils. Hitherto, with the exception of the traces of crinoidal stems found in the Lower Magnesian limestone at McGregor, we have found no fossils in the formations which precede the Trenton limestone; but in this last named formation fossils are extremely abundant. So much so in some places, indeed, that the rock is made up of a mass of shells, corals, and fragments of trilobites, together with other animal remains, cemented by calcareous material into compact rock. It would appear that the waters in which the preceding formations were deposited were comparatively free from life, but upon the introduction of the Trenton epoch its seas swarmed with life as various in its expressional forms as that of the seas of to-day. Among these fossils found in the Trenton limestone of Iowa, are those well-known species which characterize the formation in other parts of the country, besides some that are yet new to science and peculiar to Iowa, and neighboring strata.

THE GALENA LIMESTONE.

Area and General Characters. The Galena limestone, the upper formation of the Trenton group, occupies a narrow strip of country, seldom exceeding twelve miles in width, although it is fully one hundred and fifty-five miles long. It is about two hundred and fifty feet thick in the vicinity of Dubuque, but diminishes in thickness as it extends to the northwestward, so that it does not probably exceed a hundred feet where it crosses the northern boundary of the State. The area it occupies is widest about the middle, but it becomes very narrow at both ends; at the southeasterly end by passing beneath the Upper silurian rocks, and appearing only in the face of the bluffs which border the Mississippi river, and at the northwesterly end by the thinning of the formation and an increased westerly dip there. The outcrop of this formation traverses portions of the counties of Howard, Winneshiek, Allamakee, Fayette, Clayton, Dubuque, and Jackson. It occupies a greater surface area in Clayton county than in any other, but it exhibits its greatest development in Dubuque county.

It is very uniform throughout in its lithological characters, being a nearly pure dolomite, with a slight admixture of silicious matter. It is not very uniform in texture however, which causes it to decompose unequally, and consequently to present interesting forms in the abrupt bluffs of it, which border the valleys. Some of these are strangely picturesque and wild in their appearance, especially in the deep glens and valley-sides.

Economic Value. The want of uniformity of texture in this limestone, usually renders it unfit for dressing. Sometimes, however, especially near the top of the formation, the beds are more uniform, and good blocks for dressing may be obtained. It almost everywhere affords stone good enough for all purposes of common masonry, and will supply an abundance of road-materials in all the region occupied by it. Lime has been manufactured from it, but outcrops of the purer Trenton limestone are seldom far away from exposures of this. The lime from that formation being purer and better, it is of course preferred, and the Galena limestone neglected for such purposes.

The chemical composition of this rock in some parts of the the formation being known to be similar to that of some which has been successfully used for hydraulic lime, it is thought probable that it also may prove valuable for such purposes.

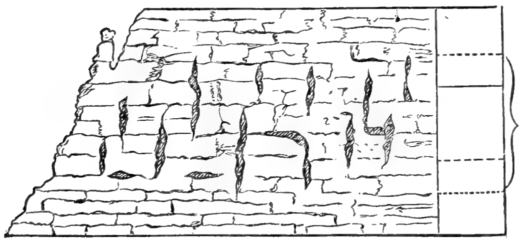
This formation becomes one of great economic importance, as being the source of the lead ore of the Dubuque lead-mines. The report of Prof. Whitney upon these mines in the former geological report, is so complete, that it is not thought necessary here to give anything more than a brief outline of the mode of occurrence of the ore. Lead, in the form of the sulphuret, has been found in small quantities in this formation at various localities, but it has never been profitably mined in it outside of Dubuque county. It has also been found in the Trenton and Lower magnesian limestone in other counties, but always, so far as Iowa is concerned, in quantities too small to be profitably mined.

The lead region proper is confined to the immediate vicinity of Dubuque, and within an area of about fifteen square miles. The ore occurs principally in vertical fissures which traverse the rock at irregular intervals from east to west; a little being found in those which have a north and south direction, and some occasionally in "quartering" lodes or fissures. The ore is mostly that known as Galena or sulphuret of lead; very small quantities of the carbonate only being found with it, and that probably occurring by decomposition of the sulphuret. There is considerable physical difference between the ore of the east and west and the north and south lodes or crevices. Cubical crystals of it are said never to occur in the latter while that is the prevailing form in the others. This probably occurs from the fact that the north and south crevices being very narrow, are usually filled with ore when it occurs at all, and the natural form of the crystals thus confused. But yet there is also a slight difference in color and lustre.

Prof. Emery has made a full series of analyses for the purpose of ascertaining whether silver is present in any of the ores. The results will be found in his report in volume two.

The ore has not a uniform vertical range through the formation in the Dubuque lead region, but is confined principally to its central portions. Its vertical range may be understood with considerable exactness by the accompanying diagram, (Fig. 5,) which represents the full thickness of the formation at Dubuque.

FIG. 5.



If the two hundred and fifty feet of vertical thickness of the formation be divided into three equal horizontal parts, as shown in the right hand column of the diagram, almost all the lead-ore will be found to be contained within the middle part, together with the lower half of the upper, and the upper half of the lower parts, as indicated by the brace in the diagram. In other words, the upper half of the upper third, and the lower half of the lower third of the whole thickness of the formation is found to be almost entirely destitute of lead-ore. This is the rule, but a few rare exceptions exist. One of these exceptions was shown in the discovery of a lead-bearing crevice in the extreme upper part of the Galena limestone at the base of the Maquoketa shales, by Messrs. McCraney and Hickok, in the summer of 1867. The value and extent of the ore there has not been learned, but it is supposed to be unimportant.

This formation is in part the "Upper Magnesian Limestone' of Dr. Owen. The existence of the Maquoketa shales not having been recognized by him, he united, in his descriptions, the Galena limestone, with the Niagara limestone, which has very similar lithological characters. Thus it was erroneously supposed that the Niagara limestone of New York increased greatly in thickness in its westward extension, and became the lead-bearing rock of the Mississippi valley.

Fossils. Fossils are rare in this formation, as they usually are in Magnesian limestones. The most characteristic species is *Lingula quadrata* of Owen; but the genera *Orthoceras*, *Pleurotomaria*, *Murchisonia*, &c., have been recognized, all the species of which probably also occur in the Trenton limestone.

CINCINNATI GROUP.

THE MAQUOKETA SHALES.

Syn.—HUDSON RIVER SHALES OF HALL.

Area and General Characters. The surface occupied by this formation is comprised within a singularly long and narrow area, seldom reaching more than a mile or two in width, but more than a hundred miles long within the State. It lies like a narrow sinuous band upon the surface between the regions occupied respectively by the Galena and Niagara limestones; having, like them, a northwestward and southeastward trend. Its most southerly exposure is in the bluffs of the Mississippi river near Bellevue, in Jackson county, and the most northerly one yet recognized is in the western part of Winneshiek county.

The whole formation is largely composed of bluish and brownish shales which weather into a tenaceous clay upon the surface, and the soil derived from it is usually stiff and clayey. The shales are sometimes slightly arenaceous, and sometimes calcareous bands compose a considerable part of its bulk. The latter is the case at the typical localities on the Little Maquoketa river about twelve miles westward from Dubuque. These calcareous bands have really a large proportion of magnesia in their composition, as shown in the report of Prof. Emery. The shales are sometimes bituminous, but there is no reason to suppose that they contain enough for the profitable distillation of petroleum.

Economic Value. Its economic value, being wholly composed of soft or fragmentary materials, is very slight, principally consisting of the brick clay into which it disintegrates upon the surface.

Geological Age. The fossils contained in this formation, together with its position in relation to the underlying and overlying formations, leave no doubt as to the propriety of referring it to the same geological period as that in which the rocks at Cincinnati, Ohio, were formed; but as a formation, it is regarded as distinct from any other one of that group hitherto defined. In the former report upon the geology of Iowa, it received the name of "Hudson River Group," in consequence of its supposed equivalency to certain rocks abundantly exposed along the Hudson river in New York. But the designation "group" refers to a whole period in geologic time, and when it is applied to any single formation, its indefiniteness differs only in degree from a mere reference of the formation to its proper system or age. Therefore, as the strata of this formation, all referable without doubt to a single epoch of its period, are well developed on the Little Maquoketa river, where its characteristic fossils are also abundant, the name Maquoketo shales is given to this particular formation of the group.

Again Messrs. Meek and Worthen of the State Geological Survey of Illinois, have shown that these Iowa shales, as well as their equivalents and associated strata in their own and other interior States, are not equivalent to those upon the Hudson river to which the name of "Hudson River Shales" was first applied. They therefore have very properly dropped the name of Hudson River Group as applied to these, and proposed the name Cincinnati Group, because the group or its principal formations are well exposed at that city, where also its abundant and characteristic fossils are well known. Relying upon the determinations of these able geologists, as well as upon my own observations, I also reject the name "Hudson River Group" as applied to our own strata and their equivalents, and apply the name "Cincinnati Group" to the formations of the whole period as they do, but use the name Maquoketa shales to designate that particular epochal subdivision or formation of the group which alone is found in Iowa.*

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* See "Classification of Iowa Rocks," in the introduction.

Fossils. Several species of fossils which characterize the Cincinnati group are found in the Maquoketa shales, such as *Orthis testudinaria*, *O. occidentalis*, *Strophomena alternata*, *S. sericea*, *etc.*, but they contain a large number of species that have been found nowhere else than in these shales in Iowa. They belong to the genera *Orthoceras*, *Murchisonia*, *Pleurotomaria*, *Schizodus* (?) *Discina*, *Graptolithus*, *etc.* The distinct faunal characteristics presented by these fossils last referred to, seem to warrant the separation of the Maquoketa shales as a distinct formation from any others of the group. Its true position is probably at the base of the group.

3. UPPER SILURIAN SYSTEM.

NIAGARA GROUP.

THE NIAGARA LIMESTONE.

Syn—LE CLAIRE LIMESTONE, IN PART, OF HALL.

Area and General Characters. In the former report upon the geology of Iowa, two distinct formations of the Niagara group were recognized and described, namely, the Niagara limestone and the Le Claire limestone; the latter resting upon the former. Subsequent stratigraphical and palæontological examinations fail to show any good reasons for referring any of the Upper Silurian rocks of Iowa to any other than the epoch of the Niagara limestone; therefore, they are all regarded as belonging to that formation alone. Messrs. Worthen and Meek, of the State Geological Survey of Illinois, long since came to the same conclusion, and in the recently published State reports, they re-affirm it.

The Niagara limestone, as thus understood, occupies a very large area of the surface of the State, much larger in fact than that of all the formations of Lower Silurian age together. Its area has also a shape quite different from those occupied by the preceding formations, being somewhat in the form of a scalene triangle, with its longest side to the southward, and its widest portion nearest the southern end.

This form necessarily changes the trend of the succeeding formations several degrees nearer to the northward and southward than that of the preceding formations is.

The area occupied by the Niagara limestone is nearly a hundred and sixty miles long from northward to southward, and between forty and fifty miles wide in its widest part. At its narrowest part, which is near its northern limit in Iowa, it is not more than four or five miles wide. The narrowing of the area here is due to two causes; namely, the thinning out of the formation in its northward extension, and the increased westerly dip of the same, together with that of its associated formations in that part of the State. That increase of dip is well shown in the section from McGregor to the mouth of Broken Kettle creek. The rapidly increasing width of the area which the formation has to the southward, is not wholly due to its increasing thickness in that direction, but is due also to disturbance of its strata and change of dip. In consequence of this, and also of the irregularity and diversity of its stratification, no satisfactory conclusions have yet been arrived at concerning its thickness. It is estimated at two hundred and seventy-five feet, but its maximum thickness in Iowa is probably much more.

A line of disturbance of the strata of this formation, passes into Iowa in a direction almost corresponding with the direction of its trend; crossing the Mississippi river at LeClaire, and being last recognized in the valley of the Wapsipinicon about three miles west of Anamosa. This disturbance apparently partakes more of the nature of an abrupt fold than of a true fault, leaving the general dip of the strata on each side of its axis seemingly unchanged from what it would have been if the disturbance along that axis had not taken place.* This disturbance seems confined to a very narrow area, for the strata within less than a mile on each side of both the localities named, appear entirely undisturbed, although the

*This is the only known instance in Iowa of a fold having the general direction of any of the streams. Other slight folds exist, as will be shown in the general sections accompanying this report, but they do not coincide with the courses of the streams.

angle of dip has reached, in some places, twenty-eight degrees with the horizon.

This formation is entirely a Magnesian limestone with, in some places, a considerable proportion of silicious matter in the form of chert or coarse flint. A large part of it, especially its lower portion, closely resembles both the Galena and Lower Magnesian limestones, having the same want of uniformity of texture and bedding, which causes it to weather into rough and craggy forms upon its outcrops, and renders it unsuited for purposes of architecture.

Economic value. A large part of the formation, however, is more evenly bedded, and taking it together it probably affords the best and greatest amount of quarry rock of any in the State. The quarries near Anamosa, in Jones county, are most remarkable for the uniformity and precision of the bedding of its strata. These quarries, together with those at Le Claire and Farley, all of which are opened in strata of Niagara limestone, will be found more particularly described in another part of this report. Wherever this rock is exposed there is always an abundance of material for roads and for common masonry.

At Le Claire, most excellent common lime is prepared from this formation, and a fair article of it may be made from that of any part of it. Some of the layers, however, seem much better adapted to the preparation of lime, although the chemical analysis shows but slight difference of composition.

4.—DEVONIAN SYSTEM.

HAMILTON GROUP.

HAMILTON LIMESTONE AND SHALES.

Syn.—Upper Helderberg Limestones in part of Hall, in Report of Geology of Iowa, for 1858.

Area and General Characters. The area of surface occupied by the Hamilton limestone and shales, is fully as great as those occupied by all the formations of both Lower and

Upper Silurian age in the State. This area comprises a wide strip of country, the general trend of which is northwestward and southeastward. It is nearly two hundred miles long and from forty to fifty miles broad; the details of its outlines may be seen upon the geological map.

All the limestones hitherto described are nearly pure dolomites except the Trenton, which is also in part magnesian. After the close of the Upper Silurian age the proportion of magnesia in the limestones of Iowa are gradually diminished. Thus the limestones of Devonian age are composed in part of magnesian strata, and in part of common limestone. These magnesian strata do not seem to be confined to any particular part of the vertical thickness of the formation, and their texture is also variable. In some parts of it, mainly towards its base, these strata are quite uniformly bedded, compact and uniform in texture, and afford some excellent material for solid masonry. In other parts, they are soft, sandy, and worthless; and in still other parts they are comparatively soft, fine grained, slightly silicious—as for example, at Waverly—and afford material for hydraulic lime. A large part of the formation is composed of calcareous shales and shaly limestone. At Rockford, in Floyd county, the shales assume the character of a marly clay which is very fossiliferous.

So far as has yet been ascertained, none of these lithological variations characterize any particular horizon of this formation over any large portion of the area occupied by it, but the concretionary, or partially brecciated, bluish-grey, common limestone is its prevailing lithological characteristic. This portion is inclined to become fragmentary upon exposure to atmosphere and frost.

Owing to this lithological variation, and the fact that no very deep exposures of its strata are found at any one locality, because the streams upon it run in the direction of the line of strike, the full thickness of the formation has not been accurately ascertained, but it is estimated at about one hundred and fifty feet.

Economic Value. Although a large part of the material of this formation is practically quite worthless, yet other portions are very valuable for several economic purposes; and having a very large geographical extent in the State, it constitutes one of its most important formations in a practical point of view.

The magnesian limestones of this formation, are not so near a pure dolomite in any case as those are which constitute the greater part of the Upper and Lower Silurian formations in Iowa, but the admixture of other substances seems beneficial to them for economic purposes. For example, the admixture in a finely divided condition of five or six per cent each of silica and alumina, to the proportions of the carbonates of lime and magnesia that form dolomite, is found to give the rock very decided hydraulic properties. Rock of this kind occurs in considerable quantities at Waverly, in Bremer county, and its value for the production of hydraulic lime has been practically demonstrated there by Mr. Robert D. Brown, an account of which is given Volume two, besides the analysis of the rock in Prof. Emery's report. It is not improbable that the same formation will furnish material equally good for the same purpose in other parts of the State, but thus far the rock at Waverly alone has been practically tested.

Wherever any part of this formation is exposed, the common limestone portions exist in sufficient quantity to furnish abundant material for common lime of excellent quality, as well as good stone for ordinary masonry. The heavier and more uniform magnesian beds furnish in many places excellent material for dressed stone, and for bridge piers, as well as for other works requiring strength and durability.

The clayey portions are usually too calcareous and impure for any economic use, but some indications were observed in Bremer, Floyd, and Cerro Gordo counties, that lead to the supposition that its clayey portions there may possibly furnish a clay suitable for the manufacture of light colored brick.

Geological Age. The full series of formations of Lower Silurian age are nearly complete in Iowa, but, as we have shown, only a single formation of Upper Silurian age—the Niagara limestone—is recognized within its limits. Thus, although the formations that immediately underlie and overlie the Niagara limestone in this State are stratigraphically conformable with it, yet there are several formations recognized in other portions of the country as parts of the full geological series, the serial position of which are in part between it and the Maquoketa shales, and in part between it and the Hamilton limestone and shales above.

The formation here designated as the Hamilton limestones and shales is, like the Niagara limestone also, serially isolated, although it is quite conformable both with the Upper Silurian strata below, and the Carboniferous above throughout their whole extent in Iowa. This is evidently the case, although the exact junction, neither above nor below, has ever been distinctly seen. The greatest hiatus that exists in our actual observations of the order of succession of Iowa strata, is that between this formation and the Kinderhook beds above, but enough is known to make it certain that no other formation exists between them. Even the "Black Slate," which forms so distinct a horizon at the top of the Devonian series in Ohio, Indiana, Kentucky, Illinois, and Missouri, seems to be entirely wanting in Iowa.

All the Devonian strata of Iowa evidently belong to a single epoch, undoubtedly referable to the Hamilton period, as recognized by the New York geologists, but when we come to apply a specific name to the formation as it exists in Iowa, it becomes difficult to say with precision to what previously recognized formation of that group it belongs. In its palæontological characters, however, it so much more nearly corresponds with the Hamilton Shales of New York than with any other part of the group, it is referred to that formation; and its name retained as far as the lithological character of the Iowa rocks will admit, rather than to propose a new name, or refer it indefinitely to the whole group as has been previously done.

Fossils. The most conspicuous and characteristic fossils of this formation are brachiopod mollusks and corals. They belong to the following named species: *Spirifer pennatus*, *S. Parryanus*, *Strophodonta demissa*, *Atrypa reticularis*, *A. aspera*, *Orthis Iowensis*, and *Acervularia Davidsoni*. Other species are abundant in some places, but those named have a range throughout the formation in Iowa. The following species found in this formation in Iowa, are also found in the Hamilton shales in New York, namely: *Strophodonta demissa*, *S. fragilis*, *Atrypa reticularis*, *A. aspera*, *Orthis Vanuxemi*, *Spirifer frimbriatus*, and *Cyrtia Hamiltonensis*.

Near the town of Rockford, Floyd county, very great numbers of well preserved specimens of the fossils of this formation are found in its marly clays. Several species are abundant there besides those here enumerated, but they seem to have a limited geographical range. A species of *Smithia* replaces *Acervularia* here, for which the name *S. Woodmani* is proposed, in honor of H. T. Woodman, Esq., of Dubuque.*

The coral *Acervularia Davidsoni* occurs near Iowa City in considerable abundance solidified, with pure calcareous material and consolidated in the rocky strata. These receive a fine polish and make beautiful cabinet specimens, but are always too small to be of any practical use as marble. It has been known under the names of "Iowa City marble" and "Bird's-eye marble."

*This species differs somewhat conspicuously from S. Verrilli, of Meek, in the uniformly larger size of the calyces, the great prominence of their margins above the intermediate spaces, and the width of those spaces between the calyces.

CHAPTER II.

CARBONIFEROUS SYSTEM.

Of the three groups of formations that constitute the Carboniferous System, namely, the Sub-carboniferous, Coal-Measures, and Permian, only the two first named are found within the limits of Iowa. Both of these are well developed here in all their distinctive characteristics.

THE SUB-CARBONIFEROUS GROUP.

Syn—CARBONIFEROUS LIMESTONE, SUB-CARBONIFEROUS LIMESTONE, MOUNTAIN LIMESTONE.

Area and General Characters. The area of surface occupied by this group is very large, and is shown as accurately as practicable upon the geological map. Considerable difficulty exists in determining the boundaries of the area in its northern part, particularly along its western border; because the exposures of strata are so very rare there, and we have been obliged to rely to a great extent upon its general trend for this purpose rather than upon actual observations of outcrops.

Its eastern border passes from the northeastern part of Winnebago county with considerable directness in a southeasterly direction, to the northern part of Washington county. Here it makes a broad and direct bend nearly eastward, striking the Mississippi river at the city of Muscatine; this of course being the western and southern boundary of the area occupied by the Devonian rocks. The southern and western boundary of the area is to a considerable extent the same as that which separates it from the coalfield, but northward from the southern part of Pocahontas county we know little about it with accuracy. From this point it passes southeastward to Fort Dodge, thence to Webster City, thence to a point three or four miles northeast of Eldora, in Hardin county, thence southward to the middle of the north line of Jasper county, thence southeastward to Sigourney, in Keokuk county, thence to the northeast corner of Jefferson county, and thence, by sweeping a few miles eastward, to the southeast corner of Van Buren county. The area, as thus defined, is nearly two hundred and fifty miles long and from twenty to forty miles wide.

The general southerly and westerly dip has carried the strata of the group beneath the Lower coal-measure along the line last designated, but after passing beneath the latter strata for a distance of from fifteen to thirty miles, they appear again in the valley of the Des Moines river, where they have been bared by the erosion of that valley.

The following is a full list* of the formations of the Sub-carboniferous group as developed in the Mississippi valley. They are given in their natural order of superposition, commencing with the uppermost.

1. Chester limestone.
2. St. Louis limestone.
3. Keokuk limestone.
4. Upper and Lower Burlington limestones.
5. Kinderhook beds.

Of these formations all but one are found in Iowa. This missing formation is the Chester limestone of the Illinois geologists, so named from the town of Chester, where its

* The beds referred to a separate epoch in the former Geological Report under the name Warsaw limestone, are in this report, included among those referred to the epoch of the St. Louis limestone, to which they properly belong, and the use of the name of Warsaw limestone, as indicating a separate formation of the Sub-carboniferous group discontinued. The "Geode bed" and "Ferruginous sandstone" are also regarded as only subordinate divisions respectively, of the Keokuk and Chester limestones.

characteristics are well shown. The coal-measures rest conformably upon it in southern Illinois, where it attains a thickness of eight hundred feet—a thickness greater than that which the whole Sub-carboniferous group attains in Iowa. Its most northern known limit is near Alton, Illinois, which is a hundred miles south of the most southern point in Iowa. This formation received the name of Kaskaskia limestone in the former geological report of Iowa, but the name here used had been previously adopted by the geologists of the State where it has been most studied, and ought therefore to be used in preference to any other.

As the Chester limestone has no direct connection with Iowa geology, no description of it will be given in this report, but the other formations of the group will be described separately in the ascending order as before named. No attempt has been made to define accurately the surface area occupied by each formation of the Sub-carboniferous group in Iowa, either upon the map or in the text, but a general idea of the subject may be obtained from the separate descriptions which follow.

1. THE KINDERHOOK BEDS.

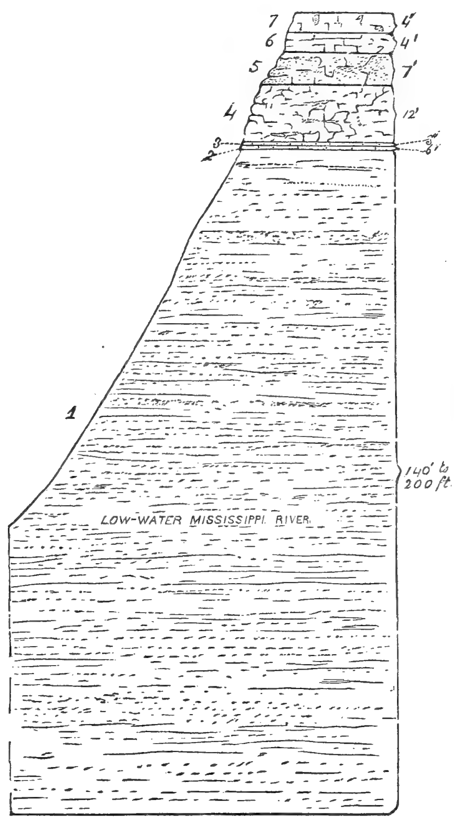
Syn.—Chemung Group of several Authors.

General Characters. This formation was referred to the Devonian system in the former geological report of Iowa, but its carboniferous characters are now recognized by almost all geologists. Messrs. Meek & Worthern, of the Illinois Geological Survey, recognized its characters as such, gave it the name of "Kinderhook group," from the town of Kinderhook in the southern part of that State, where it is well developed. Since the word group, as used in this report, is so restricted in its meaning as to designate a group or assemblage of formations, it is not deemed advisable to use in this place the same word to designate one of the component parts of a group as thus defined. To avoid this, and still to recognize the priority of the name those gentlemen have applied to this lowest formation of the Sub-carboniferous group, its specific designation is modified as in the preceding heading.

The term beds is literally very appropriate to the formation as it exists in Iowa, because at its typical localities here it is made up of a series of alternating beds of sandstone and limestone, the majority of which are comparatively thin. The section, represented by fig. 6, shows its lithological composition at Burlington, where it is more fully exposed than at any other point in the State, and where also its characteristic fossils are most abundant.

Fig. 6.

Section of Kinderhook Beds at Burlington.



Bed No. 1 of this section is largely composed of fine grained, sandy shales, but varying from bluish, clayey shale, to fine grained, yellowish sandstone. The greatest thickness of this bed yet measured in actual exposure is eighty-two feet, but by artesian borings made in the city, it is recognized with certainty at a depth of sixty-five feet beneath that measurement, making the recognized thickness of the whole to be one hundred and forty-seven feet. Further prosecution of the borings at Burlington, made by Mr. Bosch, are reported to have passed through "two hundred and fifty feet in all of blue clay" beneath the level of the water in the Mississippi river. This, like the results of all borings of the kind, is not entirely satisfactory, and yet it is not improbable that Bed No. 1 has a much greater thicknesss than is indicated in the foregoing section.

The upper portion of this bed is, in some places, quite fossiliferous, the fossils being mainly in the form of casts and largely confined to *Lamellibranchiates* and *Brachiopods.*

Mills & Co. Lith Des Moines.

VIEW ON FLINT CREEK DES MOINES CO. (LOOKING N W) EXPOSURE OF THE "KINDERHOOK" AND "BURLINGTON LIMESTONE", 1868.

BED No. 2, is merely a layer of compact limestone, everywhere crowded with shells, principally *Chonetes.* It averages about six inches in thickness, and caps the sandy bed No. 1 with marked distinctness.

BED No. 3, is another mere band of limestone only about three inches in thickness, but is very distinct on account of its oolitic structure, and principally interesting as showing the tendency of the limestones of this formation to assume that peculiar structure, as will be shown further on.

BED No. 4, reaches a maximum thickness near Burlington of twelve feet. It is dark grey compact limestone, sometimes slightly arenaceous. It breaks up into small fragments upon exposure, and is very fragmentary, even where not exposed to the atmosphere.

BED No. 5, is a fine grained, yellowish sandstone, so much like some parts of No. 1, that it is impossible to distinguish them apart, unless seen in connection with its associated beds. This bed at Burlington reaches a maximum thickness of seven feet, and is often found crowded with casts of fossil shells, embracing many genera and species; some of which are peculiar to that bed alone, although a majority of the fossils range vertically through the entire formation without interruption. The fossils of this bed, like those of No. 1, are principally *Lamellibranchiates* and *Brachiopods.* They are also generally of small size; yet adult.

BED No. 6, is a light gray oolitic limestone, very uniform in its lithological characters, and has a thickness in the vicinity of Burlington, varying from two to four feet.

BED No. 7, is composed of impure limestone, sometimes magnesian, and at Burlington it passes so gradually into the Lower Burlington limestone that it is difficult to say where the distinctive characters, whether lithological or palæontological, of one formation end and those of the other begin. There are three or four feet in thickness here, however, that cannot be referred to any other than the Kinderhook beds, however closely it may be joined to the strata of the Burlington limestone. This portion, as well as all the other beds beneath it, disintegrate more readily than the true Burlington limestone which rests upon it; so that the ledges of the last named formation are often found jutting over the mural face of the Kinderhook beds, which gradually give way by disintegration beneath them.

The accompanying sketch, taken near Starr's Mill, on Flint creek, three miles northwest from Burlington, shows the general aspect of the two formations at their junction. The projecting strata here represented are those of the Burlington limestone, the real base of which can be distinctly traced in the sketch. All beneath the projecting mass belongs to the Kinderhook beds. Beneath these overhanging layers, which project sometimes as much as twenty feet, no rain can reach, and it is here that the epsomite (native epsom salts) mentioned on another page has been found. The explanation of its production there seems to be this: The magnesian portion of the Kinderhook strata contain carbonate of magnesia and also sulphuret of iron, in the form of common pyrites, in a finely divided condition. The decomposition of the latter upon exposure to the weather, produces sulphuric acid. This uniting with the magnesia by displacing the carbonic acid, with which it originally combined, forms the epsomite. This substance is doubtless often formed by similar decomposition of magnesian limestones elsewhere; but wherever their decomposing surfaces are exposed to rains or moving-water, the epsomite, being very soluble, is removed as fast as it is formed. Here, however, it is protected by the overhanging rocks from the access of any water, except such as the atmosphere contains, but which is quite sufficient to aid in the natural production of the salt without removing it by solution.

All the beds enumerated in the foregoing section, may be distinctly recognized at, and in the immediate vicinity of Burlington, wherever the formation is exposed; but beds No. 2, 3, 4 and 5, may be regarded as local only. Nos. 1, 6 and 7 are, however, more or less characteristic of the formation throughout its extent in Iowa. The oolitic member is especially constant and characteristic, and the last to disappear at its northern limit. The most southerly exposure of the Kinderhook beds in Iowa is near the mouth of Skunk river, in Des Moines county, where they pass beneath the Burlington limestone and the Mississippi river also, by their southerly dip. The most northerly exposure of the formation now known is in the eastern part of Pocahontas county, more than two hundred miles from the locality first named.

The principal exposures of this formation, are along the bluffs which border the Mississippi and Skunk rivers, where they form the eastern and northern boundary of Des Moines county; along English river, in Washington county; along the Iowa river, in Tama, Marshall, Hardin, and Franklin counties, and along the Des Moines river in Humboldt county.

Although the southern part of the formation in Iowa has the best development of all its distinguishing characteristics, yet the width of the area it occupies is much greater in its northern part, reaching a maximum width there of about eighty miles. This increased width of area occupied by the formation does not necessarily indicate an increased thickness of it, but it is evidently caused by a broad fold of the strata in that part of the State, which places them for that distance almost exactly parallel with the general surface of the country, and consequently without any perceptible dip to the westward.

At Bunker's mill, on English river, near Richmond county, the following section was measured, commencing at the water level:

No. 2, roughly bedded, earthy, yellowish limestone, with much silicious cherty material, 12 feet.

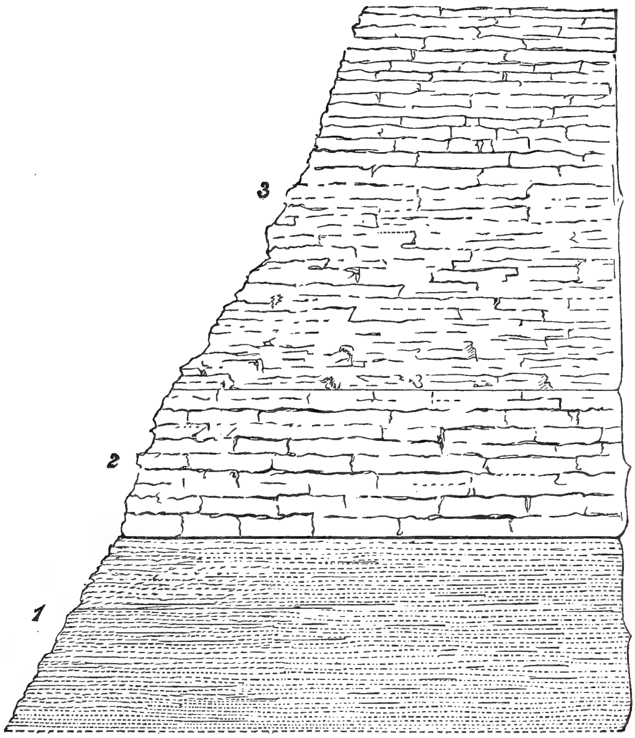
No. 1, bluish and bluish-green, indurated, sandy clays, 47 feet.

No. 1 of this section is, without doubt, equivalent with No. 1 of the section at Burlington. No. 2 of this section is the equivalent of No. 7 there, all the intervening beds observed at Burlington are wanting at this locality. The characteristic fossils of the formation were obtained from No. 1, but the material of No. 2 is not well suited to the preservation of fossils, if it ever contained any.

Going northward from Washington county, no other exposures of any of the sub-carboniferous formations are found until the valley of the Iowa river is reached. Here the river cuts obliquely across the whole area occupied by the group, but no rocks except those referred to the Kinderhook formation appear. It is possible that the true Burlington limestone may extend so far northward, but no proof of it has yet been observed.

At Indiantown, in Tama county, the section, represented by Figure 7, was measured, commencing at the water-level of the Iowa river:

FIG. 7.



No. 3. Soft, irregularly bedded, Magnesian limestone, passing up into purer and more regularly bedded limestone.............. 40 feet.
No. 2. Light gray oolitic limestone, in heavy layers..... .... 15 feet.
No. 1. Yellowish, shaly, fine-grained sandstone .... 20 feet.

No. 1 of this section at Indiantown is equivalent to No. 1 of the section at Burlington; No. 2 is equivalent to No. 6 there; and No. 3 to No. 7 at the same place. The characteristic fossils of the Kinderhook formation prevail throughout the whole series of beds found at Indiantown, even including the whole forty feet of No. 3. Although the upper part of No. 3 presents the lithological appearance of some parts of the Burlington limestone, yet its distinctive palæontological characters are wanting or feebly shown. The whole is therefore referred to the epoch of the Kinderhook beds, especially since the line of demarkation between the rocks of that epoch and those of the Burlington limestone is nowhere definite.

At Orford, near Indiantown, bed No. 2 is well exposed, and is there extensively quarried for lime, as it is also at the last named place. Near LeGrand, in the eastern part of Marshall county, and only a few miles west of Indiantown, No. 3, of the preceding section is well exposed, showing a thickness of about forty feet from the level of the Iowa river. Nos. 1 and 2 do not appear there, having passed beneath its surface by a westerly dip, aided by the slope of the stream. The exposure here is composed almost entirely of light brown or buff-colored limestone, more or less magnesian; and in some of the more calcareous layers a slight tendency to oolitic structure is seen. Some of the layers are cherty, but a large part of it is quite free from silicious matter.

The stone is largely quarried for various purposes, and the finer layers, which frequently have a beautiful veining of peroxyd of iron, are wrought into various ornamental and useful objects, and it is known in the market as "Iowa marble." This stone is further described upon another page, and an analysis of it is given in Prof. Emery's report.

Several other exposures of the Kinderhook beds are known in Tama and Marshall counties, but those here mentioned are the principal ones.

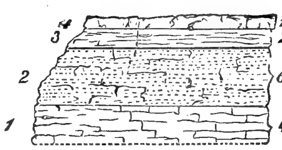
Going northward, into Hardin county, we find the rocks of this epoch somewhat changed in lithological characters, particularly at Iowa Falls. At this place, a slight anticlinal axis, having a northward and southward direction, has brought up these beds, and they have all been cut through by the Iowa river, so that they are well exposed in its banks. They are here composed of two distinct divisions, each about fifty feet in thickness. The lowest is composed of somewhat regularly bedded, tolerably pure limestone, but with little, if any, tendency to oolitic structure, although it is probably the equivalent of the oolitic bed at Indiantown and Burlington. It is soon lost to view by dipping both eastwardly and westwardly from the falls, and receives the upper division upon it. This is a rough, and in most places in this vicinity, a fragmentary and worthless magnesian limestone with occasional sandy layers.

In both of these divisions, fossils of all kinds are rare but those discovered are referred without doubt to the epoch of the Kinderhook beds, the upper division being regarded as equivalent to No. 3 at Indiantown, and No. 7 at Burlington. Going up the river from Iowa Falls, the upper division becomes somewhat more regularly bedded, and presents the common aspect of magnesian limestone in the weathering of its low cliffs. Still further up, at Alden, the lower division rises again and appears in the banks of the river for a considerable distance.

The next we find of this formation is in the banks of both branches of the Des Moines, in Humboldt county, just above their confluence. At Springvale, on the west branch, there is about fifteen feet in thickness of light gray oolitic limestone exposed. It appears in the banks and bed of the stream for the distance of nearly a mile and then passes from sight both above and below. The rock here is all more or less oolitic and is, without doubt, equivalent to Bed No 6, at Burlington.

A couple of miles eastward from these exposures, other strata are seen exposed in the banks of the east branch of the river just above the town of Dakota, and are represented by fig. 8.

FIG. 8.



These strata consist of the following beds:

No. 4.	Gray fragmentary limestone	1 foot.
No. 3.	Marly and sandy clay	2 feet.
No. 2.	Calcareous sandstone, in thin layers	6 feet.
No. 1.	Heavy bedded, yellowish, magnesian limestone	4 feet.

No positive evidence of the relation of these strata to those found at Springvale, a couple of miles to the westward, was obtained, but they are supposed to belong above those oolitic strata there, and in part equivalent to the upper division at Iowa Falls.

In the valley of the west branch of the Des Moines, about five miles above Springvale, the Kinderhook limestone again appears, showing a thickness of about fifteen feet. It is here composed of grayish, thin bedded limestone, inclined to become fragmentary upon exposure, but shows very little of oolitic structure.

Going westward from here to a point near the headwaters of Lizard creek, in the eastern part of Pocahontas county, we find the most northerly and westerly exposures of the Kinderhook formation yet known anywhere. The exposures are somewhat inconspicuous and are found in a shallow prairie valley. The rock is similar in character to that last named but a little oolitic in its texture. The fossils it contains here are very few, but they leave no doubt as to the correctness of referring the strata to the Kinderhook formation. Some other important exposures occur in the eastern part of Franklin and the western part of Butler counties, but those described are sufficient to give an idea of the general characters of the formation.

Economic Value. The economic value of this formation is very considerable, particularly in the northern portion of the region it occupies. The only material, however, of any practical value is its stone, and this, although not usually of fine quality, is of greater value there than elsewhere, because stone of any kind is scarce in that part of the State, while the southern portion of the region is in immediate neighborhood with the Burlington limestone which there furnishes better material.

In Pocahontas and Humboldt counties the Kinderhook beds, although so slightly exposed, are almost invaluable because no other stone, except a few boulders, is found there, and because it makes excellent lime, besides serving a good purpose for ordinary masonry.

At Iowa Falls, the lower division is very good for building purposes as well as for lime. Many of its layers produce excellent blocks for dressing into window and door caps and sills and other important parts of good buildings. In Marshall county, all the limestone to be obtained comes from this formation, and the quarries near Le Grand are very valuable. Many of the best layers there are so massive and free from silicious impurities, that they are readily sawed into all desired forms for building purposes, by machinery erected there for the purpose. Some of the layers as before mentioned are finely veined by per-oxyd of iron, and are wrought into beautiful table tops, mantels, and other ornamental and useful objects. Without wishing to under estimate the real value of this stone for such purposes, which is very great, it is, nevertheless, proper to say that the hardness of none of it is equal to that of real marble, and consequently its polish cannot be expected to endure so long when exposed to the weather. Therefore, it is not so well suited for monuments and other similar purposes as true marble is, but no valid objection can be raised against its use in the walls of the most important buildings. The analysis of this rock may be found in Prof. Emery's report in volume two.

In Tama county the oolitic member is well exposed at several places where it is quarried and used for the manufacture of lime of excellent quality. It has been proposed to manufacture this oolitic stone into table-tops, mantels, etc.; but although it may be made to receive a fair polish and its oolitic structure gives it considerable beauty, it is feared that the well known tendency of all oolitic limestones to become fragmentary will be found to render it worthless for such purposes. However, that near Orford and Indiantown promises to prove valuable for such uses.

This tendency of oolitic limestone to become fragmentary has been very often shown at Burlington, where stone from the oolitic bed there has frequently found its way into buildings and street improvements. Upon exposure to the atmosphere and frost, it sooner or later crumbles to pieces, and must be replaced by more durable stone. At Burlington, where good stone is abundant, this oolitic stone should be wholly rejected for all purposes except for lime, and in walls that are never wet; and the citizens should not allow themselves to be deceived by the fine appearance of it when first quarried.

Fossils. The remains of fishes are the only fossils yet discovered in this formation that can be referred to the sub-kingdom VERTEBRATA; and so far as they have yet been recognized they all belong to the order Selachians. They are referred to the following genera, namely: *Cladodus*, *Helodus*, *Cochliodus* (?) (and undetermined species.)

Of ARTICULATES, only two species have thus far been recognized. Both of them belong to the genus *Phillipsia*.

The sub-kingdom MOLLUSCA is largely represented, including the classes *Cephalopoda*, *Gasteropoda*, (including *Heteropoda*,) *Pteropoda*, *Brachiopa*, *Lamellibranchiata*, and *Polyzoa*. Want of time has prevented the preparation of a complete list of the genera and species of these fossils.

The RADIATA are represented by a few Crinoids, usually found in a very imperfect condition, but the following genera have been recognized, namely: *Platycrinus*, *Actinocrinus*, *Rhodocrinus*, *Schaphiocrinus*, and *Poteriocrinus*. The sub-kingdom is also represented by the coral genera *Zaphrentis*, *Tavosites* (?) *Leptopora*, *Syringopora*, *Aulopora*, and *Chætetes* (?)

The prominent feature in the life of this epoch was molluscan; so much so in fact, as to overshadow all other branches of the Animal Kingdom. The prevailing classes are *Lamellibranchiates* in the more arenaceous portions, and *Brachiopods* in the more calcareous portions.

No remains of vegetation have yet been detected in any of the strata of the formation.

So far as Iowa is concerned, it is a fact worthy of notice that fossils in this formation are far more abundant in its southern part, where it is more arenaceous, than they are in its northern part, where it is more calcareous.

2. THE BURLINGTON LIMESTONE.

Syn.—ENCRIMTAL LIMESTONE OF OWEN AND OTHERS,

Area and General Characters. It has been shown that the Kinderhook beds pass so gradually into the Burlington limestone, both by their lithological and palæontological characters, that it is difficult to say where the one ends and the other begins; but the separation of the other formations of the Sub-carboniferous group from each other is of a different character, being more abrupt and distinctly defined, and very similar in all cases.

This separation consists in the interposition of a series of silicious beds between each of the distinctive limestone formations, which, although they form an uninterrupted stratigraphical passage from one to the other, constitute the palæontological boundary between them. This change in the lithological character of the deposit, which, commencing gradually, foretold the close of the epoch, seems to have had the effect to check, and finally to arrest the progress of those forms of life which previously existed in great profusion. Then with the resumption of the calcareous deposits that ushered in the succeeding epoch, similar, but not identical forms were introduced, which flourished and progressed until checked and arrested again by similar deposits of silicious strata that continued to accumulate until the close of another epoch.

Thus the accumulation of the strata which compose all the formations of the Sub-carboniferous group in southeastern Iowa, from the Lower Burlington limestone to the St. Louis limestone, inclusive, was evidently uninterrupted, while the epochs that passed during the time in which the accumulation took place, are marked by lithological changes in those strata, and also by the specific changes in their fossil contents.*

The Burlington limestone formation consists of two distinct calcareous divisions which are separated by a series of silicious beds, such as have been referred to as separating each limestone formation of the group. These beds consist of light grayish or yellowish layers of silicious shale and

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*This is the case in the southern part of the State where the series is complete as far as it is represented, but, as will be seen further on, there is some unconformability among the different formations of the group farther to the northward, as well as the unconformability of the coal-measures upon them.

chert together with nodular masses of flint; the whole mixed with a smaller proportion of calcareous matter. The existence of these silicious beds of passage from one calcareous division to the other, itself suggests the propriety of regarding the Burlington limestone as two distinct formations, and this suggestion is strengthened by some well marked palæontological differences also, especially in its crinoidal remains. Both divisions of the Burlington limestone are eminently crinoidal, that is, they are prominently characterized by a profusion of crinoidal remains, all of which in each divisions are specifically distinct from all of those in the other, so far as yet ascertained. It seems that the accession of silicious material to the waters of that epoch resulted in or at least was followed by the extermination of all the species of crinoids then existing, and although they flourished in just as great profusion when the calcareous condition of the waters was restored, they were all of new species; these being all in turn exterminated by the accession of the silicious material which we find to mark the close of the full epoch of the Burlington limestone.*

The objection to the separation of the two divisions lies in the fact that the area over which this distinction has been recognized is quite limited, and the interests of geology can hardly be served by multiplying names that have only a local or very limited application. The two divisions will therefore be considered as one formation in this report, and the thickness of it as given in the table and section on preceding pages includes both divisions of the limestone together with both series of silicious beds which separate and terminate them respectively.

A characteristic outcrop of the Burlington limestone is

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* From the fact that the extinction of the forms of life, that characterized each of the limestone epochs of the Sub-carboniferous group, was commenced with and gradually accomplished during the deposition of those silicious beds of passage, the latter are regarded as the upper portion and the limestone as the base and middle portions of the formation. Therefore, the silicious beds above all the Burlington limestone are included with it, and the "geode bed" is for the same reason included with the Keokuk limestone.

shown in the next preceding full page sketch, which also shows an exposure of a part of the Kinderhook beds, the projecting portion being Burlington limestone. The locality is near "Starr's mill," about three miles northwest from Burlington.

The lower division of this formation is composed of yellowish, gray subcrystaline limestone, about twenty-five feet in thickness. It is somewhat regularly bedded and seldom has any shaly or clayey matter in the partings of the layers. A few feet in thickness of the lower portion, where it joins the Kinderhook beds, are sometimes a little sandy, but rarely so.

The central portion contains the purest and best limestone layers, but they gradually become flinty towards the top as they merge into the silicious beds of passage to the upper division.

These last named beds are composed of compact cherty or flinty layers alternating with thicker beds of looser silicious but not sandy shales, of a light yellowish color, and an occasional thin, irregular layer of limestone. These silicious beds are also about twenty-five feet in aggregate thickness, making fifty feet for the whole thickness of the lower division.

The upper division consists in its lower portion of light gray subcrystaline limestone, the color, however, varying to yellowish gray, and is about fifty feet in thickness. It is composed of somewhat regular layers, usually thin, but sometimes massive, with occasional clayey partings, but the latter are not common. The limestone of this division is, as a rule, more silicious than that of the lower division. Even those layers that are not intercalated with flinty seams have numerous small flinty masses imbedded in them, and the fossil shells they contain are not unfrequently silicified when the rock imbedding them is not so. Towards the top the silicious matter increases in amount, until the limestone merges into the silicious beds which complete the formation and form a final passage to the Keokuk limestone. In the vicinity of Burlington these silicious beds are not found to exceed forty or fifty feet in thickness, but farther southward they reach near a hundred feet in thickness, and produce the obstructions in the Mississippi river known as the Lower Rapids. These are the most important and thickest of any of the silicious beds which separate the limestones of the Sub-carboniferous group.

The southerly dip of the Iowa rocks carries the Burlington limestone down, so that it is seen for the last time in this State in the valley of Skunk river near the southern boundary of Des Moines county. Fifty miles to the southward of this, at Quincy, Illinois, it rises again, unchanged in any of its characters, and is seen well exposed also at Hannibal, Missouri, as well as at various other places in both of those States. To the northward of Burlington, its typical locality, it is found frequently exposed along the bluffs that border the Mississippi and Iowa rivers in the counties of Des Moines and Louisa, as well as occasionally upon their smaller tributaries in the same region. The most northerly point at which it has been recognized in its unmistakable characters is in the northern part of Washington county, but it doubtless extends still further in that direction, although hidden by the overlying drift. Indeed it probably exists as far north as Marshall county, but it has not been recognized there in its unmistakable characters.

Economic Value. The Burlington limestone affords much valuable material for economic purposes, but which is confined, however, entirely to its stone. The lower division being much exposed within the city of Burlington, it has been very largely used there for building purposes and street improvements. It is seldom that it affords suitable ashlars for dressing, but for the purposes of common masonry it is excellent, as it endures exposure to the atmosphere and frost without appreciable change. Good lime may be made from it, but the greater part of the lime used in the region occupied by the formation is made from the upper division, because it usually produces whiter lime, and because that rock is usually nearer to supplies of the necessary fuel.

The upper division furnishes excellent common quarry rock wherever it is exposed, and from some of the layers suitable blocks are obtained for dressing into the various forms needed in the better kind of buildings. The rock of this division is also strong and endures exposure well. That of both divisions has been largely used for macadamizing the streets of Burlington, to which is sometimes added the flinty masses of the silicious beds, the only purpose for which the latter are of any economic value. The upper division is of the greatest economic value, the material being a little better than that of the lower, greater in amount and occupies a greater surface area.

The color of some portions of the limestone of the upper division is so nearly white and its texture somewhat crystaline, the purer pieces resemble marble, but the want of uniformity in its texture and the presence of silicious lumps and particles in it will prevent its successful use for any ornamental purpose.

Fossils. The Burlington limestone received its name from the city where its peculiar characteristics are best shown, and have been most studied. The formation has in turn caused the name of the city to be spoken among men, who otherwise would have hardly been aware of its existence; for the great abundance and variety of its characteristic fossils—*crinoids*—have justly attracted the attention of geologists and naturalists in all parts of the enlightened world. Although the area occupied by the outcrop of this formation in Iowa is comparatively so small, yet the fossil remains it has afforded are of the most remarkable character and profusion. The abundance and variety of the crinoidal remains of both divisions constitute indeed the most distinctive palæontological feature of the formation, but were this characteristic absent or less conspicuous, it would still have a distinguishing palæontological feature in its fish remains.

Vertebrates. The only remains of vertebrates which the formation has thus far afforded, are those of fishes. The greater part of these are the teeth and spines of *Selachians*—

fishes related to the sharks of the present seas. The others, which are rare, consist mainly of the dermal plates of *Ganoids* —fishes somewhat related to the gar-pike of the Mississippi and its tributaries. No remains of bony fishes, like those most common at the present day, are found in these rocks, and it is believed that none such existed at the time the material of those rocks were being deposited.

Besides the occurrence of fish remains as isolated specimens at various localities, and throughout the whole vertical range of the formation, they are particularly numerous at some limited localities, where they are sometimes found crowding the entire substance of a single stratum for a considerable dis-ance. It has been supposed that the strata of this formation, thus charged with these remains as seen at many and distant localities, were parts of one continuous and uninterrupted horizon, all having had a simultaneous origin. It was thought that this assumed horizon was to be recognized at many localities in southeastern Iowa and western Illinois, some of which are more than a hundred miles apart. It is more probable, however, that there are many horizons in the formation, characterized by a profusion of fish remains, all of which are comparatively quite limited in extent.

On Buffington creek near Columbus City, in Louisa county, there is a stratum in an exposure of this limestone having a thickness of from eight to twelve inches, so fully charged with these remains, that a part of it might with propriety be called bone breccia.* Above and below the stratum are the ordinary firm layers of Burlington limestone. The fish-stratum itself is nearly of the same texture, but a part of it is soft and friable, and sometimes slightly magnesian. The rock, as usual, is colored yellowish with per-oxyd of iron, and where the fish remains are the most abundant, it has a greenish tinge, with numerous specks of deeper green. A qualitative analysis of this greenish rock by Prof. Emery, shows the

* This interesting locality was discovered by Frank Springer, Esq., of Burlington, who has made for himself a fine collection of all species found there.

presence of a considerable quantity of phosphoric acid, the phosphorus, without doubt, having been originally derived from the decomposed bodies of the fishes. Irregular, globular or elongated masses of small size are not unfrequently met with in the strata that contain more or less fish remains. These also show a considerable proportion of phosphoric acid upon analysis, and are without doubt coprolites—the fossilized excrement of fishes. Besides their chemical composition and other characters which suggest such an origin for those bodies, the microscope, and often even the unassisted eye, discovers them to be partly composed of the comminuted shells of mollusks that formed the food of these rapacious tyrants of the ancient seas.

The fish-stratum at Buffington creek can be distinctly traced for the distance of half a mile, with only slight interruptions by concealment, and is as well marked where it is finally lost from view in both directions as it is in any part of the exposure.

In the valley of a small creek a few miles west of Burlington, another similar stratum is to be seen enclosed between firm layers of Burlington limestone. Still others have been found in the same formation at Monmouth; on Honey creek in Henderson county, and at Quincy, all in the State of Illinois; but the most remarkable locality of the kind yet discovered, is the one in Louisa county, Iowa, which has just been described.

Besides many specimens not yet studied and identified, some of which are probably yet new to science, the following genera have been recognized as occurring in the Burlington limestone, namely: *Cladodus*, *Petalorhynchus*, *Polyrhizodus*, *Antliodus*, *Chomatodus*, *Orodus*, *Helodus*, *Psammodus* (?) *Cochliodus*, *Deltodus*, *Sandalodus*, *Trigonodus*, (and undetermined species). These are all Selachian genera; the Ganiod remains are comparatively rare, and have thus far been very little studied.

In the lower division of Burlington limestone, fish remains are less common than they are in the upper division, but more so than they are in the Kinderhook beds. In the upper division their abundance is so largely increased that they form a very conspicuous feature of its palæontology; and taken together, with the abundance of similar remains in the Keokuk limestone, these vertebrate relics constitute a prominent character of the palæontology of the whole group of Sub-carboniferous rocks of Iowa.

ARTICULATES. Remains of Articulates are rare in this formation, and, so far as yet discovered, they are confined to two species of trilobites, both belonging to the genus, *Phillipsia*. One, if not both of these, is specifically different from the two species found in the Kinderhook beds.

MOLLUSKS. Fossil shells are very common in this formation, but they constitute a much less prominent palæontolgical character of it than they do of some of the other formations of the group. The classes *Gasteropoda*, *Pteropoda*, *Brachiopoda*, *Lamellibranchiata* and *Polyzoa* are all represented; but thus far no *Cephalopods* nor any specimens of the *Heteropod* division of *Gasteropods* have been recognized in the true Burlington limestone.

RADIATES. The two lowest classes of the sub-kingdom Radiata, are represented in the genera *Zaphrentis*, *Amplexus* and *Syringopora*, while the remains of the highest class—Echinoderms—are found in both divisions of the formation, in the most extraordinary profusion. A few of these are Asteroids and Blastoids, but Crinoids are more abundant than all other Radiates. The number of species of Crinoids alone that have been obtained from the Burlington limestone of Iowa and the adjoining States, is now known to reach more than three hundred.*

* At Burlington several persons have made important collections of fossil Echinoderms; but the collection made there by Mr. Charles Wachsmuth, within the last twelve years, is most remarkable, and is without doubt the most extensive collection of the kind in the world, made at one locality. Mr. Wachsmuth has furnished me with the following summary of his collections made at, and in the vicinity of Burlington alone, from both divisions of the Burlington limestone:

Crinoidæ	338	Species, included	in	40	Genera.
Blastoidæ	17	"	"	4	"
Echinidæ	6	"	"	3	"
Asteroidæ	4	"	"	2	"
Ophiuridæ	1	"	"	1	"
Total Species	366			50	Genera.

3. THE KEOKUK LIMESTONE.

Syn.—LOWER ARCHIMEDES LIMESTONE OF OWEN AND OTHERS.

Area and General Characters. The Keokuk limestone consists in Iowa of about fifty feet in maximum thickness of grayish limestone, usually having a bluish tinge, together with about forty feet of shaly, calcareo-silicious strata, usually containing many silicious geodes, and forming a gradual passage to the St. Louis limestone above. It occupies a more limited area than any other formation of the Sub-carboniferous group in Iowa. It is well developed and largely exposed at the city of Keokuk, from which the formation derives its name, but the most northerly point at which it has been recognized is in the northern part of Des Moines county, where it has nearly thinned out, and it appears also much thinner all along the eastern border of its outcrop in that county than it does in the vicinity of Keokuk. In the southwestern part of Washington county, the St. Louis limestone appears in such proximity to the Burlington limestone as to render it almost certain that the Keokuk limestone has thinned out there. The general westerly dip of the rocks in this part of the State is so great, that the Keokuk limestone not only thins out upon the Burlington limestone in Des Moines county, but it also passes beneath the St. Louis limestone in its southwestern portion. The general dip of all the formations, being southerly as well as westerly, would naturally carry the Keokuk limestone so far beneath the surface in Van Buren county, that it would not appear at all there if it were not that a gentle anticlinal axis, having a northerly and southerly direction, brings it up to the surface again along the Des Moines river at and in the vicinity of Bentonsport. From this region the general dip carries it beneath the succeeding strata, and it is seen no more in Iowa. It is only in the four counties of Lee, Van Buren, Henry, and Des Moines that the Keokuk limestone is to be seen ; but it rises again and is seen in the banks of the Mississippi river some seventy-five or eighty miles below Keokuk, presenting there precisely the same characters that it has in Iowa.

The calcareous portion of the formation—the Keokuk limestone proper—consists of more or less massive layers of subcrystaline limestone, alternating with layers of bluish marly shale, sometimes amounting only to a mere parting between the layers of limestone, but at other times they form beds of two or three feet in thickness. This is its character at and in the vicinity of Keokuk, but as it thins out to the northward it is less shaly. The upper silicious portion of the formation, known as the Geode bed, nowhere reaches so great a thickness as the upper silicious portion of the upper division of the Burlington limestone does at the rapids above Keokuk; but the great thickness there of the latter is probably only a local development. If that is the case, we have a gradual increase in bulk of these silicious beds of passage from that one which separates the two divisions of Burlington limestone, to the Geode bed inclusive. Not only is this probably the case, but there is also a gradually increasing amount of silicious matter disseminated throughout the limestone itself, from the lower Burlington limestone to the Keokuk limestone inclusive. This silicious matter in the limestones has not been mechanically deposited as sand has, yet much of it is in a finely divided condition. It has a tendency to form irregular concretions in the limestone, sometimes accumulating around a fossil shell as a nucleus, or the shell itself becomes silicious while the imbedding limestone is quite pure, showing that there has been a movement and re-arrangement of the molecules of silex since the original deposition of the material now composing the rock. With the completion of the Geode bed above the limestone portion of the formation, the tendency to the accumulation of silicious strata by precipitation of silex is very greatly diminished. The St. Louis limestone is not free from cherty bands and nodules, but their aggregate amount is so small that it presents quite a contrast with the formations which preceded it.

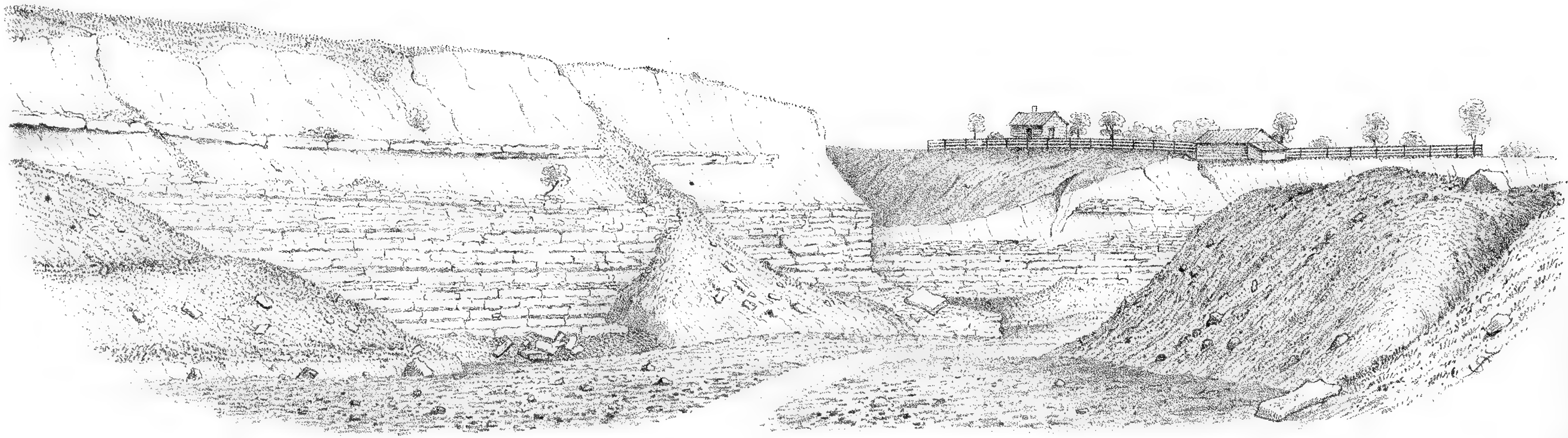
The geodes of the Geode bed are so attractive, as showy specimens in mineralogical cabinets as to merit a brief notice. They are more or less spherical masses of silex, usually hollow and lined with crystals of quartz. The outer crust is rough and unsightly, but the crystals which stud the interior cavity are often very beautiful. The prevailing kinds of crystals are of quartz, but those of calcite are quite common in the same geode. Sometimes they also contain crystals of the sulphurets of iron and zinc. They vary in size from that of a walnut to a foot in diameter. The crust of the geodes in this formation is invariably silicious, but geodes are found in the soft magnesian limestone of Devonian age in Bremer county, the crust and lining crystals of which are carbonate of lime, some of which are quite free from silex.

The Geode bed of the Keokuk limestone seems to be somewhat local in its development as such, because it is not recognizable in the northern portion of the formation in Iowa, nor in connection with it when it rises again, seventy-five or eighty miles below Keokuk.

Economic Value. The economic value of this formation consists entirely in its stone, but this is very great. Some of its layers furnish the finest quality of building material yet found in the State; large quantities of which have been carried to distant points for the erection of costly structures, among which is the Custom House and Post Office building at Dubuque, and a part of that also at Des Moines. The principal quarries of it are upon both banks of the Mississippi river from Keokuk up to Nauvoo, a distance of about fifteen miles. Many quarries are also worked within the city of Keokuk.

The accompanying sketch of one of them in the southern part of town will give an idea of the stratification and general aspect of such exposures.

Notwithstanding the great value of much of the stone of this formation, care is requisite in selecting building rock from it, because some of the layers, although they look well when first quarried, will, nevertheless, split and crumble to pieces upon exposure to the atmosphere and frost much in



EXPOSURE OF KEOKUK LIMESTONE, KEOKUK LEE CO, LOOKING EAST.
1868

the same manner that the stone of the oolitic limestone at Burlington does. These layers, however, as well as the greater part of the others, make excellent lime, so that the whole region occupied by this formation is well supplied with that indispensable article.

Fossils. The only vertebrate remains in this formation are, as might be expected, those of fishes. These are so frequently met with that with the perceptibly waning prominence of the crinoidal characters of this limestone, as compared with those of the Burlington epoch, they constitute, next to the crinoids, the most prominent palæontological feature of the formation.

So far as yet discovered, the fish remains of the Keokuk limestone all belong to the order Selachians, and consist of both teeth and spines; the latter being referred wholly to that order, because no undoubted Ganoid remains are found in the formation. Some of the teeth and spines are of great size, indicating that their owners probably reached a length of twenty-five or thirty feet.

None of those distinct layers of rock crowded with fish remains, such as were before mentioned, as occurring in the Burlington limestone, have been discovered in the Keokuk limestone within the limits of Iowa, but such remains are more generally distributed throughout the strata of the formation. The genera thus far recognized in this formation are *Cladodus*, *Petalorhynchus*, *Chomatodus*, *Antliodus*, *Helodus*, *Orodus*, *Psammodus* (?), *Cochliodus*, *Pœcilodus*, *Deltodus*, *Sandalodus*, *Trigonodus*, *Oracanthus*, *and Drepanacanthus*.

ARTICULATES. Two species of the genus *Phillipsia* are the only representatives of this sub-kingdom yet found in the Keokuk limestone in Iowa.

MOLLUSKS. No *Cephalopods* have yet been recognized in this formation within our State; *Gasteropods* are rare, and the *Heteropod* division of the latter class has not been recognized. A few *Lamellibranchiates* are found, and *Brachiopods* and *Polyzoans* are quite abundant. Among the latter is the form supported upon a spiral axis, known by the sub-generic name of *Archimedes*, and which gave the former name to this formation. Although the remains of those two classes of mollusks are common, and in some parts of the formation even abundant, its crinoidal and fish remains constitute its most important palæontological features.

RADIATES. Of corals, the genera *Zaphrentis*, *Amplexus*, and *Aulopora* are found, two species of the former genus being quite common, but crinoids are far more abundant than all other radiates. Indeed the Keokuk limestone is decidedly crinoidal, but not so conspicuously so as both divisions of the Burlington limestone are.

In an article published by the writer in 1860, an interesting relation was shown to exist between these limestones of the Sub-carboniferous group, by means of their crinoidal forms. Thus, by comparing collections of these fossils from both divisions of the Burlington limestone, together with those from the Keokuk limestone, we find that they exhibit three successive grades of general type. Taken as a whole, those of lower Burlington limestone are of smaller size than those of the upper, and these latter are generally smaller than those of the Keokuk limestone. Again, those first named, have generally a delicacy of construction and surface ornamentation, together with a pleasing symmetry of outline, which cause them to present quite a contrast with those of the upper division, the aspect of the latter being more gross, and their ornamentation coarser. In the Keokuk limestone, most of the species are large, and they reach there a culmination of rudeness in their ornamentation and a strange extravagance of form, quite characteristic of its crinoidal forms.

With this culmination, crinoids cease to have much prominence among the fossils of the Carboniferous system, although they are absent from none of its formations.

The genera of crinoids and other echinoderms are not so numerous in the Keokuk limestone as they are in either of the divisions of the Burlington limestone. It is proposed to give a complete catalogue of these interesting fossils from all the Iowa formations in a future report.

PROTOZOANS. Of these low forms of animal life, a small fossil related to the sponges is found in small numbers in the Keokuk limestone. It is known by the generic name of *Sphenopoterium*, (Meek and Worthen.)

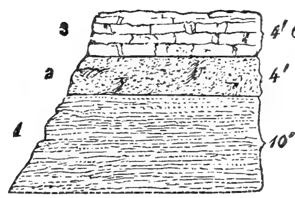
4. THE ST. LOUIS LIMESTONE.

Syn.—CONCRETIONARY LIMESTONE (OWEN); WARSAW LIMESTONE IN PART (HALL).

Area and General Characters. Although the St. Louis limestone is not the uppermost one of the Sub-carboniferous formations, as the group is recognized in the valley of the Mississippi river, yet it is the uppermost one of the group in Iowa, where the Lower Coal-measures are usually found resting directly upon it, forming, so to speak, a limestone floor for the coal-bearing formations. There are exceptions to this, but they will be more fully explained further on under the head of Unconformability of the Coal-measures upon the Older Rocks, &c. The lithological characters of the St. Louis limestone are very constant wherever they are found in the State; and being principally limestone, it presents a marked contrast with the coal-bearing strata which rest upon it. The superficial area which this formation actually occupies in Iowa is comparatively small, because it consists of long, narrow strips; but its extent within the State is known to be very great from the fact that it is found at points so distant from each other. Commencing at Keokuk, where it is seen resting upon the geode division of the Keokuk limestone, and proceeding northward, it is found forming a narrow border along the edge of the coal-field in Lee, Des Moines, Henry, Jefferson, Washington, Keokuk, and Mahaska counties. It is then lost sight of beneath the Coal-measure strata and overlying drift until we reach Hamilton county, where it is found in the banks of Boone river with the Coal-measures resting upon it as they do in the counties just named. The exposures here are very limited, and the next seen of the formation is in the banks of the Des Moines river at and near Fort Dodge. These two last named localities are the most northerly ones at which the formation is exposed, and they are widely isolated from the principal portion of the area it occupies in Iowa; between which area, however, and those northerly points it appears by a small exposure in the valley of a tributary of Skunk river, near Ames, in Story county.

At Sternberg's mill, on Boone river, six miles below Webster city, the following section, illustrated by fig. 9, was measured, commencing at the water-level below the mill-dam:

FIG. 9.



No. 3. Compact, gray, fragmentary, and concretionary limestone. 4½ feet.
No. 2. Soft, clear-grit grayish sandstone........................ 4 feet.
No. 1. Shaly calcareous sandstone............................. 10 feet.

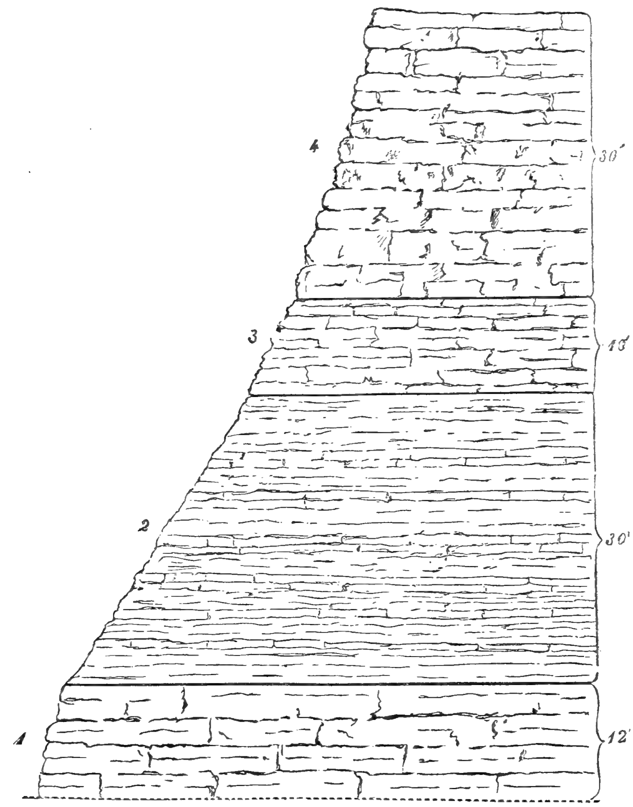
No. 3 contains fossils characteristic of the St. Louis limestone, and although none of any kind were found in the other strata they are also referred to the same formation without hesitation. A full section of the rocks at Fort Dodge, including the St. Louis limestone there, the coal-measures, and the gypsum will be found in connection with a description of the geology of Webster county.

The eastern part of the Lower coal-measure formation is so thin that the larger streams which traverse the region it occupies, have cut their valleys down entirely through it and exposed the St. Louis limestone floor upon which it rests. It is found exposed in this manner at frequent intervals in the valley of the Des Moines river from a point near the centre of Marion county to the mouth of the river. This is also the case in a part of the valley of Skunk river and of some of its larger tributaries.

The St. Louis limestone formation, as it exists in Iowa, consists of three tolerably distinct sub-divisions, principally dependent on lithological characters. These are magnesian, arenaceous, and calcareous. The first and lowest consists of a series of yellowish gray, more or less magnesian and usually massive layers. The second is a yellowish or light gray friable sandstone, and the third or upper division is principally composed of light gray compact limestone, sometimes uniformly bedded, but it often has a concretionary and even a brecciated character. These divisions may be observed to best advantage in the southeastern corner of Iowa and the adjacent parts of Illinois.

Mr. Worthen, State Geologist of Illinois, gives in his report the following section of the rocks of this formation at the town of Warsaw, on the east side of the Mississippi river, immediately opposite the southeast corner of Iowa. It is represented by fig. 10, and introduced here because it is more complete than any afforded by exposures upon the Iowa side:

FIG. 10.



No. 4.	Concretionary and brecciated limestone	30 feet.
No. 3.	Arenaceous limestone	10 feet.
No. 2.	Blue argillaceous shales and limestone	30 feet.
No. 1.	Magnesian limestone	12 feet.

The three lowest members of this section and their geological equivalents elsewhere were designated by Prof. Hall in the former geological report of Iowa as a distinct formation, under the name of "Warsaw limestone," but as there seems to be no sufficient reason for such a separation, they are in this report all referred to the epoch of the St. Louis limestone, and the use of the name Warsaw limestone dis-discontinued. The bluish argillaceous shales which so prominently characterize the exposures of this formation at Warsaw are scarcely recognizable in Iowa, even upon the opposite bank of the river; so that only the three divisions before mention are recognized in our State.

The upper division, consisting of the compact concretionary limestone, is the one most commonly met with, but both the magnesian and sandy divisions are frequently found in connection with it, and are seen even at those northern localities in Hamilton and Webster counties. The maximum thickness of the whole formation in Iowa, including its three divisions, is about seventy-five feet. The upper calcareous portion, especially in southeastern Iowa, is usually capped with several feet in thickness of grayish, fossiliferous, marly clay, and similar material often forms partings between the layers of limestone. This portion reaches a maximum thickness of about thirty-five feet. The sandstone, or middle division, reaches a thickness of twenty feet at Keosauqua, but it is usually thinner. It is sometimes shaly, but usually a clear-grit sandstone, and has been distinctly recognized in Lee, Van Buren, Mahaska, Webster, and Hamilton counties. The lower, or magnesian division, although generally consisting of a tolerably pure magnesian limestone, sometimes has a part of its layers sandy or shaly. It reaches a maximum thickness of about twenty feet.

During the time of the deposition of this formation, there seems to have been some slight disturbance of the strata, apparently amounting only to local disarrangements of its own layers. This is principally shown in the upper division and consisted in the slipping, bending, or slight distortion of

View on the Desmoines, one Mile above Keosauqua Van Buren Co, looking eastward Exposure of St. Louis limestone with interlocated Sand stone bed.
1868

all the strata. Also by the breaking up of that limestone into angular fragments, which have in many cases become re-cemented together by similar limestone material, forming the breccia before referred to. The most of this disturbance seems to have prevailed during the deposition of the upper division and to have commenced with its beginning, for at Keosauqua we find angular fragments of the limestone imbedded in the upper layers of the sandstone of the middle division, while the limestone strata above it retain their continuity. The slight local distortion of the strata of this formation is shown in the accompanying sketch of an exposure on the right bank of the Des Moines river, half a mile above Keosauqua. The upper and middle divisions only are shown in the sketch, but the extreme upper part of the lower division exists at the water's edge there, where it is brought up by one of the slight folds. At that point instead of being as usual, magnesian, it is nearly pure limestone.

Economic Value. The upper division, consisting as it does of almost pure carbonate of lime, furnishes excellent material for quicklime, even when it is so concretionary and brecciated that it will not serve a good purpose for building material. When quarries are well opened in it the layers are usually found to be sufficiently uniform for common purposes, and sometimes massive, as they are in the northwestern part of Van Buren county, where large blocks were formerly quarried for use in the now abandoned Des Moines river improvements. At several points in the vicinity of Pella in Marion county, as well as elsewhere, the upper layers of the upper division are rather thin and regularly bedded, while the lower layers of the same are uniform and thicker, and furnish some of the best quality of limestone for dressing into all desirable forms for building purposes. Wherever the strata of the upper division are exposed they furnish good material at least for common masonry and for lime.*

*Some layers of this division having a very compact texture have lately been tested for lithographic purposes, with results thus far only partially satisfactory. Further trial is necessary to fully test its value, and a company has been formed for that purpose.

The sandstone, or middle division, is of little economic value, as the rock is usually too soft for any practical use. It hardens a little, however, upon exposure, and in the absence of better material might serve for cheap structures. It is much like the sandstone of the coal-measures. The lower, or magnesian division, furnishes some excellent material for heavy masonry. On Lick creek in Van Buren county, near Kilbourne station, four massive layers of this division have furnished some excellent material for abutments and piers for the railroad bridges, and almost any desired quantity may yet be obtained there. Actual tests have shown this to be a very durable and valuable stone. In Des Moines county the magnesian layers of this division are found exposed in the valley of Long creek, about seven miles west of Burlington, and are much used in that city for the necessary dressed stone for the better class of buildings. This is the most easterly extension of the formation in that region, or the exposures there are probably part of an outlier. Wherever the magnesian rock of this lower division of the St. Louis limestone has been used it has proved to be a good and durable stone.

Fossils. None of the palæontological features of this formation stand out with such prominence as some of those of the two preceding formations do, but still they are well marked, and its characteristic fossils are so uniformly present wherever the limestone and its accompaning shales are found that one feels no hesitation as to its identity wherever it appears.

VERTEBRATES are represented only by the remains of fishes. They belong to the two orders, Selachians and Ganoids, principally to the former, among which the following genera are recognized in Iowa strata, but several other genera are known in the same formation in Illinois: *Cladodus*, *Helodus*, *Deltodus Chomatodus*, *Cochliodus*, and *Homacanthus*.

The Ganoid remains belong to the genus *Holoptychins* or to a closely allied genus. They consist of detached, subcircular scales from one inch to nearly two inches in diameter.

Associated with them, and probably belonging to the same species, are found long, slender, hollow, curved spines.

ARTICULATES are represented by one species of the trilobite genus *Phillipsia*, and two ostracoid genera *Cythere* and *Beyrichia*. The latter is so abundant at one locality, a couple of miles northward from Pella, that a bed of limestone four feet in thickness is principally composed of its cast-off shells. Specimens of both the other mentioned genera of Articulates are rare.

MOLLUSKS. The fossil shells of mollusks distinguish this formation more than the remains of any other branch of the animal kingdom. They include the classes *Gasteropoda*, *Lamellibranchiata*, *Brachiopoda*, and *Polyzoa*. No *Cephalopods* have yet been recognized in these rocks in Iowa, although they are well known to exist in the formation elsewhere. *Gasteropods* are not abundant; *Lamellibranchiates* prevail most in some of the layers of the lower division; *Brachiopods* are more characteristic of the upper division, in the marly clay and shales of which they are sometimes abundant. *Polyzoans* are not abundant in the strata of Iowa, but at Warsaw, Illinois, the lowest division there contains them in the greatest profusion.

RADIATES are comparatively rare, with perhaps the exception of the large conspicuous coral *Lithostrotion*, which is frequently met with in southeastern Iowa. Other genera are *Zaphrentis*, *Syringopora*, *Chætetes*, etc. Crinoids and all other Echinoderms are rare, showing a marked contrast in that respect between this formation and the two which preceded it. *Pentremites Koninckana*, *P. conoideus*, *Rhynchonella Ottumwa*, supposed formerly to be characteristic of the "Warsaw limestone," are all found in the St. Louis limestone of Iowa, but the two former are very rare here. The following species are regarded as more characteristic of the formation than any others: *Spirifer Keokuk var.* (Hall) *Rhynchonella Ottumwa*, (White), *Athyris ambigua*, (Sowerby), and *Lithostrotion canadeuse*, (Castelnau). The three first named species are as common at Fort Dodge as they are in the southeastern part of the State, although the two points are two hundred miles apart.

VEGETABLE REMAINS. Although Dr. Owen reported some years ago the discovery of the vegetable genera *Lepidodendron* and *Calamites* in the sandstone division of this formation in southeastern Iowa, subsequent careful search has failed to detect any trace of such remains in that sandstone, and it is therefore believed that they were observed in the sandstone of the Lower coal-measures, which closely resembles that of the St. Louis limestone formation in its lithological characters, and is frequently found exposed in the same neighborhood with it. This supposition is the more probable since he reports two divisions of the concretionary limestone, identical in character, with a series of sandstone layers between them. The existence of more than one of these we have been unable to verify. The only remains of vegetation yet known to exist in this formation consists of a few inches of carbonaceous shale found between layers of limestone near Pella, and a few fucoid-like markings upon the limestone strata there.

5. CONCLUDING REMARKS UPON THE SUB-CARBONIFEROUS GROUP.

In Iowa, the distinguishing lithological character of the Sub-carboniferous group is its limestones. These are both common and magnesian limestones; the former largely predominating. The sandstones of the earliest epoch are fine grained, which seems to indicate that the waters in which they were deposited were without strong currents. In the Burlington and Keokuk limestone formations, as seen in Iowa, sandy material is very rare, but among the strata of the St. Louis limestone, we find the first clear grit or coarse sandstones. From and after this epoch the coarse sandstones prevail, and sometimes even exceed any other strata in aggregate bulk. In southern Illinois and in some parts of Kentucky, the Chester limestone formation is largely made up of them, and by these sandstones that formation gradually merges into the Lower coal-measures, instead of the latter resting directly upon the St. Louis limestone as they do in Iowa.

The Sub-carboniferous group has another lithological peculiarity, not entirely unknown in other rocks it is true, but its prevalence and periodical occurrence are remarkable, as well as the effect it seems to have produced upon animal life in the waters in which the strata were deposited. This is the presence of the silicious material which forms the beds of passage from one of its limestone formations to another, and has been before referred to. The silex, except in a few unimportant instances, is not in the form of sand, but has evidently been precipitated from the waters of the seas in which it was at first held in solution, the increasing prevalence there of which seems to have been incompatible with the continuance of the forms of marine life that existed so abundantly during the deposition of the limestones. It seems to have been especially uncongenial to the echinoderms, for from and after the first material increase of silex in the limestone strata they began to diminish in numbers and became wholly extinct when the strata became mainly silicious; but they were introduced again in great abundance under other specific forms as soon as the limestone of the next epoch began to accumulate.

These peculiar silicious deposits, which have already been described, prevailed periodically, from the epoch of the lower Burlington limestone to the Keokuk limestone inclusive, and then ceased: at least in their distinctive form after the last named epoch.

The rocks of the Sub-carboniferous period have in other countries and in other parts of our own country, furnished valuable minerals and even coal; but so far as we know them in Iowa, the economic value of the group is confined to its stone alone.

It has been shown upon previous pages that the Lower Silurian, Upper Silurian, and Devonian rocks of Iowa are largely composed of magnesian limestones, the proportion diminishing in those of Devonian age. Coming next to the Sub-carboniferous rocks we find that magnesia enters largely into their composition also, but in a still further diminished proportion. Magnesian limestone forms a considerable proportion of the Kinderhook beds; less in the Lower Burlington limestone; it is almost absent in the Upper Burlington limestone; and also in the Keokuk limestone proper, although the Geode bed contains some magnesia. In the lower division of the St. Louis limestone there are important beds of magnesian limestone again. With the completion of the last named formation the production of the magnesian limestone seems to have ceased among the rocks of Iowa, for numerous analyses of Iowa rocks of later date fail to show more than an insignificant amount of magnesia in their composition.

Again, at the commencement of the Kinderhook epoch there was a considerable deposition of argillaceous material. Afterwards, and during the whole epoch of the Burlington limestone there was very little of such material deposited.

In the Keokuk limestone formation again we find important beds of bluish, shaly clays, and similar material also prevails in the St. Louis limestone, both as beds of considerable thickness, and as marly partings between the layers of limestone.

The remains of fishes and echinoderms constitute such prominent features in the fossil fauna of the Burlington and Keokuk limestones, as to impress that prominence upon the palæontology of the whole group. Although the Devonian age has been called the age of fishes, and perhaps very properly so as relates to the geology of the whole earth, yet so far as Iowa is concerned the rocks of no period can compare with the Sub-carboniferous in the abundance and variety of its fish remains.

Crinoids and other echinoderms are found in the strata of all ages, but they reached an extraordinary degree of profusion in the seas of the Sub-carboniferous period, as shown by their abundant remains in different parts of the world, and the rocks of that age in our own State possess a distinguished reputation in this respect, particularly those of the Burlington limestone. With their crinoidal and fish remains, the Burlington and Keokuk limestones will in the future become more famous among geologists, perhaps, than any other formations in North America. Next to those just mentioned, the most conspicuous fossils of the Sub-carboniferous rocks of Iowa are *Brachiopods*.

With the exception of a very little carbonaceous shale in the St. Louis limestone, and some traces of fucoids in the same and other strata, no remains of vegetation have yet been discovered among the Sub-carboniferous strata of Iowa. All other organic forms yet found, belong to the animal kingdom, and are all marine.

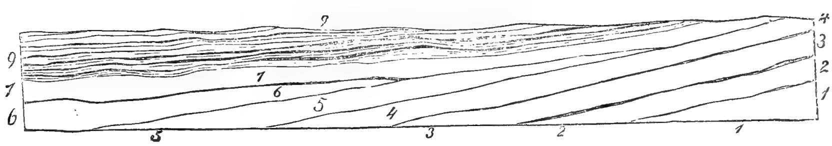
6. THE UNCONFORMABILITY OF THE COAL-MEASURES UPON THE OLDER ROCKS, AND OF THE ST. LOUIS LIMESTONE UPON THE OLDER FORMATIONS OF THE SUB-CARBONIFEROUS GROUP.

It has been shown that quite a number of the formations, which in other parts of the country help to make up the full geological series, are wanting in Iowa; yet, notwithstanding these deficiencies there is, from the Potsdam sandstone to the Keokuk limestone, inclusive, strict conformability of each one of our Iowa formations upon the next preceding one; even in those cases where several successive formations are wanting from the full geological series between them. That is, there is no lapping back of any of them over another, but their borders gradually recede from each other to the southwestward. It has been explained also, that the Kinderhook beds, resting all the way upon the Devonian rocks, can be traced from Des Moines county to Pocahontas county, a distance of more than two hundred miles. Then we find the most northerly extension of the Burlington limestone, falling far short of the most northerly point to which the Kinderhook beds have reached; it having been recognized no farther north than the northern part of Washington county in its unmistakable characters, or at most, no farther north than Marshall county. Then we find in the northern part of Des Moines county the most northerly recognized limit of the Keokuk limestone. In short, we recognize the same gradual recedence of the borders of the formations of this group, thus far mentioned, from each other, and their strict conformability upon each other that we do in all the other formations previously described.

The border of the St. Louis limestone, however, does not recede as the others have been seen to do, but on the contrary, this formation extends much farther to the northward than any of the preceding ones of the Sub-carboniferous group do, except the Kinderhook beds, and nearly as far northward as these. Consequently, the St. Louis limestone rests unconformably upon all the other formations of the Sub-carboniferous group in Iowa, notwithstanding the fact that at Keokuk, its most southerly point in the State, the Keokuk limestone, through its Geode bed, can be traced, layer by layer, to a strict conformability with and gradation into the St. Louis limestone.

Fig. 11, illustrates the relations of these formations to each other, as before described, and also their relations to the Lower coal-measures.

FIG. 11.



No. 1. Lower Silurian; 2. Upper Silurian; 3. Devonian; 4. Kinderhook beds; 5. Burlington limestone; 6. Keokuk limestone; 7. St. Louis limestone; 9. Lower coal-measures.

The number 8 is omitted to indicate the absence of the Chester limestone, which would, if present, occupy that relative position.

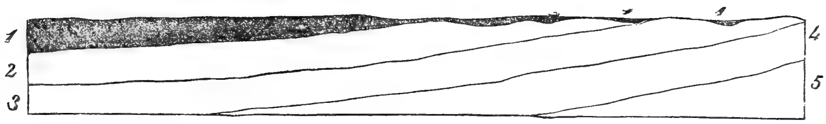
This relation of the St. Louis limestone to the older formations of the Sub-carboniferous group it will be seen is true unconformability, and differs only in degree from the greater unconformability of the coal-measures upon the older rocks, presently to be described. It is worthy of remark, that although these facts leave no doubt that the sea did re-occupy an area of land nearly two hundred miles in width which it had once receded from, we have also the evidence that it was accomplished with very slight disturbance, because we see very little of the effects of the receding and encroaching shore-line; and all flexures of these strata thus far examined can be traced to causes which flexed other and subsequently formed strata also at the same time.

At the close of the St. Louis limestone epoch the elevation of the land, and the consequent recedence of the shore line to southwestward again, was resumed upon about the same line of elevation that the previously formed strata had. The elevation now seems to have taken place more rapidly than before, because the sea border reached much farther to the southward than it had previously done, leaving no trace of the next formation, which might have been deposited during its recedence if it had tarried. The sea-border receded so far to the southward that the northern border of the next formation —the Chester limestone—did not reach within a hundred miles of what is now the southern boundary of Iowa.

At the close of the epoch of the Chester limestone, the shallow seas in which the Lower coal-measures were formed, again re-occupied the land, extending almost as far north in Iowa as that sea had done in which the Kinderhook beds were deposited. To the northeastward, its deposits originally extended much farther than the border of any of the Subcarboniferous formations, outliers of which are now found resting not only upon them, but also upon strata of Devonian age; the remainder of the formation which originally connected these outliers with each other, and with the main body of the coal-field having been removed by subsequent denudation.

The following diagram, Fig. 12, represents this unconformability of the coal-measures upon the older rocks, and the resting of the outliers upon strata of different ages :

FIG. 12.



No. 1. Coal-measures and outliers of the same; 2. Sub-carboniferous; 3. Devonian; 4. Upper Silurian; 5. Lower Silurian.

From and after the early part of the epoch of the Lower coal-measures, the former order and direction of the axis of elevation of the strata from the sea as they were successively formed, and the consequent recession of the sea to the southwestward, seems to have been exactly restored, and not to have had the general direction of the dip of subsequently formed strata at all changed, by either of the two elevations and subsidences before mentioned which the land had undergone. We consequently find the Middle and Upper coal-measures having the same general dip to the southwestward, and their outcrops the same northwesterly and southeasterly trend that the older formations have. It will thus be seen that none of the coal-measure strata lap back; or, in other words, none of them are unconformable, upon each other, although the Lower coal-measures are unconformable upon the older rocks. On the contrary, the lowest strata are found at the borders of the coal-field, and we come to higher and higher ones as we go towards the main body of the field.

The whole surface of Iowa, as well as that of other parts of of the country adjacent, having been above the sea during the time that the Chester limestone formation was being deposited beneath it to the southward, the surface was subjected to the same kind of erosion that now produces irregularities upon the earth's surface, such as that of streams and falling rains, and the disintegrating effects of the atmosphere and frost. It is probable that some of the present streams of northeastern Iowa—that part of the State never having been covered by the sea since its first elevation in early palæozoic time—now run in valleys that received their initial hollowing at that early period. In addition to this, the receding shore-line of the sea at the close of the St. Louis limestone epoch, and the encroaching one of that in which the Lower coal-measures were deposited, produced other irregularities upon the surface as well as modifications of those previously existing. Thus, when the last named sea had occupied that uneven surface, it of course formed an uneven bed for the sea until the depressions became filled with sediment deposited from its waters; after which the strata thus formed were more nearly horizontal and continuous.

The present existence of outliers of coal-measure strata at a distance from the now unbroken border of the coal-field, is largely due to the former existence of these depressions; for there is presumptive evidence that the coal-field originally extended unbrokenly as far as Scott, Cedar, Linn, Benton, and Humboldt counties, but its deposits there were doubtless originally very thin, too thin, it is believed, to have afforded profitable beds of coal if they had remained, and they were subsequently nearly all swept away by glacial or other agency, leaving only those portions which occupied the hollows as "basin-outliers." The real character of these outliers, as found in Scott, Cedar, Johnson, Benton, Tama, Marshall, Humboldt, Poweshiek, Washington, Louisa, and other counties being popularly misunderstood, has given occasion to much useless expenditure of labor and money in the search for coal.

As a rule these outliers may be regarded as practically worthless, although they are so unmistakably of coal-measure age. The large outlier extending from Muscatine nearly to Davenport is an exception, and probably others may prove to be so, but even this contains only a single bed of little comparative, although it might be of great positive value under some circumstances. The mining of it will be unprofitable, however, when brought into competition with the main coal-field by railway transportation. The writer is fully aware of the possibility of finding profitable although comparatively limited deposits of coal beyond the designated border line of the coal-field, but his object is to inform the public of the unusual hazard they are believed to incur in seeking it beyond that line.

CHAPTER III.

CARBONIFEROUS SYSTEM.—(CONTINUED.)

THE COAL-MEASURE GROUP.

The name "coal-measures" is one that originated long ago among the miners of England, and is now altogether without significance, except as an arbitrary term used to designate all that group of strata in which coal is found. It was formerly supposed that all the coal of the world was contained among the geological equivalents of the strata which contained it in England. The study of the great coal-fields of the United States and of Europe for a long time confirmed this opinion, because they were found to correspond as exactly in geological age with those in England as we can ever hope to determine geological equivalency of strata. It was afterwards found that certain varieties called 'lignite" or "brown coal" were contained in strata geologically, much more recent than those of the Carboniferous System, but it was still supposed that true coal was found alone in that System among the strata of which it was first discovered. We now know that these views are erroneous, and that all the coal of the earth was not formed simultaneously during any one particular period of its history, but that much coal was formed in the ages subsequent to the carboniferous, and some was probably previously formed.

This question of the later formation of coal has been very definitely settled by late researches in China, Mongolia and Japan, by Prof. Raphael Pumpelly, and by others in the western part of our own continent, which reveal the fact that the strata containing the coal of these vast regions are of much later geological age than the coal bearing strata of Europe and America, which were known and studied as coal-bearing strata up to within the past few years. These Asiatic coals which are shown to be of Mesozoic age, consist of both bituminous and anthracite varieties, and some of their mines are the oldest coal-mines in the world.

The coals of the western part of our own country are probably of still later origin than those of Asia, just mentioned, it being now reported that they are found in strata of Tertiary age. These western coals have been generally called lignite, but they show no more than, if as much woody structure as our Iowa bituminous coals do. In view of all these facts, not known to the earlier geologists, Prof. Newberry justly remarks, "the question is suggested whether the name given to the formation which contains the most important European coal-strata has not been somewhat hastily chosen.

However, be that as it may, the coal-measure strata of Iowa occupy the same relative position in the geological series that those do to which the name was first applied, and to which it was once supposed all the coal of the earth belonged. These later discoveries then, need cause no misconception in the mind of the student of Iowa geology when comparing it with the ordinary classification of the text-books.

The coal-measure group of Iowa is properly divided into three formations, namely: the Lower, Middle, and Upper coal measures, each having a vertical thickness of about two hundred feet where it has been most fully studied, but they probably all thicken to the southwestward.

1. THE LOWER COAL-MEASURES.

Area and General Characters. It is a matter of great regret, that circumstances require the publication of this report before this most important of all the geological formations of

Iowa has been fully and minutely studied. The very nature of the work has made it impossible to do this before other and more general portions of it were accomplished. The Upper and Middle coal-measures have been more fully studied than the Lower, the results of which will be found upon other pages.

It was shown in the preceding chapter, that the area at present fully occupied by the Coal-measure strata is considerably smaller than it was when the deposit was first formed; that from subsequent causes a wide portion of its thin border was removed, leaving only outliers or patches of that portion of the formation, resting within depressions in the older strata; many of these outliers now being found at considerable distances beyond the unbroken border of the field, with which they were doubtless once continuously connected. For this reason, and also because all the strata are so generally covered by the Drift Deposit, it is difficult to draw a line which shall indicate the exact limit of the area occupied by the coal-bearing strata. However, a line drawn upon the map of Iowa, as follows, will represent the eastern and northern borders of the coal-field of the State with sufficient distinctness for ordinary purposes, but the line, as now understood, may be found more definitely drawn upon the geological map.

Commencing at the southeast corner of Van Buren county, carry the line to the northeast corner of Jefferson county by a slight easterly curve through the western portions of Lee and Henry counties. Produce this line until it reaches a point six or eight miles northward from the one last named, and then carry it northwestward, keeping it at about the same distance to the northward of Skunk river and its north branch that it had at first, until it reaches the southern boundary of Marshall county a little west of its centre. Then carry it to a point three or four miles northeast from Eldora, in Hardin county; thence westward to a point a little north of Webster City, in Hamilton county, and thence still further westward to a point a little north of Fort Dodge, in Webster county.

Such a line, it is true, will leave to the northward and eastward of it a number of points and outliers which, although composed of true coal-measure strata, are believed to be too slightly developed in almost all cases to give reasonable hope that they will furnish a profitable coal bed. To the southward and westward of such a line the coal-field will be found unbroken save by the occasional cutting of the river valleys down through its strata to the underlying Subcarboniferous strata.

In consequence of the recedence to the southwestward of the borders of the Middle and Upper coal-measures as before described, the Lower coal-measures alone exist to the eastward and northward of the Des Moines river. It is also a fact that over the whole of this great area, comprising more than three thousand square miles, the formation is very thin, and has been often cut entirely through by the erosion of the valleys by their rivers and creeks. Considering this fact, we can only wonder that it contains coal so abundantly as it does. The Lower coal-measures also occupy a large area westward and southward of that river, but their southerly dip there passes them beneath the Middle coal-measures at no great distance from the river. The western and southern border the surface area occupied by the Lower coal-measures is somewhat irregular, and in some parts indefinite, but the area on that side of the Des Moines is more than half as great as it is upon the other.

Westward from the Des Moines river, in Webster county, nothing more is seen of the coal-measure strata except a small exposure on Lizard creek, about four miles west of Fort Dodge. The coal-measure strata of this part of the State are all of the Lower formation, and beyond it to the westward; these as well as all other stratified rocks, are lost to view beneath the heavy Drift Deposit which helps to constitute the broad ridge of the Great Watershed, until we reach the Missouri river, at Sioux City. Here we find strata of Cretaceous age. These last named strata belong in the geological series, above all others in the State, and if the coal-bearing strata exist in that region at all, they are far beneath the surface.

Proceeding southward on the west side of the Des Moines river, the next exposures of Lower coal-measure strata, except those along the banks and in the immediate valley of that river, are found in the valleys of the North and South Raccoon rivers in Greene, Guthrie, and Dallas counties. In the two last named counties the Lower coal-measure strata are seen to pass beneath those of the Middle formation. These also are the most westerly points to which the dividing line between those two lower coal formations can be traced, and it is only southerly and southeasterly from here that we find the Middle coal-measures occupying the surface. The line of division between the Lower and Middle coal-measures, so far as it can be traced, may be approximately designated upon the map as follows:

Commence at a point some five or six miles south of the northeast corner of Guthrie county, and carry the line a little south of eastward to the east boundary of Dallas county, thence southeastwardly through Indianola to the southwest corner of Marion county, thence to the northwest corner of Appanoose county, thence along Chariton river to the southern boundary of the State.

The order of succession of the strata which constitute the Lower coal-measures has not been completely made out for want of time, but some of the more important practical facts will appear in the chapter on the coal counties. The thickness of this formation, summing up all the measurements of accessible strata, is estimated at about two hundred feet.

The lithological characters of the strata of the Lower coal-measures, are greatly in contrast with those of the Sub-carboniferous formations upon which they rest. It has been shown that the latter consist principally of limestones, and that almost no carbonaceous matter is to be found among them within the limits of Iowa ; but the Lower coal-measures from their very beginning is composed of very different materials. The great bulk of this formation is sandstone and shales; the former often impure and shaly, and the latter frequently clayey. In addition to these, there is occasionally found in thin isolated layers, or, in somewhat concretionary masses, impure compact bluish limestone. At intervals among the strata are the beds of coal with their underlying beds of so-called fire-clay, the thickness of other strata between the beds of coal being very variable.

It will thus be seen that all the materials composing the formation are easily disintegrated and destroyed by exposure to the atmosphere and frost, so that the valley-sides of the whole region have gentle slopes and are nearly destitute of those precipitous, rocky bluffs which characterize a limestone region. In a few instances, however, the sandstone of this formation is firm enough to present precipitous fronts in the valley sides as may be seen in the valley of the Iowa near Eldora, and that of the Des Moines near Ottumwa; at Red-rock in Marion county, etc.

The fact that the natural exposures of the Lower coal-measures are so few, makes it difficult to obtain a correct knowledge of the order of superposition of the strata. They are few because the edges of the strata, if ever exposed, are now covered by the debris from the easily disintegrated materials which compose them. It is believed, however, that by careful study of the natural and artificial exposures of its strata, we may yet arrive at a correct knowledge of the full details of the formation.

Economic Value. No formation in the whole State possesses anything near the economic value that the Lower coal-measures do, nor is there one which will have so great an influence upon its future prosperity. These remarks, of course, refer to the coal which the formation contains; for although the Middle coal-measures will furnish no inconsiderable quantities of coal, and the Upper coal-measures also small quantities, far the greater part of that indispensable element of material prosperity is contained in the strata of the Lower coal-measures. The Middle coal-measures probably contain as many separate beds of coal as the Lower, but they are mostly too thin for profitable mining. It is true that occasionally a bed of coal in the Lower coal-measures is also too thin to be profitably mined, but there are also beds now being mined in this formation that reach from upward of three feet to seven feet in thickness of solid coal. At the close of this chapter, and in that upon the Geology of the Coal Counties also, the subject of supplies of coal will be still further discussed.

The beds of clay that underlie almost every bed of coal furnish a large amount of material suitable for potters' use, some of which is excellent for the manufacture of common stone ware.

The sandstone of the Lower coal-measures is usually soft, and much of it shaly and unfit for any practical use; but at some places it is quite a clear-grit sandstone, and has sufficient firmness to serve as excellent building material, if selected with care. This stone has some advantages not possessed by ordinary limestone. It is often so massive in its stratification, that blocks of large dimensions may be obtained, and then its comparative softness enables the workmen to fashion it into any desired shape with little labor. It hardens considerably after being quarried and exposed to the atmosphere for a few months. The best quarries at present opened in this rock are those near the town of Redrock, in Marion county, which received its name from the stone. Here the greater part of the stone is of a pleasant brick-red color, produced by the per-oxyd of iron. Some of it has been carried to the City of Des Moines for building purposes, examples of which may be seen in the State Arsenal there. It is well to repeat the caution to avoid carefully the softer portions of this sandstone for use in important structures, notwithstanding the fact that much of it is valuable.

In Davis county there is a bed of dark bluish, impure limestone, about four feet in thickness, being the heaviest deposit of limestone yet found among the strata of the Lower coal-measures in Iowa. It is of comparatively little value for the ordinary purposes to which stone is applied, but several years ago it was used for the manufacture of hydraulic lime. The lime thus produced was used in some of the now abandoned works of the "Des Moines River Improvement," but it seems to have been at least only a partial success.

On the whole then, it will be seen that the portion of the State which is occupied by the Lower coal-measures is not well supplied with building stone. Its brick clays are, however, abundant and good, and fuel for burning bricks is cheap and accessible. The clays used for bricks are the drift clays which have been derived mainly from the shales and clays of the coal-measure strata; while that used for pottery is taken from the beds which almost invariably underlie each bed of coal. The clay of some of these beds is purer and better than that of others, and excellent common stoneware is manufactured from it. Some of the clays or clayey shales of the Lower coal-measures contain so much oxyd of iron, giving it a brownish red color, that with proper grinding, it would furnish a fair article of common mineral paint, similar to that now known in the market under the name "pecora."

In another part of this report, it will be shown that some springs containing a little salt are found issuing from the Lower coal-measure strata; and an explanation of the origin of the term "Saline lands of Iowa" will also be found there.

In other countries, and in other parts of our own country, much valuable iron ore is found among the strata of the coal-measures, but although this ore in the form of hematite is almost everywhere present among similar strata in Iowa in small quantities, it is seldom of sufficient purity, and has never been found in sufficient amount to be profitably worked, even if suitable fuel for smelting were abundant and cheap.

Among other minerals found among the strata of the Lower coal-measures are sulphates of lime, strontia, and baryta, and the sulphurets of zinc and iron. All except the latter are found in very small quantities and very rarely; and they are all of no practical value, their presence there being interesting only as mineralogical facts.

Fossils. None of the strata of the Lower coal-measures of Iowa are usually found containing many fossils, but such animal remains as have been thus far discovered among them are without exception of marine origin. Judging from their analogy with existing species which inhabit salt water, they are supposed to have existed in shallow seas and estuaries.

VERTEBRATES. This sub-kingdom is, so far as yet discovered, represented only by the remains of fishes, and these belong to both the orders, Selachians and Ganoids. These remains consist of the dermal plates, teeth, and spines of the last named order, and thus far of the teeth only of Selachians. They are all rare and are mostly confined to the dark carbonaceous shales. The spines referred to the Ganoid order with some doubt, are rather small, flattened, and have a somewhat bushy extremity. They are found associated with the teeth of the genus *Petrodus*, no other fish remains being found immediately associated with them. They have thus far been found only in the dark colored laminated carbonaceous shales. Associated with these spines and teeth in the shales are often found compressed globular or ovoid lumps, from half an inch to an inch in diameter, with a dull gray color upon fracture. These are, doubtless, the fossilized excrement of the same fishes, analysis showing them to contain much phosphate of lime.

Articulates. The only remains of Articulates thus far discovered in the Lower coal-measure strata of Iowa, are a few incomplete specimens belonging to the Trilobite genus *Phillipsia*, which are very rare. It is likely that ostracoid crustaceas also exist in these strata as they do in those of the Upper and Middle coal-measures. Possibly insects also exist among them as they are known to do in their equivalents in Illinois.

MOLLUSKS. These are represented by remains belonging to the classes *Cephalopoda*, *Gasteropoda*, *Lamellibranchiata*, *Brachiopoda*, and *Polyzoa*. *Cephalopods* are rare; one small species of *Orthoceras* only being yet discovered. *Gasteropods* are not unfrequently found; and species of the *Heteropod* division of the order appear again in these strata, none having yet been found in any of the Iowa strata that intervene between them and the Kinderhook beds. *Lamellibranchiates* are found in some places in considerable numbers, but *Brachiopods* are the most characteristic fossils of the formation, *Productus*, *Chonetes*, *Spirifer*, and *Athyris* being the most characteristic genera. *Polyzoa* are also found, but are not abundant.

RADIATES are very rare in the Lower coal-measure strata, the genus *Zaphrentis* only, being thus far recognized.

PROTOZOA. No specimens of these lowly organisms have been detected in the Iowa strata of this formation, but as they are not uncommon in the Middle, and abundant in the Upper coal-measures, it is probable that they exist in the Lower also, because many of the species of fossils pass uninterruptedly through the whole series of strata which compose the coal-measure group.

FOSSIL PLANTS. With the possible exception of some specimens of silicified wood that have been found in the Lower coal-measure sandstones, which seems to have exogenous structure, all the remains of terrestial vegetation yet discovered in this formation probably belong to the class *Acrogens*. The most conspicuous of these remains, and the most characteristic of the Lower coal-measures, is one or more species of *Lepidodendron* and another of *Calamites*. Imperfect specimens belonging to these two genera are occasionally found in all parts of the region occupied by these strata, but the best collections yet obtained were made by Prof. T. S. Parvin, from the sandstones of the large coal-measure outlier at Muscatine, and during the present season he has obtained from the same place some interesting bodies that are probable the spore-cones of *Lepidodendron*. Specimens of *Calamites*, as well as of several species of ferns, are found among the strata of all three of the coal-measure formations, but the genus *Lepidodendron* seems not to have existed later than the epoch of the Middle coal-measures, or if it did its remains seem not to have been deposited in Iowa strata of later date. Specimens of it are rare in the last named formation, and have not yet been found at all in the Upper coal-measures.

Among the shales of this formation one not unfrequently finds what are evidently markings or remains of seaweeds, but they are usually too indistinct for satisfactory classification. Some interesting specimens of the impressions of fucoids, closely resembling the *Fucoides canda-galli* of the Devonian rocks of New York, have been found in the calcareous sandy shales the Lower coal-measures in Wapello county. They are probably of the same species as those described by Prof. Leo Lesquereux, from the coal-measures of Lawrence county, Pennsylvania, under the name of *Caulerpites marginatis*. Markings of *Lepidodendron* and *Calamites* have been found in the coal itself of this formation, as well as an abundance of the remains of woody fibre, that closely resembles pine wood charcoal.

2. MIDDLE COAL-MEASURES.

The passage of the strata of the Lower, into the Middle coal-measures is not marked by any well defined line of division, but considering the strata in the aggregate, they each possess characters sufficiently distinct to warrant their separation.

The area occupied by this formation is smaller than that of either the Lower or Upper, and constitutes a narrow region between them. It has been carefully studied by Prof. St. John, whose report upon it will be found in the next chapter.

3. UPPER COAL-MEASURES.

Area and General Characters. The area occupied by the Upper coal-measure formation in Iowa is very great, comprising thirteen whole counties in the southwestern part of the State, together with parts of seven or eight others adjoining. It adjoins by its northern and eastern boundary the area occupied by the Middle coal-measures. That boundary may be described approximately as follows:

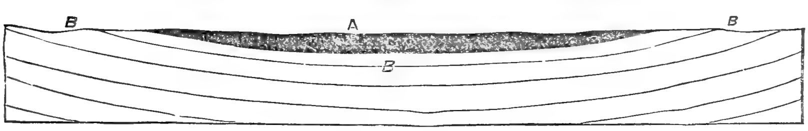
Draw a line from the northwest corner of Harrison county almost directly to the middle of the northern boundary of Madison county, thence to the northwest corner of Lucas county, thence to the middle of the northern boundary of Wayne county, thence to Centerville, and thence to the south boundary of the State, along the west side of the valley of Chariton river.

The western and southern limits in Iowa of the Upper coal-measures are the western and southern boundaries of the State, but the formation extends without interruption far into the States of Missouri, Nebraska, and Kansas.

It has been previously shown that with the beginning of the Lower coal-measure epoch, there was an abrupt change from the deposition of calcareous rocks to those of sandy and shaly composition, with comparatively little calcareous material; which material continued to be deposited throughout the whole epoch. Also, that although there was an accumulation of a somewhat increased amount of calcareous material in the Middle coal-measures, it is yet characterized principally by argillaceous and sandy shales. But when we come to the Upper coal-measures, we find the formation in Iowa to be as fully characterized by limestones as any of the formations of the Sub-carboniferous group are. Indeed, the St. Louis limestone which in Iowa immediately underlies the Lower coal-measures, and that of the Upper coal-measures are so similar in aspect and lithological characters that they have not unfrequently been confounded together. This mistake has not been made by the ignorant alone, but even geologists of acknowledged ability have regarded the two formations as one; or, at least, have mistaken the Upper coal-measure limestone for Sub-carboniferous limestone in spite of the well marked difference in the palæontological characters of each. The error of the former is doubtless due alone to the similarity of aspect and lithological characters; but that of the latter seems to have originated principally in the acknowledged similarity and even identity of some of the fossils found in our Upper coal-measure strata with those of unquestioned Sub-carboniferous age in Europe. They knew that these fossils held a position there *beneath* the coal-bearing formation of Europe, but they did not know, which is the fact, that in our Iowa strata the same species of fossils hold a position *above* our coal-bearing strata. They had not demonstrated this to be the case as has been done by the writer since the present organization of the Geological Survey of Iowa, by tracing the strata in the field consecutively from the lowest to the highest, and observing them as they dip beneath each other successively to the westward; but they erroneously assumed a position for our Upper coal-measure strata beneath our coal-bearing rocks because of a real or supposed identity of the fossils of the former with such as they had found beneath the coal-bearing strata in Europe. In consequence of this they were obliged to infer that the coal-bearing strata of Iowa occupied a broad, shallow depression or basin, and that they thinned out in all directions from its centre, allowing the Sub-carboniferous strata that dip beneath them in central and eastern Iowa to come to the surface again in western Iowa and elsewhere along the valley of the Missouri river.

The following diagram, Fig. 13, illustrates this fallacious view of the relations of the Sub-carboniferous strata with those of the coal-measures:

Fig. 13.

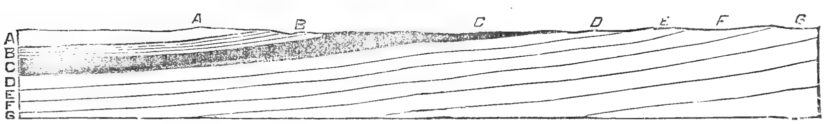


A, represents the coal-bearing strata in the position they were erroneously supposed to occupy, thinning out both to the eastward and westward upon the Sub-carboniferous strata, B., B., B.

The facts are, that while the coal producing strata do thin out at the surface, upon the sub-carboniferous rocks at the eastern border of the Iowa coal-field, they do *not* so thin out to the westward within the State of Iowa, but dip beneath the Upper coal-measure limestone to the southwestward, the sub-carboniferous limestone previously having passed beneath them, neither of which are to be seen again in that direction. Thus the sub-carboniferous rocks do not anywhere appear in the western part of the State, nor along that part of the Missouri river-valley which borders Iowa, but they are there hundreds of feet beneath the surface. It is the rocks of the Upper coal-measure age alone that appear at the surface there, if we except the Cretaceous strata farther up the river.

The next diagram, Fig. 14, shows the true relation of the coal producing strata of Iowa to the two limestone formations which respectively underlie and overlie them. This is also still further illustrated both by the geological map-model, and the lithographed plate of sections accompanying this report.

FIG. 14



A, represents the Upper coal-measure limestone formation, which is almost destitute of coal; B, the Middle coal-measures with a few thin beds of coal; C, the Lower coal-measures which contains the most important coal-beds of Iowa; D, the St. Louis limestone, formerly but erroneously confounded with A; E, the Keokuk limestone; F, the Burlington limestone, and G, the Kinderhook beds.

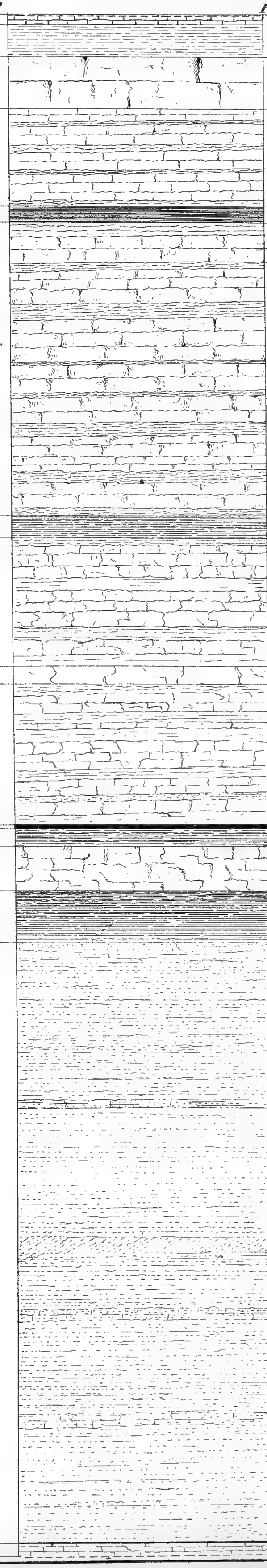
Thus, instead of there being only one formation of Carboniferous limestone, as has been supposed, and that dipping beneath the coal-producing strata at the eastern border of the coal-field of Iowa, and rising again from beneath them in the western part of the State, the truth is, there are two separate limestone formations, each possessing similar lithological, but very different palæontological, characters; the one overlying, and the other underlying the coal-producing strata. The subject of the relative age of these formations will be

GEOLOGICAL SURVEY of IOWA.

WINTERSET

SECTION

Form.		No.	Ft. In.
UPPER COAL MEASURES.	Thin bedded yellowish Limestone	16	1'
	Marly Clay	15	4'
	Massive Limestone	14	6'
	Regularly bedded limestone with marly partings	13	12'
	Black fissile carbonaceous shale	12	2'
	Compact, regularly bedded limestone with marly partings, and occasional nodular bands of Chert	11	34'
	Black fissile carbonaceous shale	10	2' 6"
	Limestone – similar to No. 7	9	15'
	Compact limestone with concretionary structure	8	2'
	Concretionary, marly limestone, some what silicious and in some parts micaceous and finely arenaceous in the intersticial layers	7	16' 6"
	Impure Coal	6	6"
	Light bluish marlite	5	2'
	Bluish concretionary limestone	4	5'
	Bluish and reddish clays	3	6'
	Arenaceous bed forming the base of the upper series of Coal measures; consisting of bluish sandy micaceous shale, and thin bedded fine grained sandstone	2	71'
M. Coal	Bluish shaly, impure Limestone	1	1' 6"



referred to further on in this chapter, under the head of Fossils.

The question is one not only of great scientific interest, but one also of the greatest practical importance to the people of the State. If the views formerly entertained by some geologists and others are correct, there is no hope of finding profitable beds of coal in the western part of Iowa, at any depth; but as the relative positions of the formations are now understood, it is reasonable to expect that we may reach profitable beds of coal by sinking shafts there at considerable but not impracticable depths. The question is further discussed under the head of Practical Conclusions at the close of this chapter.

The prominent lithological feature of this formation as before intimated is its limestones, yet it nevertheless contains a considerable proportion of shales and sandstone. The latter is usually fine grained and shaly, and the shales are often somewhat sandy, mica in minute quantity being usually present in the sand. The shales are largely composed of clayey material, but are also always more or less calcareous, so much so, sometimes, that they show little trace of stratification, become somewhat concretionary, and may with propriety be called marls; or, when more indurated, as they often are, the term marlite has been sometimes used to designate them. These marlites, which are usually partings between layers of limestone, but often form beds of considerable thickness, are sometimes very fossiliferous.

The accompanying lithograph, represents a section of Upper coal-measure strata in the order in which they are found exposed in the valley side of Middle river at Winterset, in Madison county. The exposures here are so extensive that the strata comprise the greater part of the vertical thickness of the whole Upper coal-measure formation in Iowa, so far as any opportunity has existed for measuring them, and yet the locality is only about ten miles from the border of the area occupied by the formation.

This section may be considered a typical one then, for the whole formation in our State, particularly as the litholog-logical characters here described, are the prevailing ones throughout its whole extent.

DESCRIPTION OF THE SECTION AT WINTERSET.

16.	Thin bedded, yellowish-gray limestone	1	foot.
15.	Fossiliferous, marly clay	4	feet.
14.	Massive, light gray limestone	6	feet.
13.	Compact, regularly bedded limestone with marly partings	12	feet.
12.	Black, fissile, carbonaceous shale	2	feet.
11.	Compact, regularly bedded limestone, with marly partings	34	feet.
10.	Black, fissile, carbonaceous shale	2½	feet.
9.	Grayish limestones, often silicious and impure	15	feet.
8.	Compact, heavy bedded limestone	2	feet.
7.	Grayish limestones, often cherty, and sometimes finely arenaceous	16½	feet.
6.	Impure coal	½	foot.
5.	Light bluish, marly clay	2	feet.
4.	Light bluish, concretionary and fragmentary limestone	5	feet.
3.	Bluish and reddish clays	6	feet.
2.	Fine grained shaly sandstone and sandy shales	71	feet.
1.	Bluish, shaly, impure limestone	1½	feet.
	Total	181	feet.

No. 1, of this section, belongs to the Middle coal-measures; all the remainder, to the Upper coal-measures. The locality thus receives additional interest by exhibiting the junction between the two formations. Deducting No. 1, we have remaining nearly one hundred and eighty feet in vertical thickness of Upper coal-measure strata, and yet this locality, as before remarked, is only ten miles distant from the thinned-out edge of the formation.

Other sections, illustraing exposures of strata of this formation, will be found among the descriptions of the geology of various regions and counties in PART III; the Winterset section being selected for insertion here as typical of the general characters of the formation.

As shown in the preceding section, there are throughout the whole formation occasional layers of decidedly carbonaceous material, which, although very much too impure for fuel, is nevertheless to a certain extent combustible. One of these carbonaceous horizons, and only one, so far as known, assumes the character of true coal. It is of very fair quality, but reaches only about twenty inches in maximum thickness, and thus far it has been found exposed only in the valley of the Nodaway river within the counties of Adams, Montgomery, Taylor, and Page, and at one point in Fremont county at the borders of the Missouri river valley. In the four first named counties coal for domestic and manufacturing use, has been taken from this bed, although it is so thin. In Fremont county it is too thin and impure for any practical use.

Economic Value. The material furnished by this formation of value for economic purposes is confined principally to its limestone. Wherever this stone is exposed it furnishes good material for common masonry and also for lime. In many places, excellent blocks also may be quarried for dressing into caps and sills and other desired parts of the better class of buildings.

The prevailing color of the limestone is light gray, with usually a tinge of blue. In Madison and Fremont counties, the best layers are found for the purpose of dressing, and will be mentioned in the descriptions of the geology of those counties. The sandstones of this formation, so far as yet observed, are usually shaly, and alway quite worthless. The shaly and clayey beds have yielded to glacial action and furnished material for the drift clays, and a part also of the soil. No beds of clay, sufficiently pure for good pottery, has been found in the whole formation, although it is so abundant in some parts of the Lower coal-measures. Consequently, potter's clay is scarce throughout the whole region occupied by the Upper coal-measures in Iowa.

Although this formation is known by the name of Upper coal-measures, it has been shown that it contains but a single bed of true coal, and that very thin.

Fossils. The fossils of this formation are much more numerous than they are in either the Middle or Lower coal-measures, which is doubtless due largely to the fact that the conditions of their living existence were more favorable during the deposition of the calcareous material of this formation, than during the deposition of the sandy and shaly material of the two which preceded it. Very many of the species common in and characteristic of this formation, range without interruption through the whole series of strata that constitute the Lower, Middle, and Upper coal-measures. A few species, it is true, seem to be confined, respectively, to each one of these three formations, or are otherwise restricted in their vertical range so far at least as Iowa is concerned. Thus *Chonetes mesoloba* seems to be confined to the Middle and Lower, while *Spirifer opimus* has not been recognized above the Lower, etc., etc. Some of the species of the Upper coal-measures are confined to that formation alone, but seem to appear in any part of it that presents similar lithological characters, evidently indicating that the material they are imbedded in, formed a congenial habitat for them while living.*

VERTEBRATES are, so far as ascertained, represented by the remains of fishes alone, which belong to both orders, Selachians and Ganoids; the former being most common, although rather rare. The Ganoids have not yet been studied; the following Selachian genera have been recognized: *Cladodus*, *Diplodus*, *Petalodus*, *Chomatodus*, *Peripristis*, *Petrodus*, *Helodus*, *Psammodus*, and *Deltodus*.

ARTICULATES. Two species of trilobites, belonging to the genus *Phillipsia* are found, but they are not common. The Ostracoid genera *Cytherina* and *Beyrichia* are not unfrequently met with. Of the latter there are two species, one of

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*It was with surprise and great regret that in the latter part of the year 1867, I received a copy of a work by Dr. H. B. Geinitz, of Dresden, Saxony, entitled, "Carbon formation and Dyas in Nebraska," and learned from it that that able palæontologist had referred certain fossils described in it which were collected by Prof. Jules Marcou from the rocks of Eastern Nebraska, to the Dyas (Permian) and others from other localities but in the same region partly in Iowa, to the Kohlenkalk (Sub-carboniferous limestone). I have elsewhere in this report, shown in the plainest manner that no Sub-carboniferous limestone can exist along the valley nor in the vicinity of that part of the Missouri river which divides Iowa and Nebraska. Whether the strata which do exist in Western Iowa and Eastern Nebraska are of Permian or Upper coal-measure age, may, in a manner, be regarded as a mere question of terms. If any Permian strata exist there, then indeed are all our Iowa strata of Permian age down which, *B. Americana*, is often abundant and it has also been found in the upper part of the Middle coal-measures.

MOLLUSKS. This sub-kingdom is represented by the classes *Cephalopoda*, *Gasteropoda*, *Lamellibranchiata*, *Brachiopoda*, and *Polyzoa*. *Cephalopods* are more numerous in genera, species, and individuals, than in any other Iowa formation of later age than the Devonian. *Gasteropods* and *Polyzoans* are numerous in species and individual specimens, but *Brachiopods* and *Lamellibranchiates* are the most characteristic forms.

Notwithstanding the fact that the families *Orthidæ*, *Productidæ*, and *Spiriferidæ* are approaching the close of their range in geologic time in this formation, they are fully represented here, and their species are among the most characteristic of its fossils. Of the first named family, we find the genera *Orthis*, *Meekella*, *Hemipronites*, and *Syntrielasma*. Of *Productidæ*—*Productus* and *Chonetes* are well represented by several species and numerous individuals, and *Aulosteges* also by a single small species. The family *Spiriferidæ* is represented by the genera *Spirifer*, *Martinia*, *Athyris*, and *Retzia*.

RADIATES are much more numerous than in the Lower and Middle coal-measures. Among these are two or three species belonging to the order *Echinoids*, and four or five species belonging to the family *Cyathocrinidæ*. Of corals the genera *Campophyllum*, *Axophyllum*, *Zaphrentis*, and *Syringopora* are not unfrequently met with.

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to and inclu ing a large part of the coal-bearing strata, which we denominate Lower coal-measures. I have visited in person all the Nebraska and Iowa localities from which Prof. Marcou collected the fossils described by Dr. Geinitz, and from all of them I have collected our common species of coal-measure fossils, some of which are common in the Lower coal-measures also, even down among our heaviest beds of coal. The *Brachiopods* from those Nebraska localities are *mainly* our characteristic coal-measure species, while a majority of the species of *Lamellibranchiates*, upon which Dr. Geinitz and Prof. Marcou seem most to rely to prove the Permian age of those strata, I have found far down in the series of Upper coal-measure strata of Iowa. Some of them I have found even in the middle coal-measures. It is worthy of remark, that these last named fossils especially, almost always occur in layers having a similar lithological character, the material of which, doubtless, formed a more congenial habitat for them while living, than that which produced the other strata, PROTOZOANS are represented in the greatest abundance by *Fusulina cylindrica*, some layers of limestone being almost entirely composed of their small fusiform shells. Another form, probably Protozoan, and belonging to the genus *Amphistegina* has also been found in these strata; but the details of its structure have not yet been fully made out.

4. GENERAL OBSERVATIONS UPON THE CARBONIFEROUS ROCKS OF IOWA.

It will be seen from the preceding descriptions of the formations which compose the two groups of the Carboniferous System in Iowa, that the aggregate thickness of the four formations of the Sub-carboniferous group is not far from five hundred and fifty feet. The thickness of the three formations of the Coal-measure group is by estimate and actual measurement about six hundred feet, not allowing in either case for thickening of the strata to the southwestward, which, doubtless, takes place to some extent at least. Accordingly, the entire thickness of the Carboniferous strata in Iowa is put down at about eleven hundred and fifty feet.

With the exception of rare, and usually unsatisfactory results of artesian borings, it is of course only by measurements made upon the outcrops of any formation that we are able to ascertain its thickness. We are consequently not able to say with precision where and how much a formation may thicken, or where it may thin out after it has passed from sight and reach beneath other formations. It is also often difficult to ascertain whether or not a certain formation increases or decreases in thickness in any given direction, especially if it has a dip so slight that it corresponds nearly with the general drainage-slope of the region it occupies, as for example the Upper coal-measures of a large part of southwestern Iowa do. As a rule, however, it may be inferred that the thickening, if any occurs, will be found to increase in the direction of the centre from the border of the area occupied by the formation, or in any direction within it at right angles with its border.

In the preceding pages, a general southwesterly dip of the strata of the State has been often referred to; by which it is meant that all the formations are seen to disappear beneath each other as one goes in any direction, between west and south, from the eastern part of the State. This will be more clearly understood by referring to the geological map-model in the first part of this volume. The true line of general dip is usually assumed to be at right angles with the trend or border of the formation, but this is at best only approximately correct. In the case of the Iowa strata, the true line of general dip is much more nearly to the southward than is indicated, by the trend of the borders of the respective formations, as represented upon the geological map and the map-model. This arises from the fact that the southward slope of the surface of the State is in the same direction that the dip of the strata is there, while the eastward slope of the surface of the State is in a contrary direction from the dip of the same; namely, to the westward, as well as southward. All the formations thus far described, except the last, pass beneath each other to the southward by an actual dip, which is greater than the southerly slope of the surface, while to the westward their disappearance is partly due to an actual dip in that direction it is true, but also largely due to their passing beneath others that occupy levels which are in some cases successively almost as much higher than the preceding one, as the amount of its vertical thickness.

Thus the westerly dip of the strata is more apparent than real, or at least it is actually less than it appears to be, if we lose sight of the fact that there is a westerly rise of the surface from the Mississippi river to the Great Watershed. A profile of the Burlington and Missouri river railroad, kindly furnished by its Chief Engineer, Mr. H. Thielsen, shows that Highland station, the highest point between the two great rivers, is nearly eight hundred feet above low water in the Mississippi river at Burlington, and nearly four hundred feet above low water in the Missouri river at Plattsmouth. This high point is in Union county and upon the Upper coal-measure formation with probably only the drift intervening. Allowing for the deep deposit of drift which evidently exists at Highland and in its vicinity, we may assume that the strata of the Upper coal-measures there reach an altitude of something more than six hundred feet above low water at Burlington. Now the estimated and measured thickness of all the formations which successively occupy the surface between Burlington and Highland is not much above one thousand feet; consequently, if the dip of those strata were uniform and direct to the westward, the Burlington limestone would appear in the valley of Skunk river at Chicaqua, and the Keokuk limestone in the valley of the Des Moines at Ottumwa, whereas the St. Louis limestone alone is found at both those places. This, as well as other observations, plainly shows that the westerly dip of the formations is not direct and uniform.

Although the Kinderhook beds and Burlington limestone have an exposed thickness in Des Moines county of nearly two hundred and fifty feet, the westerly dip is so great in that part of the State that these formations are seen no more west of the western boundary of that county. Continuing westward we find the St. Louis limestone alone exposed in the valleys which we cross, for a distance of more than sixty miles, showing that within that distance the strata have lost all, or nearly all, their westerly dip. We have still further evidence that a slight *easterly* dip of the same formations occurs westward from the Des Moines river on the line of the Burlington and Missouri river railroad, besides minor folds or undulations at intervals between Burlington and Highland. These are partially shown in the sheet of sections across the State, which accompanies this report.

These folds are slight, it is true, but they are, nevertheless, real. One of them has been before noticed as having brought up the Keokuk limestone at Bentonsport, on the Des Moines river where it has carried up with and above it, the St. Louis limestone and Lower coal-measure strata. Another broad one has brought up the St. Louis limestone, so that it appears at considerable height above the Des Moines river in its valley sides, in Marion, Mahaska, and Wapello counties, as may be seen illustrated in the sheet of sections just referred to. Indications of another slight fold have been observed, passing down through Warren, Clarke, and Decatur counties, and sill another is known to have nearly the same course as the East Nishnabotany river, or in other words, that stream occupies a very slight anticlinal ridge throughout the greater part of its course.

These folds have a general northerly and southerly direction but they do not all seem to be entirely parallel with each other. Some of them are so slight that their existence is likely to be overlooked, without a series of extended observations in connection with railroad levelings, particularly those in the western part of the State. It is proper to remark, however, that Prof. St. John and myself arrived at the same conclusions in regard to these folds while working separately and without each knowing the other's views. As will be seen by the section from McGregor to the mouth of Broken Kettle creek across the northern part of the State, the strata there also vary very much in the angle of their dip in different parts of the line, as they do in the southern part of the State along the line of the Burlington and Missouri River Railroad. It will be seen by both these sections, that the strata of the central portions of the State are elevated as a broad fold passing through it from north to south. In the northern part, this fold keeps the Kinderhook beds at the surface, along the line mentioned for a distance of about eighty miles, although the formation is there probably less than one hundred feet in thickness. In the southern part, the same broad fold keeps the Upper coal-measures at the surface on an east and west line for a distance of more than a hundred miles ; while the strata of Lower Silurian age in northeastern Iowa, and of lower Sub-carboniferous age in southeastern Iowa, dip so rapidly as to be soon lost to view in a westerly direction.

Westward from the East Nishnabotany river, the strata of the Upper coal-measures seem to have a slight northwesterly dip.

These various folds in the strata of Iowa, thus far mentioned and referred to, all evidently took place subsequent to the deposition of the latest strata of Carboniferous age, and before any of those of Cretaceous age were deposited; probably at the close of palæozoic time. This is inferred from the fact that all our palæozoic strata appear to have partaken of those disturbances, but the Cretaceous (mesozoic) strata do not.*

The broad fold or elevation of the strata which passes down through the center of the State from north to south, becomes so flattened in southern and southwestern Iowa that in the latter region, especially the Upper coal-measure strata, occupy the whole surface, and over nearly the whole region that it occupies, its southerly dip is almost exactly coincident with the southerly slope of the streams. This fact will be definitely referred to in the following remarks.

A section of the rocks exposed in the valley of Middle river, near Winterset, in Madison county, is given on a previous page in connection with the description of the Upper coal-measure formation, to which the reader is again referred. Although this locality is only about a dozen miles from the extreme border of its outcrop, the section is the most complete one of this formation to be found exposed at any one locality in the State, and is believed to comprise in a few of its upper members the highest beds of the Upper coal-measures to be found within its limits. Therefore, that section is frequently referred to as a typical one for the formation.

It is almost necessary to infer the gradual thickening of all the coal-measure strata to the southwestward, to some extent at least, and we have the evidence that although a few of the upper members of the Winterset section disappear, the lower members of the same do thicken in that direction, so that the

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* The strata of Cretaceous age in Western Iowa, although they seem to occupy a perfect level are found by railroad levelings and other data to have also been slightly inclined since their deposition. Their unconformability, however, upon the palæozoic strata is unmistakable.

formation, instead of being diminished in aggregate thickness further southwestward, by the absence there of a few of the upper strata found near Winterset, is doubtless thicker in the southwestern part of the State than it is near that last named town. Besides the exposures near the town where this section was measured, Madison county also contains many other fine exposures of Upper coal-measure rocks, principally along the valley of Middle river, but so rapidly do the six or seven upper members represented in that section disappear, (by thinning out, or by having been eroded), in all directions from the centre of the county that they have not been recognized outside its boundaries, except in a limited region a few miles from its southeastern corner. This disappearance of the upper members of the section is of course most rapid to the eastward and northward, because the drainage, as well as the extreme borders of the formation are in those directions, the dip of the strata being in opposite directions.

Going westward from Madison county, the first exposures to be seen are west of the Great Watershed, in the valley of the East Nishnabotany, near Lewis, in Cass county, the deep drift deposit of the intervening space having covered all strata from view. The last named exposures are referred to about the horizon of Nos. 6 to 9, inclusive, of the Winterset section. So deep are the Bluff and Drift Deposits in southwestern Iowa, that the only other exposures found in a westerly direction from Madison county are: 1, in the valley of the West Nishnabotany, in the southern part of Pottawattamie county; 2, three miles east of Council Bluffs, in the valley of Mosquito creek: 3, six miles north of that city, at the base of the Missouri river bluffs; 4, in the valley of Boyer river, a few miles from Magnolia, in Harrison county. The horizon of all these exposures is not far from the same as that to which those near Lewis, in Cass county, belong. The third and fourth, however, are probably a little higher in the series, as would also be suggested by the slight west-northwesterly dip which the strata there are known to have.

To the southward and southwestward, the exposures are more numerous, but still not abundant; because in addition to the deep surface deposits, the southerly dip of the strata there coincides so nearly with the southward drainage-slope. Going about nine miles southward from a point in the valley of Middle river, near Winterset, the whole series of beds seen at the last named point, except No. 1, are also found represented in the valley of Clanton's fork of Middle river. Proceeding still further southward, the next exposure we find is on the other side of the Great Watershed, in the valley of Grand river, and about twenty-five miles from Winterset. The strata found exposed here are referred to about the horizon of Nos. 6 to the base of 11 inclusive, of the Winterset section;* the higher beds of that section being absent here.

Following down the river, which has a general course considerably east of south, we find that its slope is a little greater than the general dip of the strata in that direction, in consequence of which it makes its exit from the State with its channel cutting the representative of No. 2 of the Winterset section near its base; or, in other words, nearly upon the upper strata of the Middle coal-measures. If the stream had a general course as much to the westward of south as it has to the eastward of that direction, the slope of the stream and dip of the strata would, no doubt, coincide with each other more nearly than they are now seen to do, because that is the direction of the general dip of the formation. As it is, the course of the stream is obliquely in an opposite direction from the westerly dip, which, in this instance, seems to be slightly increased by being upon the western side of one of the slight northerly and southerly folds or anticlinal axes, before mentioned. In all that space, between Grand river and the East Nishnabotany, there seems to be almost no westerly dip at all, while the southerly dip, as before stated, is almost

* Among the fossils found in the strata at this locality, are a large proportion of the same species which are figured and relied upon by Dr. Geinitz to prove the Permian (Dyasic) age of the strata at Nebraska city and elsewhere in Nebraska.

exactly coincident with the slope of the streams. There may be northerly and southerly folds passing through this space beneath the heavy deposit of drift, but they are very slight if they exist at all.

Thus we have the phenomena of a very considerable westerly dip of the Sub-carboniferous rocks of southeastern Iowa, which dip has been gradually lessened by the greater elevation of all the formations together in the central portions of the State than they have at its borders, until we find a part of the upper super-imposed formations having almost no westerly dip at all, in the region of its greatest elevation.

The coincidence of the southerly dip of the strata with the slope of the stream is distinctly shown in the valley of the Nodaway river. Here the thin bed of coal, before referred to as the only one yet known to exist in the Upper coal-measure formation, forms an easily recognized horizon, and may be readily traced by its exposures at frequent intervals from a point three miles above Quincy, in Adams county, to the southern boundary of the State, a distance of forty miles. In all this distance wherever the bed of coal has been found, it occupies about the same elevation, amounting to only a few feet above the water of the stream. This coal and its associated beds are referred to about the horizon of Nos. 6 to 10 inclusive, of the Winterset section.

Passing now to the northwest corner of Fremont county we identify, without hesitation, the same bed of coal there, together with its associated strata in the bluffs of the Missouri river. This point is fifty-four miles from the one first named in Adams county, and forty-five miles from the one in the valley of Nodaway river near the State boundary. By drawing lines on the map connecting these three points, we enclose a large triangular space, which may be taken to indicate the position of an imaginary triangular plane formed by the strata of this part of the State, having its sides respectively forty-five, fifty-four, and forty miles in length. Although the assumed boundaries of this plane are imaginary, we know that the position of the strata in such a plain is real. A plane so large as this being determined by actual observation, lines produced from it in all directions will of themselves give a good general idea of the position of strata of the Upper coal-measures of southwestern Iowa, until they reach points at which we know other dips take place, even if the opportunity of actual observation of the strata at the surface cannot be obtained. Fortunately, such opportunities are not wanting and their results confirm these deductions.

5. PRACTICAL CONCLUSIONS.

Usually it is of little practical importance what becomes of a formation after it has passed beneath the surface, because the labor of obtaining at any considerable depth in the earth the more common materials it may furnish is too great to render such labors profitable. Coal, however, is so valuable, indeed, so indispensible, that men are not content with seeking it among the coal-bearing strata where they occupy the surface alone, but they also pursue it into the earth as far as it is practicable to go, seeking it far beneath surfaces upon which it does not appear, and where its existence would never have been suspected, except for the knowledge geology gives of the extensions of formations beneath each other.

By reference to the geological map-model in the first part of this volume, it will be seen that the sheet which represents the coal-bearing formations passes beneath others. That sheet upon which is printed the portion representing the southwestern part of the State, represents also the Upper or unproductive* coal-measures which rest upon and cover up a large part of the two lower, or productive coal formations. When the latter come to the surface, as they do in all that part of the State represented by the uncovered part of the sheet which itself represents the formations in question, the search for coal may be prosecuted with reasonable hope

*This formation really contains one thin bed of coal as previously explained, but it is so unimportant that the formation is often referred to as "barren, or unproductive," which it really is, as compared with the great productiveness of the Lower coal-measures.

of success, at moderate depth beneath the surface, or by drifting into the sides of the valleys. Beyond the region represented by that sheet, to the northward and eastward, the search for coal will not only be extremely hazardous, but there is in all that part of the State no hope of finding it at all, except in probably insignificant quantities from small outliers, or at no great distance from the unbroken border of the coal-field, as represented in the map-model, and also upon the geological map. To the southward and westward of the area which the uncovered part of the sheet represents in the map-model, however, the case is very different; because in those directions the coal-producing strata pass entirely beneath the unproductive ones, and do not disappear by thinning out as they do in the opposite directions.

If the coal producing formations extend nearly two hundred miles in a northwesterly and southeasterly direction, and more than fifty miles in an easterly and westerly direction, as we know they really do in the region where they occupy the surface, it is reasonable to infer that they may extend at least as far in a westerly and southwesterly direction beneath the other formations with just as little change. In other words, it is reasonable to infer, that beds of coal exist beneath the surface of the southwestern part of the State, similar to those now known and worked near the surface in the vicinity of the valley of the Des Moines river. Of course this implies their continuous extension beneath the surface of the whole area comprised between the Des Moines and Missouri rivers, and between the parallel of Fort Dodge and the southern boundary of the State; and at a gradually increasing depth, at least in a southwesterly direction.

This view of the relative position of the strata being accepted, the question of the greatest importance is, how far beneath the surface, at any given point, do the beds of coal probably lie, if they exist at all, and is the depth an impracticable one for mining operations? The conclusions arrived at from an examination of the subject thus far, may be summed up as follows: It may be regarded as certain that the Lower and Middle coal-measures, which together contain nearly all the coal, extend beneath the unproductive coal-measures to the western and southwestern parts of the State; and it is reasonable to infer that they contain their coal beds there as well as where those formations occupy the surface. It is possible that the Lower coal-measure strata occupy a position nearer the surface in that portion of the State which lies westward from Webster county, than they do farther to the southward of that region; but since all the coal-measure formations of the State thin out to the northward as well as to the eastward, we should expect greater uncertainty of finding coal there than we should in Pottawattamie county; for example, because the chances of finding a good bed of coal are necessarily small near the thinned margin of the formation or border of the field.

After allowing for a very material thickening of the Upper or barren coal-measures which probably occurs, in addition to the already ascertained thickness of that formation along its outcrop, there is good reason to believe that it does not amount to enough to cover the productive coal-measures to a depth at which it would be impractible to mine coal. From examinations thus far made, it is estimated that a shaft of one thousand feet in depth will pass through all the coal-measure strata, productive and unproductive, at any point from the base of the Drift Deposit within the State of Iowa.

Therefore, there is reasonable hope that a shaft sunk for coal at any point in Southwestern Iowa, will be attended with success before reaching a depth so great as that at which coal is profitably mined in other countries. If southwestern Iowa were densely populated, capital abundant, and labor cheap, as they are in older countries, capitalists knowing the relative positions of the formations as before explained, would not hesitate to incur the expense, great though it might be, of sinking shafts of sufficient depth to prove the correctness or fallacy of these inferences legitimately drawn from the results of these investigations.

Considering the present sparseness of population and consequent limited demand for coal in that part of the State, compared with what it is capable of sustaining, and will some day possess, the high rate of interest and great demand for capital which now prevails, will doubtless cause some years to elapse before such enterprises will be undertaken in the immediate vicinity of the Missouri river, at least, with such vigor as to insure a thorough trial. Prudent men will also hesitate to commence the first of such enterprises in the vicinity named, both because of the certainty that the coal, if it exists there at all, lies at a greater depth than it does farther to the eastward; and because more or less distrust will naturally be felt as to the actual continuation of the beds of coal beneath the surface so far from their outcrop in the more central portions of the State, even although no doubt may be entertained that the formation itself extends so far.

The best and least hazardous plan upon which to proceed in these experimental enterprises, would no doubt be to commence them only a short distance westward from those points where good beds of coal are already known. If such trials prove successful, so much experience will have been gained for other similar trials still farther westward. Thus, for example, let shafts be sunk in the valley of Chariton river in Appanoose county, with the view of proving whether those beds of coal now known to exist at and near the surface in Davis county, and the parts adjoining, extend beneath that valley, and consequently beneath the bed already worked near Centreville. If successful in this, go next to the valleys of Medicine and Grand rivers in Wayne and Decatur counties. Commence in the valleys rather than upon the uplands, because a depth of digging will thus be saved equal to the depth of the valley below the general level of the uplands.

Again, along the lower courses of North, Middle, South, and White Breast rivers, the heavy beds of coal of the Lower coal-measures are known to exist. As one passes up the valleys of these streams, he comes upon higher and higher strata; and in Lucas, Warren, and Madison counties, he finds himself among the strata that bear the thin and usually uprofitable beds of coal of the Middle coal-measures. Let shafts be first sunk where only these last named beds of coal are found, for it is certain that if the heavier beds of coal which we have seen near the surface farther eastward exist here at all, they cannot lie at any great depth beneath the bottoms of the valleys there. If successful in these trials, go farther up the valleys, and if again successful, cross over the Great Watershed to the valleys of the western drainage, and finally to the valley of the Missouri river itself. If the plan here suggested should be acted upon, it will be of the utmost importance that the most accurate and careful record should be preserved of the thickness and character of the different strata passed through before the coal was reached. By means of only a few such data, with the character and thickness of each stratum accurately known, a competent engineer would be able to determine, with a good degree of accuracy, the depth at which the same bed of coal might be reached at other points, at least in the same vicinity.

Let the fact be demonstrated that the beds of coal of profitable thickness do actually extend beneath the surface to the westward, as they are here assumed to do, careful records being kept of all the strata passed through in digging, and coal-mining in western and southwestern Iowa will, within a few years afterward, be reduced to a system as reliable in its results as that adopted in our eastern or in European mines.

In this connection, it is of the greatest importance that the fullest possible information should be had concerning the identity of the coal-beds over wide areas, that we may note the changes which take place in their thickness, quality, etc. This can only be done with any degree of certainty, by long-continued observation and patient labor, which is now prevented by the discontinuance of the Survey. Enough, however, has already been learned to show that although the coal-beds may be identified at great distances in some cases, they all lack, to a greater or less extent, a uniformity of thickness. This want of uniformity consists first, of what may be termed an undulatory thickening and thinning of the beds; and secondly, of a more general and gradual diminution and increase of thickness, at points more or less distant from each other. In the first place a bed may, if not very thick, so thin out within a few rods, as to be unprofitable for working, or it may unexpectedly increase a foot or two in thickness, forming local basins, or what the miners term "pockets." This is particularly the case with many of the mines east of the Des Moines river.

In the other case, we find that where there are more than one bed in the series, one of them may be more important at one locality, and another more important at another locality. It is of course not impossible that the thin place of each bed may come at the same locality, and the thinning may possibly even amount to an entire obliteration of the coal-bed. This hazard must of course be encountered in sinking shafts for coal in southwestern Iowa, as well as everywhere else.

CHAPTER IV.

CARBONIFEROUS SYSTEM.—(Concluded.)

MIDDLE COAL-MEASURES.

1. GENERAL SURFACE FEATURES.

The present chapter embodies the results of a rather detailed reconnoisance of the counties occupied by the Middle coal measures, made during the seasons of 1867 and 1869. At the commencement of the work, the field was almost wholly new, and we had barely the slightest knowledge of this member of the coal-measure series. However, Prof. Swallow, in his explorations in Missouri, had previously recognized its existence in that State, and it was but reasonable to expect to find the same formation within our own limits. It is proper, and it gives me especial pleasure to state that, during the progress of the field-work in this region, I enjoyed every facility it was in the power of the Director of the Geological Survey to afford me, and without which little could have been accomplished in the short time necessarily devoted to the work. As it is, we cannot presume to present the subject in a complete shape, since future explorations, may, and doubtless will, add many important details, although it is believed that, in the main, we have gained a tolerably accurate knowledge of this member.

Geographical Extent. Within the State of Iowa the Middle coal formation occupies a narrow belt of territory in the southern-central portion of the State, extending from the southern boundary in a northwesterly direction, to the west of and nearly parallel with the Des Moines river, into the southwestern portion of Polk county, thence westward into Guthrie county, embracing a superficial area about fourteen hundred square miles.

The eastern border of the formation presents an irregular zigzag outline from the Missouri boundary to a point a few miles northwest of the city of Des Moines, and then trends nearly due west, passing through the central portions of Dallas and Guthrie counties. The irregularity in the border outcrops of the formation, may be, in part, attributed to the undulations of its strata, and perhaps to a greater extent, to the erosion it has undergone in the process of the streams deepening their valleys. The line of demarkation between this formation and the succeeding Upper coal formation has a corresponding irregular outline, which is also traced into Guthrie county, in the western part of which the Middle coal-measures are lost to view beneath the extensive accumulations of drift and bluff materials in the great watershed divide in that region. To the north and east the Lower coal-measures define the marginal limits of this formation.

The counties which are in greater or less part immediately underlaid by the Middle coal-measures include the following: Guthrie, Dallas, Polk, Madison, Warren, Clarke, Lucas, Monroe, Wayne, and Appanoose, and perhaps a narrow strip along the western border of Marion county. However, in Clarke and Monroe counties, no exposures of unequivocal Middle coal strata have been observed, although the general trend of the border outcrop passes across the northeastern corner of the former and the southwestern portion of the latter county. In the counties of Guthrie, Dallas, Warren, and Lucas the formation is well developed, where it has afforded an unusually interesting field for investigation.

Surface Configuration. The surface features observed in the region of the Middle coal-measures, might not at first attract the attention of the casual observer as offering any marked difference from the country of the Lower coal-measure on the one hand, and what is seen in the region of the Upper coal formation on the other. But the section occupied by this formation certainly possesses its own topographical peculiarities, which, when once a certain degree of familiarity with this as well as with the other two formations of the coal-measures is gained, thereby rendering practicable a comparative study of these features, afford as satisfactory and reliable landmarks in detecting the presence and in tracing the limits of this formation, as are found associated with any similar set of strata.

It is not unusual to find along the outcropping border of the Upper coal-measures a belt of rolling land, which gradually merges into the more gentle undulations characteristic of the Lower coal-measure region, and strongly contrasting with the plateau-like uplands common in the country occupied by the Upper coal formation, wherever that formation is not concealed beneath the excessive accumulations of detrital material pertaining to the post-tertiary period. This broken tract is especially noticeable in localities where the water-courses traverse the formation at right angles to the general trend of its borders. In the immediate vicinity of the larger water-courses, the uplands are intersected by short, deep ravines, and their valleys are bounded by more or less steep, rounded acclivities one hundred and two hundred feet in height. However, these more strongly marked topographical features are subject to various modifications, although always of a local character, and therefore, limited in extent.

It is well known that the coal-measure series of rocks in the State are traversed by more or less regular undulations, which were communicated to the middle formations equally with the others. As often occurs, the slight depressions between the low swells in the strata, are occupied by the softer deposits of the formation, and wherever the streams take their courses through these shallow synclinal troughs, it is common to find them margined upon one or the other hand, or upon both, by wide shelving slopes; as, for example, along some portions of the South Raccoon river in Dallas county, and on North river in Warren county. There are certain indefinable topographical features associated with this formation, with which the careful observer cannot fail to be impressed, however difficult it may be to convey a clear description of their peculiarities and extent.

2. GEOLOGICAL STRUCTURE.

The Middle coal formation is composed of alternating beds of clay, sandstone, and limestone. The clays, or shales, greatly predominate, constituting indeed the bulk of the formation. These beds possess all the lithological characters common to the shales in both the Upper and Lower coal-measures, which considered separately, present somewhat striking contrasts; but in this intermediate formation these features are so blended or associated as to produce persistent and easily distinguished lithological peculiarities. They present all the variegated appearances commonly observed in the shales of the Upper coal-measures; and also the arenaceous shales prevalent in the Lower coal-measures, are again represented in this formation, though to a less considerable extent. These strata are subject to more or less variability in thickness, thickening and thinning locally, but always constituting the most prominent feature in the stratigraphy of the formation.

The sandstones are the least important members of the formation, there being few persistent horizons, and these are generally represented by thin beds. However, as was observed in reference to the shales, the sandstones are also quite variable in thickness, sometimes being so exaggerated as to replace other beds, locally changing the normal aspect of the strata with which they are associated, and giving rise to many difficulties in their identification.

Thin bands of limestone are found in all parts of the formation, usually occurring in single layers of a few inches, though sometimes forming beds of a few feet in thickness, interbedded with calcareous shales. Although these beds do not present as great an aggregate thickness as the sandstones do, they are of far greater importance, both on account of their economic value and their persistent character; and, in connection with the persistent coal horizons, they furnish the most reliable guides in the study of this formation throughout its extent in Iowa. The lithological peculiarities of the limestone bands offer many contrasts to the limestones of the Upper and Lower coal-measures. Usually they present an earthy appearance, are seldom pyritiferous and carbonaceous, like some of the limestones found in the Lower coal-measures, and are generally not as compact and pure as those so prevalent in the Upper coal-measures. According to the analysis of the State chemist, they have the composition of ordinary limestone; but many of the beds are too fragmentary and easily disintegrated from exposure to be valuable for building purposes. There are other beds, however, which afford material for the manufacture of quicklime, and are employed in ordinary masonry.

Three persistent coal horizons occur in this formation in Iowa, besides other irregular beds and carbonaceous layers, which sometimes display thin seams of coal. The strata associated with the three principal coal-beds, give to this member prominent lithological and palæontological peculiarities, in the main, quite distinct from those of any of the horizons known in the Upper and Lower coal-measures.

In the prosecution of the investigations in this formation, we have been led almost intuitively to the recognition of three sub-divisions, partly on the ground of convenience in working out the details of the stratigraphical structure of the formation, but no less so from the fact that each of these divisions is everywhere defined by the same peculiarities. Each of these members is limited above by a sandstone or arenaceous bed, and just beneath this a thin bed of coal occurs in each case. However, the arenaceous cap-rock of the upper division is not always present as a dictinct sandstone, and in some other respects this horizon partakes strongly of the characters of the Upper coal-measures.

The average stratigraphical thickness of the Middle coal formation is probably not far from two hundred feet, although the maximum thickness is between three hundred and four hundred feet. The thickness of the strata intervening between the three principal coal horizons is variable in different localities. The middle member is the thickest, the upper and lower divisions probably averaging about the same thickness or about sixty feet. The middle division on the Middle Raccoon river, in Dallas county, near Redfield, where it has an exaggerated development not observed elsewhere, attains a thickness of probably not less than one hundred and fifty feet. At some localities the lower division may reach one hundred feet in thickness; but the greatest observed development of the upper division does not exceed eighty feet.

The Middle coal-measures are traversed by more or less regular wave-like undulations, which have a parellelism that would be difficult to account for in any other way than that they are the result of widespread, through greatly modified disturbance. The conclusion is further substantiated by the discovery of similar undulations in the strata of the Upper coal-measures in southwestern Iowa, which have a north-easterly and southwesterly trend, and are apparently in continuation of those that cross the Middle coal-measures. In a field so narrow as that occupied by the outcropping strata of the latter formation, and where there are no established base lines to facilitate and systematize explorations, it is extremely difficult to distinguish the general from the subordinate undulatious, which latter may have a direction more or less divergent from that of the main folds; and it was not until the examinations made by Dr. White, in southwestern Iowa, brought to light the existence of identical phenomena that we could, with any degree approaching accuracy, determine the general trend of these undulations. That these slight folds were also communicated to the Lower coal-measures there can be no doubt; but as yet they have not received more than a cursory study in that formation. No disturbances, such as faults or dislocations of the strata, have been brought to light in the progress of the examinations in this formation, nor is there the slightest indication of such existing. All the irregularites in these strata are such as were produced by irregular deposition and the wave-like undulation mentioned above.

FOSSILS. Generally speaking, few species of fossils occur in these beds which can be said to be peculiar to them. Nevertheless, while this formation furnishes a repetition of the organic forms that are found almost throughout the coal-measure series of strata, it is distinguished by certain palæontological and lithological features that furnish infallible guides in the indentification of its various horizons at localities remote from one another. There is a certain association of forms in the various fossiliferous horizons, such as the prevalence of individuals of one or more species in particular layers, that gives to each of these horizons its prominent distinctive palæontological characteristics.

PLANTS. Some of the shales and sandstones have afforded a few imperfectly preserved land plants; three or four species of ferns belonging to the genera, *Pecopteris*, *Sphenopteris*, *Neuropteris*, and grass-like impressions. Besides these, the sandstones contain the remains of *Calamites* and *Sigillaria.* The flora, however, is meagre, and does not perform an important part in characterizing any particular horizon. Some of the carbonaceous shales afford beautiful impressions of what appear to have been sea-weeds.

Of the PROTOZOA only the *Fusulina* has been recognized in these rocks, and this fossil is rare compared with its great abundance in the Upper coal strata.

RADIATES are represented by one or two genera of cyathophylloid corals, the remains of *Crinoidea* and *Echinoidea*, and *Chætetes.*

The MOLLUSKS are the most numerously represented of all the other classes of animais. The *Polyzoa*, *Brachiopoda*, *Gasteropoda*, and *Cephalopods* are represented by numerous genera and species. But there are few if any of these forms peculiar to this formation—either occurring in one or other of the formations immediately above or below, or in both, as is more generally the case.

Trilobites and *Ostracoids* are the only remains of the ARTICULATA thus far known from these beds. The former are represented by the single genus *Phillipsia*, and the latter by *Beyrichia* and *Cythere*.

VERTEBRATES are only known by the remains of fishes. These comprise the teeth and dorsal spines of Selachians, or sharks, and Ganoids. The latter consist of detached scales belonging to the genus *Palæoniscus*, or to a closely allied genus, and rarely fragments of the internal skeleton. Among the sharks the following genera have been recognized: *Cladodus*, *Orodus*, *Helodus*, *Petrodus*, *Deltodus*. With our present imperfect knowledge of the distribution of the fishes in the coal-measure series, it would be difficult to say what forms are peculiar to any one of its members. On the other hand, it is well known that there are forms which range from the Lower measures up into the upper beds of the Upper formation. The genus *Petrodus*, for example, is represented apparently by the same species in all three members of this group; and the *Peripristis semicircularis* is known from the Lower and Upper formations, though it has not been detected in the Middle formation. Of the Ganoids, the genus *Palæoniscus* is represented by the same or very closely related species in each of the formations.

These remains are of rare occurrence in this formation, and do not seem to mark any particular horizon. However, in most of the carbonaceous shales *Petrodus* occurs, and almost invariably associated with it is a peculiar dorsal-like spine, which we are inclined to regard as having belonged to the fishes, with whose dental remains they are so generally found. The species are usually about an inch in length, regularly tapering from the base, which is about one-fifth of an inch in width, to the apex, with fluted surfaces, the ridges of which terminate on the posterior margin in delicate spiny processes.

They are always found extremely compressed, indicating that they were very thin. It has been suggested that the *Petrodi* were dermal appendages of fishes related to the Rays. But if this is the case, it is exceedingly difficult to account for the absence of the slightest trace of the dental apparatus of those fishes, which we might reasonably expect to find deposited in the same strata. Prof. McCoy, however, has shown that the microscopic structure of these teeth is essentially the same as in all the Hybodont sharks, and which differs widely from the simple structure of the dermal points that cover the bodies of the Rays and sharks.

The foregoing and other peculiarities commonly observed in connection with the various strata of which the Middle coal formation is composed, will be noticed in detail and made more apparent in the descriptions following the accompanying section, which presents a tabular view of the formation in Iowa, as it is at present understood.

3. GENERAL SECTION OF THE MIDDLE COAL-MEASURES.

No. 1. The lowermost beds of the Middle coal-measures, as exposed in the vicinity of the city of Des Moines, present variegated red and blue shales, slightly arenaceous in places, with one or two thin bands of impure limestone, more or less irregular and nodular, with *Chonetes mesoloba*, *Spiriferina*, *Kentuckensis.* At Des Moines, this stratum has an exposed thickness of fifteen feet ; it is, doubtless, considerable thicker.

No. 2. Limestone, compact, gray and dark buff, usually accompanied above and below by thin bedded layers, two to three feet. This rock is seen at the quarries on Mosquito creek, Dallas county, and on the Little Whitebreast, near Chariton, Lucas county, at both of which localities it is well stored with fossils, the following species having been obtained: *Aviculopecten rectilateraria*, very abundant; *Myalina*, *Swallovi*, *Schizodus*, (sp. undet.), *Productus muricatus*, obscure fish remains. The bed in Lucas county, referred to the above horizon, affords *Productus æquicostatus, Chonetes mesoloba, Leda,* (*Yoldia*), (sp. ?), *Loxonema,* (sp. ?), *Bellerophon,* (sp. ?).

Want of time for careful study of many of the species of fossils characterizing these beds before the report must go to press, has prevented their identification with sufficient precision to publish their names. Therefore, many species are represented by only blank lines.

GENERAL SECTION of the Middle Coal-Measures.

UPPER DIVISION	Arenaceous shale and sandstone	44	10' +
	Bituminous shale	43	4'
	Lonsdale Coal	42	2' + -
	Shales light and blue.	41	15' -
	Limestone	40	5' + -
	Shales light, red, blue, arenaceous	39	30' + -
	Limestone impure dark blue	38	2' -
	Bituminous shale and coal	37	3' - 1'
	Shale yellow and blue	36	5'
MIDDLE DIVISION	Sandstone.	35	10 + -
	Shales arenaceous yellow and blue	34	15 + -
	Marshall Coal	33	20" +
	Shales blue and yellow	32	8' +
	Limestone impure fragmentary, bluish buff	31	2'
	Shales variegated red and blue	30	10' +
	Bituminous shale	29	1'
	Calcareous shales indurated grey	28	1
	Shales blue and red	27	4
	Limestone fragmentary buff	26	3' + -
	Sandstone and variegated shales dark fossiliferous band at top	25	8' +
	Variegated shales	24	10' + -
	Sandstone micaceous shale grey	23	2
	Shales variegated and alternating layers red blue and chocolate slightly arenaceous	22	40 +
	Shales grey red and blue, capped by micaceous sandstone	21	50 +
	Sandstone soft grey.	20	2 6"
	Shales blue with fossiliferous band at bottom	19	15'
LOWER DIVISION	Sandstone	18	3
	Shales blue and yellow	17	7 +
	Wheeler coal irregular	16	10"
	Shales red and yellow	15	8' +
	Limestone impure thin bedded greyish blue fossiliferous	14	3 +
	Shales blue and yellow	13	10 +
	Calcareous shales local	12	1 6"
	Shales blue and yellow	11	8
	Limestone	10	6" +
	Bituminous shales	9	3
	Powers coal	8	1 +
	Shales variegated	7	20 +
	Sandstone micaceous	6	10 +
	Shales light and blue local bituminous shales with fossils at base	5	10 +
	Lacona coal irregular	4	20" +
	Shales light and blue	3	30 +
	Limestone compact grey	2	3
	Shales variegated with thin bands of limestone	1	20 +

They are always found extremely compressed, ind [redacted] they were very thin. It has been suggested that [redacted]

with fossils, the following [illegible]
Aviculopecten rectilateraria, very abundant; [redacted] *lovi*, *Schizodus*, (sp. undet.), *Productus murica* [redacted] remains. The bed in Lucas county, referre [redacted]

horizon, affords *Productus æquicostatus, Chonetes mesoloba, Leda, (Yoldia)*, (sp. ?), *Loxonema*, (sp. ?), *Bellerophon*, (sp. ?), all in a very imperfect state of preservation.

No. 3. Shales, bluish and light colored, with ferruginous layers, and *septaria* in the upper part. This bed is well seen on Coal creek, near Sandyville, Warren county. It is probably twenty to thirty feet thick.

No. 4. Lacona coal. This bed is not persistent, although it has been found at more or less distant localities. In the northern portion of the formation, in Dallas county, it shows a thickness of about thirty inches; but on the Middle Raccoon river, below Panora, it is only ten inches thick. In the southern part of Warren county it varies from ten inches to two feet. In this region it is sometimes accompanied by more or less calcareous bituminous shales, containing *Productus æquicostatus*, abundant, *P. muricatus, Athyris subtilita, Leda bellastriata*, ——— ———, ——— ———,* *Loxonema*, ———, ———, ———, *Bellerophon carbonaria, Hemipronites crassus*, (?) *Chonetes Verneuilianus, Nautilus occidentalis.* The fossils in this bed are quite irregularly distributed, usually occurring in colonies in excessive individual numbers, within limited areas. In quality, the coal is also very variable, usually being charged with *pyrite* and interlaminated with seams of shale.

No. 5. Shales, blue and yellow; five to ten feet.

No. 6. Bluish and gray, usually thin bedded and sometimes micaceous sandstone. This bed varies in thickness from one to twelve feet. Its greatest development is seen at Panora, in Guthrie county, where it has been passed through in shafting for coal. To the southeastward, it is usually found from one to five feet thick; though in Lucas county it may thicken again, and is accompanied by a considerable thickness of arenaceous shales, as seen on the Little Whitebreast.

* Want of time for careful study of many of the species of fossils characterizing these beds before the report must go to press, has prevented their identification with sufficient precision to publish their names. Therefore, many species are represented by only blank lines.

On Mosquito creek, Dallas county, layers referable to this bed contain *Productus æquicostatus*, *Lingula* ———.

No. 7. Shales, alternating layers of blue, red, yellow, and gray, with irregular nodular bands, and a thin layer of earthy limestone. Seven to thirty feet. At Panora, Guthrie county, a thin band of ash-colored shales in the middle portion of the bed contains great numbers of a minute Aviculoid shell, ——— ———, besides *Hemipronites crassus*, (?) *Productus muricatus*. Near the top of the bed imperfect remains of plants are not unfrequently met with.

No. 8. Panora coal. Five to eighteen inches. This bed usually presents a thickness of ten to twelve inches, but locally, in Warren and Lucas counties, it has been found eighteen inches thick. In consequence of the persistent character of this bed, it forms one of the most reliable stratigraphical horizons in the series. The quality of the coal is usually superior to that of the thicker beds; and, notwithstanding its comparative thinness, it has been mined to a greater extent than any other bed in this formation. Mining this bed is greatly facilitated by the presence of a thin band of limestone, (Bed No. 10), which usually affords a self-supporting roof. Sometimes nodular or flattened masses of pyritiferous shales occur in the coal, charged with *Productus muricatus*.

No. 9. Bituminous shales, fissile, and sometimes slightly calcareous. One to three and one-half feet. At numerous localities this bed is richly stored with fossils. *Petrodus* and spines, Ganoid scales, and undetermined fish remains, *Aviculopecten rectilateraria*, *Rhynchonella* ———, *Orthoceras* ———, *Bellerophon carbonaria*, *Pleurotomaria* ———, *Loxonema* ———, *Macrocheilus* (?) ———, *Polyphemopsis* (?) ——— *Chonetes mesoloba*, *Discina* ———, *Athyris subtilita*, *Martinia planoconvexa*, *Spiriferina Kentuckensis*, ——— ———, ——— ———, *Hemipronites crassus* (?) *Lingula* ———.

No. 10. Limestone, impure, dark bluish, weathers brown, and sometimes nodular. This rock is easily disintegrated by exposure to the atmosphere. It varies in thickness from four to twelve inches; it is generally, however, quite regular, from five to eight inches thick, and very seldom entirely absent; though sometimes it is represented by a band of rather compact lenticular masses of limestone, as is the case on Mosquito creek, in Dallas county. The following species of fossils occur in this bed: Crinoidal remains, *Productus muricatus*, *P. longispinus*, very rare; *P. æquicostatus*, *Chonetes mesoloba*, *Hemipronites crassus*, (?), *Discina* ———, *Athyris*, *subtilita*, *Martinia planoconvexa*, *M. lineata*, *Spiriferina Kentuckensis*, *Rhynchonella*, ———, *Pernopecten*, (?) ———, *Aviculopecten rectilateraria*, ——— ———, ——— ———, *Bellerophon carbonaria*, *B.* ———, *B.* ———, *Euomphalus*, (sp. undet,), *Pleurotomaria* ———, *P.* ———, *Orthoceras*, ———, *Nautilus* ———.

No. 11. Brown, rotten shales at base, overlaid by bluish, gritty shales, eight feet. Local deposit, Mosquito creek.

No. 12. Dark, indurated calcareous shales. Six to eighteen inches. A locally developed, intercalated layer, seen at Piatt's mine on Mosquito creek, where it affords the following fossils: *Productus æquicostatus*, *P. muricatus*, *Hemipronites crassus* (?), *Athyris subtilita*.

No. 13. Variegated blue, gray and chocolate-colored shales, sometimes slightly arenaceous. Five to fifteen feet. A band of dark, plastic clay occurs locally near the top.

No. 14. Limestone, impure, soft, bluish-gray, in two to four thin layers separated by marly partings. One to four feet. The continuity of this bed is uninterrupted; although it loses its upper layer in the southern extension of the formation, and wherever it is exposed it presents the same lithological and palæontological characters, which easily distinguishes this from all other horizons in the formation.

14*a*. Usually forms an eight to twelve inch layer, sometimes in two thin bands, and is particularly characterized by the prevalence of *Productus muricatus;* besides this fossil, the following species have been found in this layer: crinoidal remains, *Discina* ———, *Chonetes mesoloba*, *Hemipronites crassus* (?) *Athyris subtilita*, *Martinia planoconvexa*, *Allorisma* ———, *Edmondia* (?) ——— *Aviculopecten rectilateraria.*

Immediately below this layer a thin band of indurated clay charged with the same fossils enumerated above, occurs at some localities.

14*b*. Four to six inch band, like preceding; characterized by the great abundance of *Martinia planoconvexa;* also, the following forms are known from this layer: *Fusulina* rare, *Zaphrentis* (Sp. ?) crinoidal remains, *Productus muricatus, P. Nebrascensis, Chonetes mesoloba, Hemipronites crassus* (?) *Rhynchonella* ———, *Athyris subtilita, Spirifer cameratus, Pleurotomaria* ———, *Macrocheilus* ———.

14*c*. is very tough, even bedded gray limestone, eight to ten inches thick. It does not constitute a persistent member of the bed, and has been observed at only a few localities on the South and Middle Raccoon rivers, in Dallas county; it here presents a layer largely composed of comminuted organic remains. The shelly surfaces of the layer are crowded with one or two species of minute *Gasteropoda*, and myriads of the exuviæ of a minute crustacean, *Cythere* ———, besides *Myalina* ———, *Aviculopecten rectilateraria, Nucula,* (?) (sp. ?), *Productus muricatus, Chonetes mesoloba, Athyris subtilita.*

No. 15. Mottled reddish and yellow shales, eight to ten feet.

No. 16. Wheeler coal; twelve to fifteen inches. This bed is not persistent nor does it appear to be widely distributed. In the northern portion of the Middle coal area it has not been recognized. In the southern portion of Warren county, on Otter creek, on the Whitebreast, near Wheeler's mill, and on a tributary of Cedar creek, near Col. Walker's, in Lucas county, this coal is well exposed in connection with the underlying strata, including No. 8, or the Panora coal. The quality of the coal is average.

No. 17. Shales, blue and yellow, slightly gritty with nodules above; five to ten feet.

No. 18. Sandstone, grayish-yellow, soft, sometimes replaced by arenaceous shales, three feet. In the vicinity of Panora a remarkable set of beds is associated with this horizon, consisting of thin bedded very compact sandstone, with thin interrupted coaly partings, enclosing a massive brecciated layer with *Productus muricatus*, *P. æquicostatus*, *Chonetes mesoloba*, *Athyris subtilita*, *Petrodus;* the whole making a thickness of twenty feet.

No. 19. Blue, more or less arenaceous indurated shales; fifteen to twenty-five feet. Near the base is found a band of dark blue clays, sometimes with pyritiferous nodules, in which great numbers of *Aviculopecten rectilateraria* and imperfect remains of ferns occur. This horizon may be seen in the fine exposures on the South Raccoon river, on the line between Dallas and Guthrie counties, and on the Middle Raccoon river, above the mouth of Mosquito creek.

No. 20. Light gray, soft sandstone; two and a half feet. On the Middle Raccoon river above Mosquito creek.

No. 21. Variegated, red, gray, and blue shales in alternating layers, more or less arenaceous, and capped by thin bedded micaceous sandstone; forty to sixty feet. This portion of the section is finely exhibited in the exposures on the Middle Raccoon river, above the confluence of Mosquito creek, as is also the following Bed, No. 22, where these argillaceous deposits have a much greater thickness than elsewhere observed. Indeed, at some localities the argillaceous material is entirely replaced by laminated, more or less micaceous, arenaceous shales and soft sandstone, as shown in the exposures on the South Raccoon above the confluence of the Middle Raccoon river. On Butler's branch, near Adel, a similar arenaceous deposit is found in this horizon, which has apparently replaced all the intervening strata, and rests immediately upon the carbonaceous shales overlying the Panora coal, (Bed No. 8).

No. 22. Alternating layers of variegated shales, red, blue, and chocolate colored, indurated, with arenaceous bands, probably thirty to fifty feet; on the Middle Raccoon, near the Dallas and Guthrie county line.

No. 23. Soft, shaly, gray, micaceous sandstone; 2 feet; five miles below Panora on the Middle Raccoon. This bed presents the unusual thickness of seven to ten feet. It affords the following fossils: Polyzoa, *Productus æquicostatus*, *Hemipronites crassus*, (?), *Myalina* ———, *Pleurotomaria* ————, *Cladodus*, (?) (sp. ?)

No. 24. Chocolate-colored and blue, slightly arenaceous shales, with nodules at base; ten to fifteen feet.

No. 25. Gray sandstone, irregular, passing upwards into mottled blue, gray, and chocolate-colored, slightly arenaceous shales, with nodular layers; five to ten feet. Near the top in a thin band of dark shale a few fossils are found—*Petrodus* and spines, Ganoid scales, *Discina* ———, *Martinia*, *plano-convexa*.

No. 26. Dark-buff, fragmentary, argillaceous limestone; two to five feet.

No. 27. Shales, blue, sometimes red; local; four feet.

No. 28. Indurated, gray, calcareous shales; one foot. A local deposit seen at Van Meter's mills, and near Adel, Dallas County, contains *Productus muricatus*, *P. æquicostatus*, *Chonetes mesoloba*, *Hemipronites crassus*, (?) *Martinia plano-convexa*, *Athyris subtilita*, *Myalina*, ————, *Edmondia* (?) ———, *Pleurotomaria* ——————

No. 29. Bituminous, fissile shales, local; one foot. This bed is also present at the localities mentioned in connection with the last preceding bed. In the vicinity of Hammondsburg, Warren county, a half-inch seam of coal occurs at the bottom of this bed. The shales have afforded *Petrodus* and spines, ganoid scales, *Aviculopecten* ————, *Spiriferina*, *Kentuckensis*, *Rhynchonella* ———, *Productus muricatus*, *Lingula* ————.

No. 30. Blue and purple shales, with irregular indurated and nodular bands; five to twelve feet.

No. 31. Bluish gray or buff, soft, impure limestone, more or less regularly bedded; two feet. The bed is sometimes separated in two layers, and at some localities it has, associated with it, several thin, fossiliferous layers, as may be seen in the exposures on the Middle Raccoon on the eastern borders of Guthrie county. These layers are interbedded with shales ; also, sometimes, fossiliferous, giving to the bed a local thickness of four to six feet. The following is a list of the species known from this horizon : Crinoidal remains, spines of Echinoids, *Discina* ———, *Productus æquicostatus*, abundant, *P. muricatus* also abounds in thin local bands, *P. costatus*, rare, *P. semireticulatus*, rare, *Chonetes mesoloba*, *C. mucronata*, *Hemipronites crassus* (?) *Orthis carbonaria*, rare, *Athyris subtilita*, *Spirifer cameratus*, rare, *Spiriferina Kentuckensis*, *Martinia lineatus*, rare, *M. planoconvexa*, *Rhynchonella* —— ——, *Allorisma* —— ———, ——— *Pleurotomaria* ——— *Phillipsia* ———.

No. 32. Blue and light-colored shales, with nodular bands, and sometimes slightly arenaceous; four to twelve feet. The upper portion of the bed has afforded a few plant remains, consisting of slender linear leaves and ferns—*Pecopteris*, ———, *Sphenopteris*.

No. 33. Marshall coal, two inches to two and a half feet. Notwithstanding the variable thickness of this bed, sometimes being represented by a seam of rotten coal not more than two inches thick, (Miller's branch, near Adel), it forms a persistent horizon throughout the extent of the formation in the State. However, the usual thickness of the bed ranges from six to twelve inches, and it is only at a single locality, at Marshall's coal mine, on Long branch, in Guthrie county, where it attains the maximum thickness given above. The quality of the coal is superior, generally being quite free from *pyrite* and other impurities, and wherever it is of sufficient thickness and accessible, it has to great extent supplied the local demand for blacksmithing purposes.

No. 34. Blue and yellow, more or less arenaceous shales, with thin indurated ferruginous bands, locally developed; two to twenty feet. Its greatest development is seen on Long branch, Guthrie county. In an exposure on the Middle Raccoon, at Duck's mills, Guthrie county, it replaces the overlying sandstone, No. 35. At the exposures on Beaver creek and Long branch, in Guthrie county, and near Adel, Dallas county, the bed has afforded a few species of fossils. In its lower portion at the former locality, *Myalina perattenuata*, *Hemipronites crassus*, (?) and obscure plant remains occur. At Marshall's coal-mine on Long branch, *Lingula* ——— is found in a similar position. Above this there is a well-marked layer which is literally crowded with the exuviæ of a minute Ostracoid crustacean, resembling, if not identical with, *Beyrichia fœtoidea*. On Hickory branch, near Adel, the same fossil occurs in equivalent exposures, besides, a minute *Gasteropod*, undetermined and obscure plant remains.

No. 35. Brown, fine-grained, heavy bedded and shaly sandstone. From a few inches to thirty-five feet in thickness, although its normal thickness is about eight feet. The remarkable thickening of this stratum forcibly brings to mind similar irregularities in the arenaceous deposits of the Lower coal formation. The least observed thickness of the bed is seen on Sugar creek, Dallas county, where it is represented by two thin quartzose layers, together not more than twelve inches thick, and charged with comminuted vegetable remains. The greatest thickening of the bed occurs in Warren county, where it sometimes reaches the thickness of thirty-five feet, as exhibited in the exposures on Otter creek, in the vicinity of Hammondsburg. The rock is usually soft, and easily disintegrated from exposure. Quarries have been opened in the bed at several localities in Warren and Dallas counties. Those near Adel furnish a tolerable freestone. In the thickened bed, it is not unusual to find large lenticular masses that present the characteristics of true quartzite.

The only organic remains known from this bed at present, are a few plants: *Neuropteris*, *Sigillaria*, *Calamites*.

No. 36. Blue and yellow shales; two to eight feet.

No. 37. Bituminous shales; one to four feet. A coal-seam four to fourteen inches thick, locally occurs in the base of this bed, in Guthrie and Warren counties. It has been termed, for convenience of reference, the lower carbonaceous horizon of the upper division. Its organic remains, so far as known, consist of the following species: *Petrodus* and spines, *Beyrichia Americana*, *Aviculopecten rectilateraria*, *Discina* ——— *Lingula* ———, and beautiful fucoidal impressions.

No. 38. Limestone, dark and grayish blue, fragmentary and sometimes nodular, impure; six inches to two feet. This rock rarely answers for building purposes; besides, it is seldom of sufficient thickness to quarry to advantage. It furnishes, however, a reliable horizon, and it derives much interest on account of the prevalence of certain species of fossils which are of comparatively rare occurrence in the lower beds of the formation and which give to this horizon a somewhat striking palæontological resemblance to some of the beds in the Upper coal-measures, as is exhibited in the accompanying list of the forms common to this bed: *Fusulina cylindrica*, rare, *Zaphrentis* ———, crinoidal remains, Polyzoa, two or three species, *Spirifer cameratus*, common, *Spiriferina Kentuckensis*, *Martinia lineatus*, common, *M. planoconvexa*, common, *Athyris subtilita*, *Retzia punctilifera*, *Productus longispinus*, common, *P. punctatus*, (?) *P. aequicostatus*, *P. Nebracensis*, *P. muricatus*, *Chonetes mesoloba*, always very small, *C. mucronata*, *C. Verneuilianus*, *Hemipronites crassus*, (?) *Aviculopecten rectilateraria*, *Pernopecten* ———, *Allorisma* ———, *Bellerophon crassus*, (?) *Phillipsia* ———.

No. 39. Light, red and blue shales, with arenaceous layers; twenty to forty-five feet. At the base of the stratum locally developed fossiliferous shales afford the following species: *Cyathaxonia* ———, (sp. ?) crinoidal remains, *Productus punctatus*, *P. longispinus*, *Chonetes mucronata*, *Hemipronites crassus* (?), *Spiriferina Kentuckensis*, *Martinia planoconvexa*, *Athyris subtilita*, *Retzia punctilifera*, *Pleurotomaria* ———, *Bellerophon carbonarius*, *B.* ———.

No. 40. Rather compact, thin bedded, buff limestone; five to ten feet. This bed is sometimes locally represented by compact heavy bedded layers, and sometimes accompanied by thin bands of limestone interstratified with shales. It burns into dark colored very strong quicklime, and is a durable building stone. Although the fossils are generally in an imperfect and comminuted condition, the following forms have been identified from this horizon: *Fusulina cylindrica*, not uncommon, *Cyathaxonia* ———, crinoidal remains, two or three forms of Polyzoa, *Hemipronites crassus*, (?) *Chonetes mesoloba*, *Productus æquicostatus*, *Athyris subtilita*, *Martinia lineatus*, *M. planoconvexa*, *Meekella striatocostata*, *Syntrielasma hemiplicata*, *Myalina subquadrata* (sp. ?), *Aviculopecten occidentalis* (?), *Pinna* ———, *Allorisma lata* (?), *Loxonema* ———, *Pleurotomaria* ——— *Bellerophon crassus* (?).

No. 41. Yellow and light colored shales; ten to twenty feet.

No. 42. Lonsdale coal. The thickness of this bed ranges from fifteen to thirty inches; it is a light, brittle coal, usually quite free from impurities. At Lonsdale's mine, on Deer creek, Guthrie county, this horizon is finely displayed. Also, at Huggin's mine on the west side of the Middle Raccoon, three miles above Redfield, and in the vicinity of Hammondsburg in Warren county, a coal is found which, in connection with the overlying fossiliferous shales, exhibits an unmistakable identity with the Lonsdale bed.

No. 43. Bituminous shales, locally calcareous, indurated; two to four feet. This is one of the most interesting palæontological horizons in the coal-measures, although the number of species is limited, contrasted to the abundance of individuals. From the prevalence of a molluscean fauna for the the most part consisting of diminutive species, or dwarfed individuals of larger forms, it brings strongly to mind certain horizons in the Upper coal-measures of southwestern Iowa. The following is a list of the species identified from this bed: *Productus longispinus*, *P. æquicostatus*, *Chonetes mesoloba*, *Hemipronites crassus*, (?) *Athyris subtilita*, *Martinia planoconvexa*, *Edmondia* ———, *Leda bellastriata*, *Nucula* (?) ———, *Gervillia* ———, *Pleurotomaria* ———, *P.* ———, *Macrocheilus* ———, *Bellerophon carbonaria*, *Orthoceras* ——— *Nautilus* ———.

No. 44. Shales, passing upwards into shaly sandstone, with a locally developed bed of limestone intervening; ten feet and upwards.

In the counties of Guthrie and Warren, the last described bed is well-marked, presenting essentially the appearance represented in the foregoing general section. But in Madison and Appanoose counties, we find a coal-bed beneath well recognized Upper coal strata, which is thought may prove to be the equivalent of the upper bed, or Lonsdale coal, of the Middle coal formation. In the latter region the coal is associated with two limestone beds, one above and the other below, besides the arenaceous deposit at the base of the Upper coal-measures, as shown in the Winterset section, is entirely replaced by argillaceous shales and limestone bands, as shown in the general section of the rocks in Appanoose county. If the above intimated identity exists, the horizon has not only entirely changed its lithological aspect, but the fossils of the associated bituminous shales have little resemblance, that forcibly recalls the Lonsdale coal as it appears in the northern portion of the Middle coal area.

4. ECONOMICAL GEOLOGY.

Coal. By far the most important mineral product of the Middle coal-measures is coal. As has been already stated, these deposits are quite limited compared with the coals of the productive or Lower coal-measures. But, at the same time, their quality seems to be superior to that of the heavier beds in the latter formation; and for this reason, if on no other account, these beds will be mined for a long time on a more or less extensive scale, at least, for the supply of the local demand for those purposes which require a pure coal. Some of the beds are locally of sufficient thickness to be regarded as "workable." But it is not unusually the case that twelve-inch beds are quite extensively mined, as in the instance of the Panora coal. The Lonsdale coal is the thickest and most regular of the persistent coal-beds in the formation, and being unusually free from admixture with impurities, it will become an important resource for fuel in the region where it appears at the surface. The Marshall coal is also remarkably free from admixture with foreign mineral substances; but, at the same time, it is the most variable of the persistent beds. Those beds which are termed irregular in consequence of their interrupted continuity, also afford a fair average quality of coal, but in consequence of their less extensive distribution, they have not been wrought to near the same extent as have some of the thinner persistent beds. The aggregate thickness of the coals of this formation is about eight feet. All these coals are light and brittle, presenting a highly polished lustre upon fracture.

Building Material. Stone suitable for building purposes is not abundantly furnished by this formation. As a general thing, the limestones occur in thin bands, and being of a more or less fragmentary character and easily wasted from exposure, their economic value is inconsiderable. However, a three-foot bed in the lower part of the formation has been opened on Mosquito creek, in Dallas county, affording a very durable building stone. In the upper division of the formation, well towards the top, another limestone deposit furnishes a good quality of quicklime and answers the purposes of ordinary masonry. This stratum appears at numerous localities in Dallas and Warren counties. The sandstones are usually too soft and easily destroyed to be employed to any considerable extent in building. The bed at the top of the middle division of the formation locally affords a tolerable freestone. The best quarries in this bed are those in the vicinity of Adel, in Dallas county, and to the southward of Indianola, in Warren county.

Ferruginous nodules occur in various beds, but no valuable deposits of the ore have been as yet discovered in the formation. The under clays, associated with some of the coal-beds, may possibly be found to answer for potter's use and fire-brick, but as yet no experiments have been made upon them with the view of determining their value for those purposes.

CHAPTER V.

1. CRETACEOUS SYSTEM.*

EARLIER CRETACEOUS.

There being no rocks in Iowa of either Permian, Triassic, or Jurassic age, the next strata in the geological series which we find belonging above the Upper coal-measures, are of Cretaceous age. They are found in the western half of the State, and rest unconformably upon the strata beneath them. They do not partake of the dips and undulations of those upon which they rest, and which have been described in the preceding pages, but have a general dip of their own to the north of westward. This dip, however, is slight, and probably has nowhere a greater angle than the average slope of the surface of the country in the opposite direction which lies between western Iowa and the base of the Rocky mountains. Indeed, it seems probable that the disappearance of the palæozoic rocks beneath those of Cretaceous age is fully as much due to the slope of the surface from that direction as to an actual dip of the strata from a horizontal line in the opposite one. So far as is known to the writer, Dr. D. D. Owen was the first to publish the fact of the existence of Cretaceous strata in Iowa. Subsequently, the extensive deposits of that age, which exist along the valley of the Upper Missouri river, of which ours are a part, received the most extensive and detailed exploration that has yet been given to them, by Messrs. Meek and Hayden.

In 1863, this region was visited by Prof. Jules Marcou, and

* The term "system" is applied to the Cretaceous, in conformity with the plan of classification explained in the introduction.

he was the first to announce the existence of Cretaceous strata in Iowa at any point farther south than the immediate vicinity of Sioux City,* which he represents as extending as far southward as the mouth of Boyer river. During the labors of the present Geological Survey, rocks of this age have been recognized still further southward, in Montgomery county, and as far eastward as the eastern part of Guthrie county, more than eighty miles eastward from the Missouri river.

Although the actual exposures of Cretaceous rocks are few in Iowa, there is reason to believe that nearly all the western half of the State was originally occupied by them, but all the strata being very friable they have been removed to a great extent by subsequent denudation. This denudation has doubtless taken place during two separate periods, and is the result of two separate causes. The first was the natural surface denudation that is constantly taking place upon all land surfaces, and was accomplished both during its elevation from the Cretaceous sea, and during the long Tertiary age that passed between the time of that elevation and the commencement of the Glacial epoch. Secondly, they suffered still greater erosion during the last named epoch by the action of ice ; amounting even to their entire removal over considerable areas, so that the drift now rests directly upon strata that were once covered by Cretaceous deposits, the latter having added largely to the materials of the drift. Thus every exposure of these rocks is found to show a more or less incomplete series of strata, by having had their upper portions either disturbed or removed, and they are not unfrequently parts of outliers of greater or less extent, which have become detached from the principal deposit by the erosion before mentioned.

There are two distinct causes why there are so few exposures of the Cretaceous rocks in the region within which they are known to occupy the surface, or immediately beneath the

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*See (Bulletin de la Societe Geologique de France, 2d serie, t. xxiv, p. 56, seance du 19 Novombre 1866,) an article entitled, "Le terrain cretace des environs de Sioux City, etc., par M. Jules Marcou."

surface deposits. The first is, the great thickness of the latter, both the Bluff and Drift deposits ; and secondly, all the rocks of Cretaceous age are so soft and friable, that many of the exposures which may have once been made by the erosion of the valleys of the present streams, since the Glacial epoch, soon become covered again by their own debris, which resulted from their disintegration. The ease with which these rocks were disintegrated and ground by the glaciers, thus augmenting the amount of drift material, may account, to some extent, for the great thickness of the Drift deposit in that part of the State.

For these reasons it is very difficult to draw a line upon the map of Iowa which shall indicate the exact boundaries of the region occupied by them, but the following description may approximately indicate the outlines of the area:

Draw a line from the northeast corner to the southwest corner of Kossuth county; thence to the southeast corner of Guthrie county; thence to the southeast corner of Cass county; thence to the middle of the south boundary of Montgomery county; thence to the middle of the north boundary of Pottawattamie county; thence to the middle of the south boundary of Woodbury county; thence to Sergeant's Bluffs; thence up the banks of the Missouri and Big Sioux rivers to the northwest corner of the State; thence eastward along the State boundary to the place of beginning.

While there are many reasons to believe that the Cretaceous rocks occupy all, or nearly all, of the area thus enclosed, it is true that over a large part of it no exposure of rock in place of any kind is to be seen. Consequently, the boundaries designated are not to be understood as precise. This is particularly the case in the northern two-thirds of the area, with the exception of that part of it bordering the Missouri and Big Sioux rivers. The reasons for inferring the existence of Cretaceous rocks beneath the Drift Deposit where they do dot actually appear, may be stated as follows:

Traces of rocks of this age are found in southern Minnesota even farther to the eastward than any point indicated within the boundary just described; and it is consequently inferred that the space between that point the most easterly ones in southwestern Iowa, was originally occupied by strata which were then continuous with them. Again, as we pass westward from the Upper Des Moines river, the strata of older date than the Cretaceous, disappear beneath the surface along or near the suggested eastern boundary of the latter, and are seen no more in that direction, and the next rocks we find in place are along the western boundary of the State in the valleys of the Missouri and Big Sioux rivers, and are of Cretaceous age.

These remarks apply particularly to the northern half of the area, the boundaries of which have just been given. In its southern portion the aggregate thickness of the Cretaceous strata is less, and they have been so frequently cut through to the underlying coal-measure strata by the streams during the process of the erosion of their valleys, that the borders of the latter formations may be traced in a very satisfactory manner, through a veil, as it were, of the much-eroded sandstone of Cretaceous age.

The Cretaceous rocks of the Upper Missouri river region have a greater aggregate thickness than rocks of that age are known to have in any other part of North America, and have been explored and ably reported upon by Messrs. Meek and Hayden. These gentlemen divide them into "Earlier" and "Later Cretaceous." The former is thought to be somewhat later than the earliest Cretaceous strata of Europe, and probably the earliest Cretaceous rocks yet found in America are also later. They further subdivide their Earlier Cretaceous into the "Dakota group," "Benton group," and "Niobrara group."

The Cretaceous strata of Iowa have so slight a development in comparison with those farther up the Missouri river, that it is difficult to determine their stratigraphical equivalents with those, without actual comparison, which it has thus far been impossible to make. There is no doubt however that all the Iowa Cretaceous strata belong to the "Earlier Cretaceous" of Meek and Hayden, nor any doubt that the lowest portions of ours is equivalent to a part of their Dakota group.

All the Cretaceous strata of Iowa are of course a part of the same deposits as those farther up the Missouri river, and in reality, constitute their most easterly extension. Although they are in our State of little thickness compared with those, they are yet properly separable into three distinct subdivisions; and with no intention of superceding the names in their general application which those gentlemen have proposed for the more general subdivision of the strata where they are more fully developed, the following names are used in this report to designate the subdivisions of the Cretaceous strata as found in Iowa.

They are named in their natural order, the most recent formation first:

Inoceramus beds	50 feet.
Woodbury sandstones and shales	150 feet.
Nishnabotany sandstone	100 feet.

The maximum thickness of each is given so far as known in Iowa.

Besides the following general descriptions of each of these three formations, more detailed descriptions will be found in the chapters upon the Middle Region of Western Iowa and Southwestern Iowa, where also sketches and diagrams are introduced for illustration.

2. THE NISHNABOTANY SANDSTONE.

This formation is found well exposed at several points in the valley of the East Nishnabotany river, from which circumstance it has received its name. It has the most easterly as well as the most southerly extent of any of the Cretacous deposits of Iowa, being found as far east as the southeastern part of Guthrie county, and as far south as the southern part of Montgomery county. To the northwestward it passes beneath the Woodbury sandstones and shales, the latter in turn passing beneath the Inoceramus or chalky beds. It reaches a maximum thickness in Iowa, so far as now known, of about one hundred feet, but the exposures usually show a much less thickness.

Lithologically, this formation is almost entirely a rather coarse-grained, friable, more or less ferruginous sandstone; but in a few instances thin, irregular layers of clayey material are found in it. Sometimes the grains of sand of which it is composed, are so slightly coherent that a spade may be thrust into it by a strong man. Occasionally, layers of gravel occur intercalated with the sand, which would thus form conglomerate if the pebbles were firmly cemented together. At Lewis, in Cass county, the sandstone contains so much brown oxyd of iron that it has a uniform dark-brown color. In some other places the iron acts as a firm cementing material for the grains of sand, forming hard, brown, irregular layers and concretions in the softer and lighter colored portions of the rock. Such portions have the color and general appearance at a little distance of brown hematite ore; in consequence of which, persons unacquainted with the subject have mistaken them for valuable deposits of iron ore. This has been particularly the case in Guthrie county where there are many exposures of the Nishnabotany sandstone, and where, also, the hematite seams are numerous in it.

The pebbles contained in this sandstone, so far as yet observed, are all silicious, and never calcareous, although some of them appear to be so before being broken open. None of them have been found to be of granitic or metamorphic origin, nor even of quartzite, but appear to have been derived from the chert or hornstone nodules of the older formations, as several species of their fossils, in a silicified condition, have been detected among the gravel. The genera *Favosites*, *Syringopora*, and *Cyathophyllum* have been recognized among these pebbles of the Nishnabotany sandstone in Guthrie county, all of which were probably derived from the Niagara limestone as pebbles during Cretaceous age.

Economic Value. In consequence of the general softness of this sandstone, it is with few exceptions almost valueless for economic purposes. The most valuable quarries in the strata of this formation that have yet been observed, are at Lewis, in Cass county, and in the northeastern part of Mills county. At Lewis, it has a dark, brown color, and as it hardens considerably upon exposure, it forms a very fair building material, and being soft when first taken from the quarry, it is wrought with great facility. Several buildings have been constructed of it there, but the color is objectionable for ordinary dwellings, while it would be quite in harmony with the Gothic architecture of small churches or similar buildings, for which the stone at Lewis is sufficiently durable, if well selected.

The extensive denudation which this formation suffered during the Drift epoch, has by its sand contributed to the soil of that part of the State a warmth and mellowness that adds largely to its productiveness and facility of cultivation, without being sufficient in amount to cause it to approach barrenness.

Fossils. The only fossils found in the Nishnabotany sandstone of Iowa, thus far, are a few fragments of Angiospermous leaves which are too fragmentary for identification. The fossil corals before mentioned are of course not properly fossils of this formation, as they belong to rocks from which a part of the materials were derived of which the Cretaceous strata are composed.

3. THE WOODBURY SANDSTONES AND SHALES.

These strata, as their name implies, are composed of alternating sandstones and shales, the latter being sometimes sandy, and sometimes clayey, with more or less calcareous material intermixed. They follow next in order, and rest upon the Nishnabotany sandstone. They have not yet been observed outside the limits of Woodbury county which gave them their name, but they are found there to reach a maximum thickness of about one hundred and fifty feet. The principal exposures of these strata are at Sergeant's Bluff's, seven miles below Sioux City, at Sioux City, and at intervals along the bluffs of the Big Sioux river to the northwest corner of the county. Near the last named point, a fine exposure of them is to be seen in connection with the Inoceramus, or chalky beds, of which a sketch may be seen in the description of the Geology of Woodbury county, in PART III, of this report.

Economic Value. A large part of the sandstone of this formation is impure and shaly, but some of the layers are firm and compact. At Sioux City, and other points, these hard layers are quarried for building purposes, and furnish the only material of that kind to be found in that part of the State. It is, at best, suitable only for purposes of common masonry.

At the town of Woodbury, the clayey layers are pure enough to use as potter's clay for the manufacture of common stone pottery, an establishment for which is in operation there.

At several points in Woodbury county, a distinct carbonaceous band, sometimes approaching true coal in character, is to be seen among these strata. This has been regarded by many as a hopeful indication of the existence of profitable beds of coal in that part of the State, but after giving the subject as careful attention as possible, the conclusion is arrived at, that there is no good ground for hope that coal will be found in paying quantity among the strata of Cretaceous age in Iowa, while the known productive coal-measure strata probably thin out before reaching so far north as Sioux City.

The position of this carbonaceous band in relation to the other strata, may be seen in the illustrations which accompany Prof. St. John's report on Woodbury county. The greater part of the material of this formation is of no economic value.

Fossils. Detached scales of a *Lepidoganoid* species have been detected in the strata of this formation, but no other vertebrate remains. *Inoceramus problematicus* is occasionally met with, and also a few other imperfect specimens of other *Lamelliabranchiates*. Of remains of vegetation, leaves of *Salix Meekii* and *Sassafras Cretaceum* have been occasionally found.

4. THE INOCERAMUS BEDS.

These beds have in all a maximum thickness in Iowa of about fifty feet, and rest directly upon the Woodbury sandstones and shales. They have not yet been observed in Iowa, anywhere, except in the bluffs which border the Big Sioux river in Woodbury and Plymouth counties. Although not exposed to view, they doubtless also exist in the bluffs that skirt the Big Sioux river all the way to the northwest corner of the State.

They are composed almost entirely of calcareous material, but it is not true, compact limestone. This division is both lithologically and palæontologically more truly characteristic of the Cretaceous age than either of the preceding divisions.

These beds, although their aggregate thickness is so little, may be properly subdivided into three portions. The first and lowest consists of fine, soft, indistinctly stratified, calcareous material somewhat resembling clay, but which really contains very little true clay. Second, regularly and thinly bedded calcareous material, much of it having all the characters of true chalk, except that the greater part of it is much colored with oxyd of iron which renders it unfit for practical use. The third and upper portion may be called a shaly and chalky limestone; too hard to be called chalk and too chalky to be called limestone. It is, however, as is also nearly all of the material of the Inoceramus beds, nearly pure carbonate of lime.

Economic Value. The material of the upper portion just referred to is used extensively for the production of lime, the quality of which is equal to that obtained from common limestone. No building material at all is to be obtained from the Inoceramus beds, and the only other materials of any present or prospective value they possess, besides lime, are the marls, which in future times will probably be found useful upon some of the soils of the adjacent region.

Fossils. The only vertebrate remains yet found in any of the Cretaceous rocks of Iowa, are those of fishes. Those found in the Inoceramus beds of Iowa are two species of Squaloid selachians, one Cestratront, (*Ptychodus*), and three undetermined genera of Teliosts. *Inoceramus problematicus* is usually quite abundant. *Ostrea congesta* not unfrequent, but other molluscan remains are rare. Minute Forammifera (probably *Globulina*) are sometimes met with in great numbers.

PART III.

COUNTY AND REGIONAL GEOLOGY.

Under this head those portions of the State which have been examined since the present organization of the State Geological Survey are, as far as practicable, subdivided into regions that have common geographical characters, for the purpose of facilitating their description. A general description of each of these regions is followed by separate and more detailed descriptions of every county within it, so far as they have been examined.

CHAPTER I.

GEOLOGY OF SOUTHWESTERN IOWA.

1. GENERAL DESCRIPTION.

This region comprises the following fourteen counties of the three southern tiers, namely: Madison, Clarke, Decatur, Adair, Union, Ringgold, Cass, Adams, Taylor, Pottawattamie, Montgomery, Page, Mills, and Fremont. It has the Iowa and Missouri State line for its southern, and the Missouri river for its western boundary. It is about one hundred and fourteen miles long from east to west, and almost sixty-five miles wide from north to south, and contains more than seven thousand five hundred square miles of surface.

Although the region is so large, its geology is nevertheless very simple; for with the exception of the presence of the southern extremity of the Cretaceous formations, exposures of which are occasionally seen in Cass, Montgomery, Mills, and Pottawattamie counties, the whole region is occupied by the Upper coal-measure formation alone, a general description of which has been given upon previous pages. That is, with the exception named, this formation immediately underlies the Drift and Bluff Deposits. These last named deposits, which have also been described, constitute the soil and subsoil of the regions they respectively occupy.

With the exception of parts of Madison, Adair, and Clarke counties, the whole region is drained by tributaries of the Missouri river; while the other portions of the three counties just named are drained by tributaries of the Mississippi river. It will thus be seen that the watershed which divides the drainage of the two great rivers, passes through these three counties. The highest land in the region, however, is not along this watershed, but in Adair county and southward, as shown in a previous chapter. Railroad levelings show that the broad ridge which passes southward through Adair, Union, and Ringgold counties, where it constitutes one of the secondary watersheds only of the tributaries of the Missouri river, averages about one hundred and fifty feet higher than the ridge which divides the drainage of the two great rivers. It will be seen then, that this region has two principal surface slopes, both of which, however, are very gentle. One of these is to the southwestward, and the other a little east of southward. The first named is much the largest, and is drained wholly by the tributaries of the Missouri river, while the latter is drained by tributaries of both great rivers.

The natural wealth of this region, as at present actually known, consists of its remarkably fertile soil, its limestone, its water, wood, and to a slight extent, also, of its coal. Besides the very small quantity of coal thus far discovered, there is, as explained on previous pages, good reason to hope that abundant supplies of that indispensable article may be obtained in almost all parts of the region, by sinking shafts of considerable depth down to the coal-bearing formations, which doubtless extend entirely beneath it by direct continuity from the region along the Des Moines valley where they occupy the surface. The other resources will be mentioned under the head of each county, but the different kinds of soil being so uniform in their distinctive characters over large areas, sometimes comprising several counties without appreciable change, will be referred to further only in general terms, while for more specific descriptions, the reader is referred to the chapter on soils. In that chapter, three distinct kinds of soil are described, all of which occupy large areas in this region, and all of which are very fertile.

They are the Drift, Bluff, and Alluvial soils. The drift soil is much the most extensive, since it occupies almost the whole of the region east of the East Nishnabotany river. The bluff soil occupies the space between that river and the flood-plain of the Missouri river. The alluvial soil of the region is, as its name implies, that of the river flood-plains, principally that of the Missouri river.

2. THE MISSOURI RIVER BOTTOM.

The great "bottom," or flood-plain of the Missouri is so important, and so different from all other regions in the State, that before proceeding to the separate description of counties a general account of these alluvial lands will be given. To make the description of these lands more complete, the whole alluvial plain of the Missouri river will be here discussed, so far as it forms a part of the surface of our State, which even then will, of course, be understood to comprise only a small part of the whole flood-plain of the great river. Much the greater part of the flood-plain of that portion of the river which borders upon Iowa, is upon the Iowa side, and is continuous from the south boundary line of the State to Sioux City, a distance of more than one hundred and thirty miles. The river frequently runs near the foot of the bluffs on the western or Nebraska side, but it does so nowhere on the Iowa side, between the two points just designated. On our side, the flood-plain varies from three to twelve miles in width between the bluffs and the river. At Sioux City, the bluffs rise directly from the bank of the river, and as the latter bends away to the westward at this point, and ceases to be the western boundary of the State, the great flood-plain ends abruptly upon the Iowa side, just below that city.

This alluvial plain is roughly estimated to contain more than half a million acres of land within the State of Iowa; upward of four hundred thousand acres of which are now tillable, or may be readily reclaimed to cultivation with little labor. When reclaimed and protected, these lands will rank among the most durable and productive in the State.

The whole valley of the Missouri river, so far as it forms the western border of Iowa, is approximately a flat plain from the borders, of which the bluffs rise abruptly on either side to the height of from one hundred and fifty to near three hundred feet. It has the same average slope to the southward that the river has. The greatest inequalities of its surface have been occasioned by the action of the river currents at high water, and amount at most to only a few feet variation from the general level of the plain. The process of erosion of the valley down to its present level has been continuous from the earliest part of the Terrace epoch, during which time the channel has repeatedly occupied every part of its valley by vibrating from side to side, gradually occupying lower and lower levels also, as the valley deepened. The greater part of the depth of the valley along the border of Iowa has been cut through the Bluff Deposit alone, which has been before described, and as the valley was deepened, bluffs of this ancient deposit of the same muddy river were left bordering the subsequently made valley upon either side.

The depth to which the erosion by the river current has extended, is not alone that from the general level of the uplands to the level of the flood-plain; but its channel has, in many places at least, been cut much deeper even than the usual average depth of the water in the channel. This is well shown to be the case wherever artificial excavations have been made in the flood-plain, in which all the material reached is readily recognized as alluvial. It is thought that the strong current of the river has caused these deep excavations in some places, and that they have been refilled by the shifting of its channel. It does not seem necessary to infer from these phenomena that the excavations were made by the current when the land occupied a higher level, and that the refilling resulted from a subsidence afterward. Evidences of similar erosion beneath the usual depth of the channel of all our smaller rivers and even of the creeks are not uncommon.

Gen. G. M. Dodge, formerly chief engineer of the Union Pacific Railway, informs me that in excavating for the piers of the railroad bridge across the Missouri river at Council Bluffs, it was necessary to go to the depth of seventy-two feet below the level of ordinary low water to reach the undisturbed strata. No opportunity was had of examining the material thrown out of these excavations; but from descriptions given by others and the finding there of some of the coniferous wood so common in the drift, it is inferred that this depth of excavation into the strata may have resulted, at least in part, by glacial, and not by fluvatile action.

The Missouri river is now, as it has doubtless been from the beginning, one of the muddiest of streams, and the constant accession of the same kind of sediment that it had itself deposited as bluff material in the ancient lake, communicated much the same character to the soil of the flood-plain during the whole time that the valley was in process of erosion, that we now find it to possess. Its soil is generally similar in character to that of the Bluff Deposit, especially that portion of it which is reached only by the highest floods of the river, for the sediment now obtained from its waters has nearly the same physical and similar chemical characters as that which composes the bluffs. This may be seen by comparing the results of analyses of each in Prof. Emery's report on another page.

In many places, however, the soil of the flood-plain contains more sand, but barren sandy places are not of frequent occurrence, certainly not so frequent as they are upon the flood-plain of the Mississippi river. The presence of the sand is partly due to its transportation by the river from regions farther towards its source, and partly to the fact that the valley has been cut entirely through the Bluff Deposit and to a considerable depth into the Drift Deposit upon which the former rests, and which always contains more or less sand.

The inequalities of the surface, before mentioned, having been caused by river currents, they are consequently in the form of longitudinal ridges and parallel depressions, having the same general direction which the currents had that caused them. These ridges are not such in the strict sense of the word, but are comparatively broad, flat spaces between the shallow depressions. Some of the latter even now serve as auxiliary channels for carrying off the water in times of flood, a part of which remain as shallow ponds at other times, but the majority become dry as soon as the floods are gone. None of these depressions are really parts of ancient beds of the main channel, and now remain quite beyond the reach of the highest floods, being filled at all times with comparatively pure water, and stocked with fish. Such a one exists at the foot of the bluffs, just above the point where Soldier river enters the flood-plain. This one we sounded in company with Mr. Solomon J. Smith, the owner of the land upon which it is located, and found it at one point to measure more than thirty feet deep, which is estimated to be about fifteen feet deeper than the surface of the Missouri river at low water, the channel of which is now eight miles away to the westward. As one stands upon the adjacent bluffs he is able to trace by the eye great numbers of these longitudinal depressions that are too shallow and indistinct to attract attention while he is passing over them. These, together with those previously mentioned, are all evidences, if farther evidence were necessary, of the former occupancy of every part of the plain by the river, but it must be remembered that the greater part of that portion of the flood-plain which lies in Iowa is not now reached by the highest floods of the great river.*

It should be remarked that some of the longitudinal depressions before referred to, have been caused, not by the main or accessory channels of the Missouri river itself, but by those of such of its tributaries as enter its flood-plain on

* The term, flood-plain, as here used, is a common term to designate flat-lands that border all rivers, and owe their origin to the action of the former floods in the process of eroding their valleys. Some of such lands may be, and often are, much above the reach of present floods.

their way to its own channel. These tributary channels have themselves shifted their locations from time to time, and even now much of the flooding which the great plain suffers is caused, not by the waters of the great river itself, but by those of the tributaries which they bring down abundantly from the western drainage slope of the State in rainy seasons. It is true that the rise of water in the great river above, floods thousands of acres of land, but there are other thousands of acres which the highest floods of the principal stream do not reach, and yet they are occasionally flooded by the tributaries as they pour their waters down upon the great flood-plain. It is especially these last named lands that may be reclaimed, and in the further description of the physical features of this flood-plain, a practical plan will be suggested for the attainment of this important object.

At or near the foot of the bluffs along a great part of the whole length of the flood-plain in Iowa, there are remains to be seen of an abandoned bed of the river channel, more definite than those before mentioned which are seen to traverse it. No doubt the river coursed along this now abandoned route several times during the long epoch that elapsed while the valley was being formed, but the traces of the channel that now exist there are doubtless those of the last which the great river occupied there before it finally bore away to the westward, leaving the greater part of the flood-plain on the Iowa side, as it now exists. In Woodbury county, above the point where the west fork of the Little Sioux river comes through the bluff, these remains of the ancient river bed consist of a series of ponds. From that point southward, the west fork of the Little Sioux itself occupies the ancient bed of the great river, until it forms its junction with the principal branch of the Little Sioux, where the waters of both branches occupy it until they are joined by the Maple, all the time coursing along the base of the bluffs.

From the last named point the waters of these united streams reach the great river by a common channel, which courses obliquely across the flood-plain and empties into it at a point nearly fifty miles below Sioux City, between which two points no other stream reaches the great river on the eastern side. When the Missouri river coursed along the Iowa side of its flood-plain, however, the West Fork, Little Sioux, and Maple rivers all emptied directly into it as separate streams, within the same distance. Below the confluence of the Little Sioux and Maple rivers the remains of the ancient bed of the Missouri before referred to, are seen again as a series of ponds and marshes along the base of the bluffs. Similar traces are also frequently to be seen in similar positions at intervals all the way to the south boundary of the State, but all the streams that enter the flood-plain from the uplands, southward from Maple river, cross the plain and reach the great river by separate channels.

The drainage area of the Nishnabotany river, extending as it does so far to the northward, and so nearly parallel with the Missouri, cuts off a considerable area that would otherwise be drained directly into the last named river by smaller tributaries. In consequence of this, for a distance of more than thirty miles northward from the southern boundary of the State, no stream crosses the flood-plain from the bluffs to the great river. We see then that the numerous streams which collect the waters from the western drainage slope of the State, only six of them cross the flood-plain independently, and that these cross it within the middle fifty miles of the one hundred and thirty miles of its entire length in Iowa. These streams are the Keg, Mosquito, Pigeon, Boyer, Soldier, and Little Sioux.

These are the streams which bring down the greater part of the tributary floods upon the great flood-plain, and if their waters were controlled and passed by direct channels without obstruction to the Missouri river, the complete reclaimation of thousands of acres of the best lands in Iowa would be thereby effected. Such a work is quite practicable, but it is one of such magnitude and importance that it will require combined effort for its accomplishment, and if ever accomplished, must necessarily be done upon a systematic plan.

For the reason that each of these streams pours its waters upon that portion of the great flood-plain which lies below it, the work of reclamation should be commenced by first controlling the currents of the uppermost or most northerly streams that reach the plain from the uplands; as, for example, the Little Sioux and its branches. Afterwards the currents of all the streams should be successively controlled that reach the flood-plain below.

It is believed that this great improvement may be effectually accomplished by merely straightening the present channels, preserving their full width and depth, and raising a slight embankment upon their shores.

Those lands which are now flooded by the tributaries being thus reclaimed, a large part also of those that are now flooded by the great river, might be reclaimed by building dykes or levees upon or near its own banks, such as are constructed for the same purpose along some portions of the Lower Mississippi. This is, no doubt, quite practicable, but whether that part of the work is ever done or not, it is essential that the waters of the tributaries should be controlled as soon as they reach the flood-plain. This work alone will reclaim much land that is now periodically flooded, the greater part of which is, but for this circumstance, among the best land in the State. With both these systems of improvement accomplished, there would probably not be a more productive and valuable region of equal area in the world than this. The amount of labor necessary to accomplish such results, although really very great, is insignificant when compared with the interest involved, and also with what has been done upon similar works in other parts of the world.

The practicability and value of such a work is even now plainly indicated by the effect incidentally produced by the embankments of the Sioux City and Pacific, and the Council Bluffs and St. Joseph railroads. There are hundreds of acres upon the east side of these embankments that were formerly flooded by high water of the Missouri river, that are now tillable and secure from any flood in consequence of the interposition of, and the protection afforded by these embankments, although they were constructed for an entirely different purpose.

From the frequent use of the term "flood-plain" and from these suggestions of improvement, it must not be inferred that the great flood-plain of the Missouri river in Iowa is at present an unoccupied and unimportant region. On the contrary, a very large part of its surface is as beautiful and productive farming land as human eyes ever rested upon, and such parts being naturally secure from any floods are preferred by many farmers to the best of the uplands. The proportion of the surface of the flood-plain that is thus secure without artificial protection is quite large, and the region is even now one of fine farms, pleasant villages, well built school-houses and churches; and finally, of two well built and well stocked railroads, which together form a continuous line through its entire length of one hundred and thirty miles, besides two others which cross it from east to west.

3. MADISON COUNTY.

Boundaries and Area. This county is the most northerly one of those which comprise the region designated as southwestern Iowa. It is bounded on the north, east, and west respectively by Dallas, Warren and Adair counties, and on the south by Clarke and Decatur counties. It contains sixteen congressional townships,* four eastward and westward and four northward and southward. If its linear survey had been accurately made it would consequently contain five hundred and seventy-six square miles, or three hundred and sixty-eight thousand six hundred and forty acres; but in consequence of the inaccuracy before referred to, especially in its northeastern township, it really contains a little more.

Drainage and Surface Characters. The greater part of this county is drained by three streams that have been

*See descriptions of linear surveys in Appendix.

popularly called the "three rivers," their separate names being the North, Middle, and South rivers. The remainder is drained by a few small tributaries of Raccoon river which reach within its northern border, and also by an upper branch of Grand river which cuts across its southwestern corner. The latter stream is a tributary of the Missouri, while all the others are drained into the Mississippi. It will thus be seen that the watershed of these two great rivers passes through the southwestern corner of this county.

The numerous streams of Madison county, together with their tributaries, make it one of the best watered counties in the State; besides which, springs are numerous along the valleys, and excellent water also may be obtained almost any where by digging wells of moderate depth. The rapid slope and rocky beds of these streams render them peculiarly valuable for water-power, and a large number of costly mills have already been erected upon them.

The surface of this country may be divided into two separate parts for convenience of description, each part possessing its own peculiarities, which are derived from the two formations that respectively underlie them. The first consists of a high prairie surface with comparatively slight undulations, the streams which traverse it having cut their valleys down deeply and abruptly through the strata beneath; the uplands ending abruptly on either side of the valleys. These are the strata of the Upper coal-measures and are abundantly exposed along the steep valley-sides. The surface of the second part has a lower general level and is usually gently undulating. The valley-sides are seldom steep, and rocking bluffs are entirely wanting. This is because the underlying Middle coal-measure strata contain so few hard and durable layers of rock. Consequently, they present no bold fronts where the streams in deepening their valleys, have cut through them.

The cause of this difference in the character of the surface, it will thus be seen, arises from the difference in the resistance which the two formations have respectively presented to erosive action, both that which occurred during the Glacial epoch, and that which resulted from ordinary meteorological agencies in connection with the drainage while subsequently forming the valleys. By a glance at the following sections of strata in this county, it will be seen that those referred to the Middle coal-measures, are nearly all of such a character as to have yielded readily to the erosive action to which they have been subjected in common with others that elsewhere occupied the surface, and the resulting inequalities of surface are consequently more gentle than they are where firmer materials have been subjected to the same process. It will also be seen that the strata referred to the Upper coal-measures are in great part limestones, which are so firm that they have yielded far less to the mechanical erosion of the drift agencies than others have, but have nevertheless, yielded completely to the action of the streams. This, however, is probably accomplished by a process of solution, to a great extent, rather than by the mere mechanical attrition produced by running water.

One may obtain an opportunity to appreciate quite fully the difference in the surface-characteristics of the two formations mentioned, by going up the valley of Middle river, starting from the east boundary of the county. For the first eight or ten miles he finds the valley-sides gently sloping to the stream on each side; but he then comes suddenly upon the border of the Upper coal-measure formation, as is shown by the bold bluff exposures of its limestone strata in the valley-sides. Within a few miles further he finds himself in a narrow valley, more than two hundred feet deep, and bordered on each side by limestone bluffs. This character continues along the same valley as far as the west boundary of the county.

The deep erosion of these streams into the limestone strata sometimes ends quite abruptly, as is seen in the valley of Clanton's fork of Middle river, which, at the village of Peru, it is upward of two hundred feet deep, having cut its way down through more than one hundred feet in vertical thickness of limestone, yet within five miles further up the same valley, the stream is a mere prairie creek, with gently sloping valley-sides, composed of drift alone; and yet there are no definite falls in the whole course of the stream. This deep erosion of the limestone strata is quite characteristic of all the streams that traverse the Upper coal-measure formation in this county, as is well shown in the valleys of South and North rivers, as well as in those of the two rivers before referred to. This is doubtless largely due to the fact that their drainage is in an opposite direction from the dip of the strata, and that the limstones are intercalated and underlaid by softer strata, so that they are readily undermined by the action of running water.

Geology. Madison county, as already mentioned, is underlaid by the Upper and Middle coal-measure formations. The Upper occupies much of the largest part of the area, and is much the most conspicuous in the characters it presents for observation. Indeed the most important and interesting exposures of this formation to be found in the State, are found in Madison county. The Middle coal-measures occupy the northeastern township of the county exclusively, as well as the one also that lies immediately south of it, besides considerable portions of the townships adjoining them upon the west and south. Besides this they are to be occasionally seen in the valleys of the larger streams as far westward as the middle of the county.

The sections which follow, will give an idea of the character of the strata that underlie the county as far as they are accessible from the surface. The section measured in the valley sides of Middle river near Winterset, is so complete and extensive that the lithograph illustration of it has been used for purposes of general comparison in the chapter on the Upper coal-measure formation. The reader is referred to that as well as to the description of it which is repeated here.

Section at Winterset.

16.	Thin bedded, yellowish-gray limestone	1	foot.
15.	Fossiliferous, marly clay	4	feet.

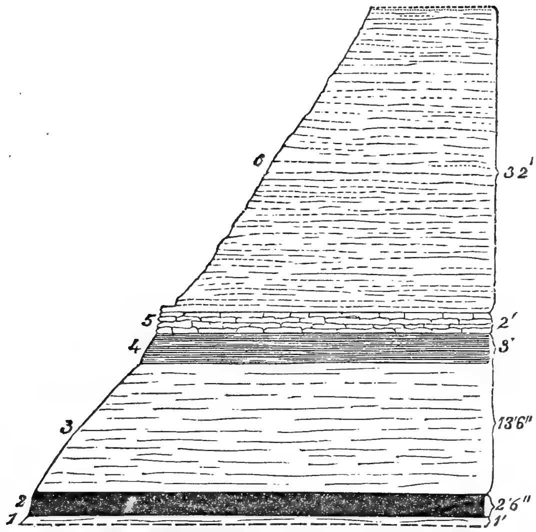
14.	Massive, light gray limestone	6	feet.
13.	Compact, regularly bedded limestone with marly partings	12	feet.
12.	Black, fissile, carbonaceous shale	2	feet.
11.	Compact, regularly bedded limestone, with marly partings	34	feet.
10.	Black, fissile, carbonaceous shale	2½	feet.
9.	Grayish limestones, often silicious and impure	15	feet.
8.	Compact, heavy bedded limestone	2	feet.
7.	Grayish limestones, sometimes finely arenaceous, and often cherty	16½	feet.
6.	Impure coal	½	foot.
5.	Light bluish, marly clay	2	feet.
4.	Light bluish, concretionary and fragmentary limestone	5	feet.
3.	Bluish and reddish clays	6	feet.
2.	Fine grained shaly sandstone and sandy shales	71	feet.
1.	Bluish, shaly, impure limestone	1½	feet.
	Total	181	feet.

No. 1, of this section, belongs to the Middle coal-measures; all the remainder, to the Upper coal-measures. The locality thus receives additional interest from the fact that it exhibits the junction between the two formations. Deducting No. 1, we have remaining nearly one hundred and eighty feet in vertical thickness of Upper coal-measure strata, and yet this locality is only ten miles from the thinned-out edge of the formation.

Going northward about the same distance from the place where the foregoing section was measured, we come upon the extreme northern border of the Upper coal-measures and find their last exposures in that direction in the banks of the north fork of North river. In such a position on section 25, township 77, range 28, the accompanying section represented by Fig. 15, was measured, the land belonging to Mr. George Clarke.

FIG. 15.

Section at Clarke's.

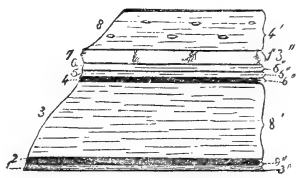


No. 6.	Sandy shales	32 feet.
No. 5.	Bluish, impure, shaly limestone, sometimes compact	2 feet.
No. 4.	Black carbonaceous shale	3 feet.
No. 3.	Bluish argillaceous shale	14 feet.
No. 2.	Coal	2 feet.
No. 1.	Fire-clay	1 foot.
	Total	54 feet.

No. 6 of this section is the same bed as No. 2 of the preceding one, measured near Winterset, and is the lowest member of the Upper coal-measure formation, while all the other members of the section at Clarke's belong to the Middle coal-measures. No. 5 of this section is the same as No. 1 of the section near Winterset, and the lower member seen at Clarke's, may no doubt be found at only slight depth beneath the bed of Middle river, near Winterset.

At Anderson's mill on Clanton's branch of Middle river, in the eastern part of Madison county, an exposure of strata was found which is represented by Fig. 16, and is evidently equivalent to that part of the section at Clarke's, from one to five inclusive, yet the different beds are more subdivided.

FIG. 16.



Section at Anderson's Mill.

No. 8.	Bluish shale with ferruginous concretions	4 feet.
No. 7.	Bluish, impure limestone	1¼ feet.
No. 6.	Bluish shale	½ foot.
No. 5.	Dark, carbonaceous shale	½ foot.
No. 4.	Coal	½ foot.
No. 3.	Bluish, marly shale	8 feet.
No. 2.	Coal	¾ foot.
No. 1.	Black, coaly, fossiliferous shale	¼ foot.

The band of impure limestone, No. 7, is, no doubt, equivalent to No. 2 of the Winterset section, and to No. 5 of the section at Clarke's. This being the case, it will be seen that the coal horizon, represented in those two sections, becomes subdivided into thin seams in the eastern part of the county, while it reaches its greatest development, so far as yet ascertained, in the northern part of the county. Within a couple of miles northward from Anderson's mill, a seam of coal has been mined by stripping, which is no doubt the same as one of those given in the Anderson's mill section, but the associated seam was not observed there. The seam mined there is only about nine inches thick.

There are numerous other exposures of strata in different parts of the county, but the foregoing are sufficient to give the whole vertical range of those yet observed. Doubtless, still lower strata than any here represented, occupy the surface immediately beneath the drift in the northeastern part of the county, but being soft or friable they have not been exposed, or if so, have again become covered by their own debris.

Economic Resources. The mineral resources at present accessible in Madison county, consists almost entirely of its stone. In this respect, it has few equals among the counties of the State, and it probably possesses more accessible material of this kind than all the other thirteen counties, enumerated in a former chapter under the head of Southwestern Iowa, except Clarke and Decatur counties.

By reference again to the sections of the strata of this county, already given, it will be seen that those which are referred to the Middle coal-measures are almost destitute of stone that is suitable for even the most common building purposes. Consequently, in that part of the county occupied by that formation alone. Such material is scarce; but the case is far different in the other portions of the county, as may be seen by referring to the strata represented by the upper and middle portions of the Winterset section. The majority of these strata, it will be seen, are limestone. Those represented by the numbers from eleven to seventeen, inclusive, are much more frequently exposed than any of the others, and from these the greatest abundance of stone may be obtained. All of it is suitable for lime, and nearly all, for purposes of common masonry ; but some of the beds also furnish excellent stone for dressing. Some fine stone for the latter purpose may be obtained in the valley of Middle river, in the western part of the county, but it is in the immediate vicinity of Winterset that the finest stone for dressing has yet been observed. No. 14 of the section there furnishes the best quality, and being near the top of the valley-sides with only slight depth of other material above it, is quarried with comparative facility. The stone of this bed is in massive layers, having an aggregate thickness of about six feet. It is light-gray in color, yields readily to the workman's tools, being uniform in texture, and endures exposure to the atmosphere and frost without damage.

Considerable quantities of this stone have been quarried and used in the town of Winterset and its vicinity; and the finer qualities of it have in some cases been carried as far as the city of Des Moines. Many new quarries may, without doubt, be opened in this bed in the vicinity of Winterset, and when railroads shall be built through this county, it will be in good demand all along the lines of such roads. It will be in especial demand in all those counties that are adjacent to Madison, to the southward and westward.

Common stone is so abundant in the greater part of this county, that there will never be any lack of such material for all necessary houses and outbuildings, the construction of roads and bridges, the walling of wells and embankments; and yet, the stone being exposed principally in the valleys, the greater part of the surface is so unbroken and unobstructed that it is tillable without difficulty.

The *clay* represented by No. 3, of the Winterset section, and which may be seen near the top of the high bank at the ford two miles south of Winterset, may probably serve a good purpose for common pottery, but potter's clay of the best quality has not yet been observed in this county.

Good brick clays are to be obtained in many parts, but they are usually most accessible along the approaches to the valley-sides where the soil is thin.

It is worthy of remark, in passing, that the material found among the Upper coal-measure strata of Madison and other counties, and popularly called "slate," is not true slate, but the black, fissile, carbonaceous shale represented by numbers ten and twelve of the Winterset section. It splits readily into thin layers of uniform thickness, in which condition it closely resembles sheets of roofing slate, but it is practically worthless, as it soon exfoliates and decomposes upon exposure to the weather.

Coal. By turning again to the sections on the previous pages, which represent all the strata exposed in Madison county, it will be seen that with the exception of the comparatively thin bed of coal in the valley of North Branch, and its representative near Anderson's mill, in the eastern part of the county, there is no other in the whole series worthy of the name of a bed of coal. It has been shown, however, that the principal beds of coal in the State lie within a series of strata that belong entirely beneath all those to be found exposed in this county. Therefore, all the coal of any importance that may yet be found within its limits, must be sought for by sinking shafts to a considerable depth beneath the surface. As all the strata lie in a comparatively horizontal position, and do not conform to the inequalities of surface, it will readily be seen that much useless labor will be saved by commencing such enterprises in the valleys. Thus, for example, if the people of Winterset should desire to commence such a work they would save more than two hundred feet of digging by commencing in the bottom of the valley of Middle river, rather than upon the general surface upon which the town is located.

The most important practical question that presents itself just here is, how deep must we go in this county to find a good bed of coal? This question cannot be answered with certainty without actual trial, nor can it be said with certainty that any profitable bed of coal will be found if such shafts are sunk there. There are, however, excellent general reasons for inferring that one or more profitable beds of coal may thus be found, and none why they should not be, all of which have been explained on previous pages. For example, at Compton's mill, near Winterset, the upper strata of the Middle coal-measures appear in the bottom of the valley. This formation, Prof. St. John has shown in his report to be about two hundred feet thick in the counties northward, and also that it contains three or four thin beds of coal, all of which are probably too thin for profitable mining at any considerable depth. The Lower coal-measure formation doubtless exists in this county beneath the Middle and Upper, but its own upper strata are probably at least two hundred feet beneath the bottom of the valley at Winterset. Since the Lower coal-measures contain all the thickest and best beds of coal it may be expected that shafts sunk in the bottom of Middle river valley would have to reach a depth of at least two hundred feet before a bed of coal will be found of sufficent thickness for profitable mining. Several thin and profitless beds of coal would probably be passed through within the first two hundred feet. It is thought that the Sub-carboniferous limestone may be reached there at a depth not exceeding five hundred feet, when of course all further work should be stopped, as it is useless to look for coal beneath or within that limestone formation. Thus it will be seen that a limestone formation both underlies and overlies the coal formations.

Since all the strata rise gently and gradually to the eastward and northward, or rather the dip being in the opposite directions, the lower ones of course come nearer the surface in the eastern and northern parts of the county, and consequently shafts of less depth would reach them from the surface there. Therefore the Lower coal-measure strata, and perhaps its bed of coal, may be reached at a less depth there than elsewhere in the county.

Such enterprises, if undertaken in Madison county, should be watched with the greatest interest, because its success would give additional confidence to those who may desire to commence similar enterprises farther westward and southward, and would tend to hasten the solution of the problem of future supplies of coal in southwestern Iowa.

As before stated, coal has already been found, and even mined at a few points in this county, but all the coal thus far discovered belongs to the thin beds of the Middle coal-measures before referred to, or to the thin seam represented by No. 6, in the Winterset section. The former come to the surface in the northern and eastern parts of the county, as before explained. The thickest bed of coal yet found in the county, is that at Mr. Clarke's bank, on North Branch, which is reported to be at one point two and one-half feet thick, but it is usually less.

The same bed, but probably much thinner, may doubtless be found within a few feet beneath the water level below Compton's mill, one and a half miles from Winterset, and also on land of Mr. McKnight, a mile or two below. On land of Mr. Cox, one and half miles east of Winterset, a thin bed of coal has been opened, which seems to belong to the horizon of No. 6 of the Winterset section. It is probably too thin to be of any value.

At Anderson's mill, on Clanton's fork of Middle river, near the east line of the county, and also at several other points in the same township, a thin bed of coal, belonging evidently to the same horizon as that at Clarke's, has been mined by stripping; but being only a few inches in thickness it cannot be profitably mined where the overlying material is more than a few feet in thickness. The quality of the coal, however, like that of the majority of the thin beds everywhere is very good.

It will thus be seen that the only hope of a sufficient supply of coal for Madison county lies in comparatively deep mining.

The abundant growth of *forest trees* along the valleys of this county afford a plentiful supply of fuel, notwithstanding the present scarcity of coal, and so rapid is the growth of trees that in this county it is found desirable to check, rather than to encourage their encroachment upon the prairies.

Water is abundant from all the usual sources, namely, numerous streams and springs in their valleys, and surface water which may be reached almost anywhere by wells of moderate depth.

The *soil* of the county is a deep rich loam, not surpassed for fertility by that of any county in the State. The general aspect of Madison county is one of unusual beauty. The monotony which often accompanies prairie views is here completely relieved by gentle undulations of the general surface and by the deep wooded valley-sides of its larger streams.

4. CLARKE COUNTY.*

Boundaries and Area. Clarke county is bounded on the east south and west respectively by Lucas, Decatur, and

* This county, for want of time, has not been as fully examined as others.

Union counties, and upon the north by Madison and Warren counties. Like the majority of the counties of the second tier, from the south boundary of the State, it is in the form of a parallelogram, eighteen miles wide from north to south and twenty-four miles long from east to west. Consequently, it contains four hundred and thirty-two square miles, or two hundred and seventy-six thousand four hundred and eighty acres.

Drainage and Surface Characters. Clarke county lies directly upon the Great Watershed, which passes through it from its eastern to its western boundary. It enters the borders of the county a little southward from its northwestern corner, and by a broad southward curve it leaves it at a point a little north of the southeastern corner, so dividing the county that nearly two-thirds of its surface is drained by the tributaries of the Mississippi and the remainder by those of the Missouri.

The greater part of the surface of Clarke county is more or less undulating or rolling prairie, but there are considerable bodies of woodland along the valleys of Long, White-Breast, Otter and Squaw Creeks. The valleys of this county are those of the forenamed creeks alone, except those of smaller upper branches which are mere depressions in the deep Drift Deposit. The streams themselves, although quite sufficient to water the county well, are too small to furnish much good water-power.

Geology. The Upper coal-measure formation alone underlies the surface of Clarke county immediately beneath the drift. The exposures are almost wholly of the limestone strata of that formation, and are consequently very uniform in their general character. The stone is its usual gray limestone with occasional layers and partings of calcareous clay. The principal, and indeed almost the only exposures of strata, are in the valleys of the creeks just mentioned, namely, Squaw, Otter, White-Breast, and Long Creeks.

Economic Resources. Sufficient quantities of limestone are obtained from the exposures before named to meet the wants of the inhabitants for all purposes for which common stone is used, and also for lime. An excellent quality of the latter may be prepared from almost all the stone found in the county. The other resources, so far as at present known or developed, are its moderate supplies of wood-fuel and its universally fertile soil.

According to the views expressed in another part of this report in relation to the relative position of the coal-bearing strata, it may be reasonably hoped that coal may be discovered in almost any part of Clarke county by deep mining.

5. DECATUR COUNTY.

Boundaries and Area. Decatur county is the most south-easterly one of those grouped under the designation of Southwestern Iowa. It is bounded on the north, east, and west respectively by Clarke, Wayne, and Ringgold counties, and on the south by the southern boundary of the State. Its outline is nearly that of an equilateral parallelogram, being twenty-four miles from its eastern to its western boundary, and a little more than twenty-two miles from north to south. Consequently, it contains about five hundred and thirty square miles, or about three hundred and thirty-nine thousand, two hundred acres.

Drainage and Surface Characters. The surface of Decatur county possesses greater diversity than the average of south-western Iowa. This diversity is produced both by the considerable depth of its valleys, and by the unusual proportion of woodland. The latter feature of its surface is all the more striking from the fact that the surfaces of the two counties adjoining, upon the east and west are almost wholly prairie.

By referring to the sections farther on, which illustrate the exposed strata of this county, it will be seen that a considerable proportion of them are of a shaly and clayey character, such as would yield readily to disintegration and erosion. This lithological character of its strata has produced its effect upon the physical features of the surface in and near the valleys. As one travels along the valleys of the creeks he not unfrequently meets with spaces of considerable length, sometimes amounting to a quarter of a mile, where the water is without apparent current. At such places, it often has a width many times that of the same creek where it flows with the ordinary current, and he can hardly believe that it is not arrested by a mill-dam, or some other artificial obstruction.

These, however, are natural features and are caused by the almost perfectly horizontal position of the strata and their alternations of clayey shale and limestone, before mentioned. The strata are so nearly level that when the current has swept out the soft shale, the firm layer of limestone beneath it serves as an unyielding bed to the stream which will not allow of the further deepening of its bed, and is only swept clean by every flood. When that stratum of limestone is finally passed over by the creek, and another soft layer is reached and swept out, another limestone floor is left which supports its still pond of water of greater or less extent as before described. These features are particularly characteristic of Elk creek and both of its branches.

Again, along some of the larger valleys of the county, although no rocks may appear in view, the presence there beneath the surface of the valley-sides of the alternating strata before mentioned, is apparent in the alternate widening and narrowing, and by other characters of the flood-plains. These are sometimes quite out of ordinary proportion to the size of the streams. Their soil in such cases is usually clayey, instead of sandy, as is commonly the case with the soil of flood-plains, the clay being evidently derived from the clayey strata before mentioned, and the presence of the latter is also the cause of the variable width of the flood-plains. These peculiar features of the valleys although occasionally recognised in those of the creeks or smaller streams of the county, are quite conspicuous along the valley of Grand river, particularly in that part of it which lies between the mouth of Elk creek and the State boundary. Here the flood-plain is broad and flat, with a rich, deep, clayey soil, and being so nearly level it presents a strong contrast with the broken valley-sides which border it. It rests wholly within, and is formed out of the shaly and clayey members (Nos. 1 and 2) of the section at Davis' mill given on a following page, its peculiar characters, and even its existence being due to the soft and yielding nature of those strata.

Taking the county as a whole, its surface is more uneven than any of those which adjoin it; yet there are quite large tracts of comparatively level land, especially in the southwestern and northeastern portions. These, and also the other high and more level parts are principally prairie, but the prairies are gradually lessening by the natural growth of forest trees. The diversity of surface before mentioned, while it may render a small part of the land unfit for the plow, adds an equal, if not greater value to the whole region by giving to the landscape beauties it could not otherwise possess.

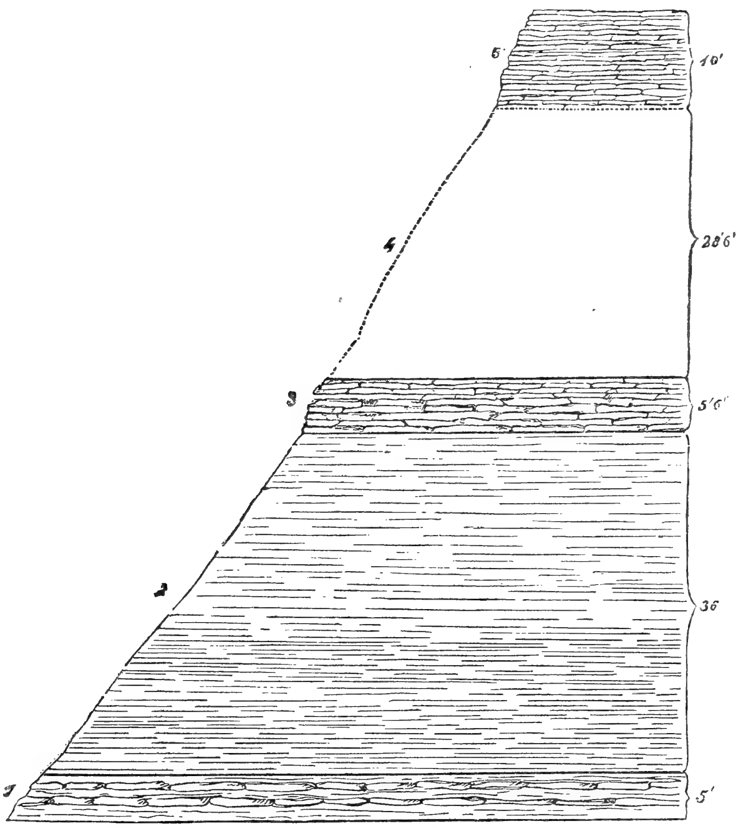
The streams of this county are all tributary to the Missouri river, and as may be seen upon the map, are quite numerous, all having a general southerly course. The whole surface is consequently so well drained that scarcely a pond or marsh of any size exists in the county except occasionally one adjacent to the streams.

Much good water-power is furnished by Grand river, but the other streams of the county are usually too small for such purposes.

Geology. The Upper coal-measure formation almost alone is found in Decatur county, the upper layers only of the Middle coal-measures appearing in the valley of Grand river near the southern boundary. If a line be drawn directly north and south through the center of the county, it will be found that all the exposures of rock, in place, appear in the western half, none having thus far been observed in the eastern half. Weldon's creek and Little river, both of which traverse the eastern half of the county from north to south have eroded their valleys to considerable depth below the general surface of the uplands. They are so deep, in fact, that they can hardly have failed to pass through the entire thickness of the drift, and also some of the strata beneath it, but none of the latter now appear. This may be due to the soft or friable character of those strata, or the abundant drift material may have covered them by falling down the slope as the valleys were deepened.

FIG. 17.

Section at Davis' Mill.



No. 5.	Thin bedded, gray limestone............................	10 feet.
No. 4.	Only partially exposed, but known to contain bluish, clayey shale, and also one or more thin beds of black fissile carbonaceous shale......................................	29 feet.
No. 3.	Thin bedded, gray limestone..........................	5 feet.

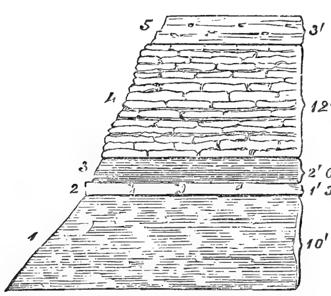
No. 2.	Bluish, clayey shale, passing upward into grayish and light bluish stratified, impure clays..........................	36 feet.
No. 1.	Bluish, clayey shale, containing occasional thin layers of impure limestone....................................	5 feet.
	Total..................................	85 feet.

It is along the valley of Grand river, and those of its tributaries which have their confluence with it in this county, that all the exposures of strata yet observed are to be found. The Drift Deposit is very thick here, as is shown by the fact the exposures of strata, which are found only in the valleys, are seldom, if ever, less than a hundred feet below the general level of the uplands. The section on preceding page, (Fig. 17), is the most extensive one measured in the county, the exposures it represents having been observed near Davis' mill in the valley of Grand river, about eight miles southward from Leon, the county seat, and four miles northward from the south boundary of the county.

No. 1 is referred to the upper part of the Middle coal-measures, and all the remainder to the Upper coal-measures. Near the mill, the clayey shales of the lower portion of No. 2 are crowded with specimens of the minute ostracoid crustacean, *Beyrichia Americana*.

Below Davis' mill, to the southern boundary, there are very few exposures of strata, but all that appear are equivalent to some part of the preceding section. Going up the valley, from that point, the next exposures found, are upon both banks of the river near the village of Terre Haute. The accompanying section, (Fig. 18), was measured at an exposure there immediately upon the left bank of the river.

Fig. 18.



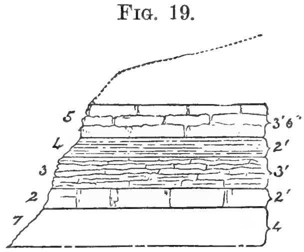
Section at Terre Haute.

No. 5.	Gray marley fossiliferous clay........	3	feet.
No. 4.	Hard, gray limestone, with marly partings..............	12	feet.

No. 3.	Black, fissile, carbonaceous shale, becoming clayey at top.	2½ feet.
No. 2.	Compact limestone in two layers with marley parting....	1½ feet.
No. 1.	Bluish, argillaceous shale, passing beneath the river bed..	10 feet.
	Total..................................	29 feet.

No. 1, of this section is regarded as equivalent to No. 2, of the section at Davis' mill, and although only a part of it is exposed here, it is probably as thick as it is there. If this identification of the strata is correct, none of the beds of the Terre Haute section are so high in the series as the highest of the section at Davis' mill are.

Fig. 19.



At Mansfield's quarries on Short creek, (section 29, township 70, range 26), a few small exposures occur, and the accompanying section represented by Fig. 19, was measured there.

Section at Mansfield's Quarries.

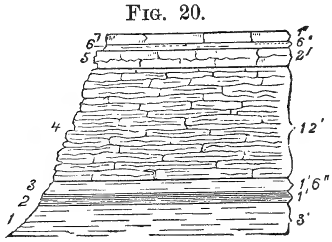
No. 5.	Compact, gray limestone.............................	3½ feet.
No. 4.	Yellowish, calcareo-silicious shale.................. ..	2 feet.
No. 3.	Yellowish, shaley limestone...........................	3 feet.
No. 2.	Bluish, gray, compact limestone.......................	2 feet.
No. 1.	Unexposed down to the level of the creek..............	4 feet.
	Total.................................	14½ feet.

At the point where this section was measured, No. 5 is quite compact, but the corresponding layers in the neighborhood are usually not so. The stone of this bed is almost everywhere largely made up of the Forameniferous shell known under the uame of *Fusulina cylindrica.*

Crossing over in a westerly direction to the valley of Grand river again, we find a few exposures of the strata of the Upper coal-measures. An exposure near Funk's mill reaches almost sixteen feet in vertical thicknes of limestone with marly partings.

Several interesting exposures occur in the valley of Elk creek, a western tributary of Grand river, and in those of both its princi pal branches. The accompanying section, (Fig. 20), was measured at a point a little below the confluence of those branches, and on section 34, township 69, range 27.

Fig. 20.

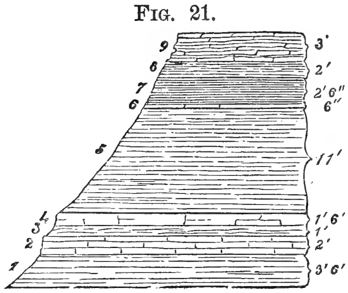


Elk Creek Section.

No. 7.	Compact limestone, (one uniform layer)	1	foot.
No. 6.	Marly clay	½	foot.
No. 5.	Grayish limestone	2	feet.
No. 4.	Grayish limestone, somewhat shaly	12	feet.
No. 3.	Bluish, clayey shale	1½	feet.
No. 2.	Black, fissile carbonaceous shale	1	foot.
No. 1.	Bluish, clayey shale	3	feet.
	Total	21	feet.

The next section was also measured in the valley of the south branch of Elk creek, commencing a little above the place of that just given, and adding the strata to that, as they are successively exposed within a quarter of a mile.

Fig. 21.



Section on South Branch of Elk Creek.

No. 9.	Thin bedded, bluish limestone, with shaly partings	3	feet.
No. 8.	Brownish, mottled, clayey shales	2	feet.
No. 7.	Black, fissile, carbonaceous shale	2½	feet.
No. 6.	Compact layer of limestone	½	foot.
No. 5.	Bluish, clayey shale	11	feet.
No. 4.	Hard, gray limestone	1½	feet.
No. 3.	Bluish, clayey shale	1	foot.
No. 2.	Hard, grayish limestone	2	feet.
No. 1.	Bluish, calcareous, clayey shale	3½	feet.
	Total	27	feet.

All the strata represented by the foregoing sections, and all others observed in Decatur county, evidently come within the verticle range of the section at Davis' mill in the southern part of the county, so that there are no higher beds within its limits than those of the Upper coal-measure formation.

Economic Resources. Stone is the most valuable mineral product yet known to exist within the limits of Decatur county, or, at least, the only one at present accessible. By turning again to the sections of Decatur county strata, it will be seen that stone is comparatively plentiful in the valleys, particularly in those of the west half of the county. All these strata that are hard enough to receive the name of stone, are limestone; all of which, besides being suitable for building purposes, furnish material for a good quality of lime. Layers of it are not unfrequently found from which the common forms of dressed stone for buildings may be obtained. Such stone was observed at Mansfield's quarries and also at several points in the valley of Elk creek and those of its branches as well as elsewhere. It will be observed that "black fissile carbonaceous shale" is mentioned as occurring among the strata represented in some of the preceding sections. Some of this shale splits readily into thin uniform sheets, closely resembling slate, which name is often popularly applied to it. Sometimes it decomposes into a soft, coaly-looking mass, and being itself in a slight degree combustible, it has been popularly believed to indicate the existence and close proximity of coal; or, that if these beds of shale were followed by drifting into the valley-sides, they would be found to have changed to coal. It may seem hardly necessary to say that these opinions are fallacious in all respects, and that the substance in question is entirely valueless. It is true that similar carbonaceous shales exist in connection with coal, but they are just as often found where no coal exists; not only in the unproductive portions of the coal-measures, but in other formations also.

All the rocks of this county, as before stated, belong to the coal-measures, and almost entirely to the Upper. It will be seen that no coal, not even the thinnest seam, is represented in the foregoing sections, and it is not probable that any exists among the exposed strata of the county. It is evident, therefore, that if coal is ever obtained in Decatur county, it must be sought beneath the level of Grand river. Again, the question comes—how deep must we go to reach a profitable bed of coal? This question cannot now be answered fully, but the following suggestions are offered:

It is known that at the western border of the Middle coal-measure formation, as shown by Prof. St. John, in another chapter, its thickness is about two hundred feet. There is some evidence of a considerable thickening of the formation to the southward and westward, so that it may possibly reach three hundred feet in thickness in Decatur county. Again, in the northern part of this formation it contains no bed of coal of sufficient thickness to be worked with profit to a great depth, although a number of thin ones are known to exist there among its strata. We have indications, however, that some of these Middle coal-measure coal beds thicken in different directions, and they may probably be found of profitable thickness when reached by sinking shafts to them in this county. This, however, is doubtful, and the main reliance for success in any enterprise of that kind should be upon reaching the Lower coal-measures, the strata of which are known to contain the thickest and best beds of coal.

If explorations for coal by deep mining should ever be undertaken in Decatur county, the work ought to be commenced in the valleys. This will save an amount of digging and raising of the coal when found, equal to their depth from the general surface. Grand river valley is the deepest one in the county, and reaches the lowest strata to be found exposed within its limits. These lowest strata, as would naturally be inferred, are found in the southern part of the county, and if coal is to be found within its limits, it is just as likely to exist in that part as in any other; therefore the chances are in favor of reaching coal there at less depth than in other parts. Some thin beds of coal, and possibly one of profitable thickness, belonging to the Middle coal measures, would doubtless be passed through within the first two or three hundred feet. In any case it is thought that the whole thickness of both the Lower and Middle coal-measures, together with all the coal-beds they may contain, would be passed through by a shaft five or six hundred feet in depth from the point before named in Grand river valley; and the hope of finding one or more good beds of coal within that depth may be reasonably entertained.

The proportionally large amount of woodland in Decatur county, in a great degree, compensates for the present want of coal. This is sufficient, not only to supply the inhabitants with all necessary fuel, but also with their fencing material and a large part of their building lumber. A very large proportion of the trees are oaks of several species, but the other ordinary varieties of forest trees are well represented.

Brick clays of good quality are obtainable in many parts of the county, especially upon the ridges and approaches to the valleys where the soil proper is thin. Thus with its timber, stone, and brick clays, Decatur county is comparatively well supplied with building materials of its own production.

The soil may be designated in general terms as clayey, at least enough so to make it retentive and durable; preserving its primitive fertility undiminished through many years of cultivation without manuring. It is claimed by the inhabitants to be peculiarly adapted to grass and pasturage. The question of the success of fruit raising has not yet been fully tested, but there are good reasons to believe that the ordinary orchard fruits and grapes will prove a complete success. The numerous valley-sides and slopes possess the same general characters in every respect, and the same climate that those portions of Lee and Des Moines counties do whose fruits have already become so justly celebrated.

6. RINGGOLD COUNTY.

Boundaries and Area. Ringgold county lies immediately west of Decatur, which consequently borders its whole eastern side, Union and Taylor counties bounding it respectively upon the north and west, while the southern boundary line of the State forms that also of the county.

Like Decatur county, it is four townships in width east and west and a little less than four from north to south. The southern boundary line of the State, although intended to be straight and uninfluenced by any geographical features, does not exactly coincide in direction with east and west lines of the linear surveys. Following the boundary line from east to west, it is found to diverge to the southward of the section lines of the surveys, amounting to about one mile in seventy. In consequence of this divergence of the State boundary line, Ringgold county, although nominally of the same size as Decatur, really contains a little greater superficial area. It amounts to about five hundred and forty square miles, or three hundred and forty-five thousand, six hundred acres.

Geology. If our knowledge of the geological character of the strata that underlie the surface of this county, beneath its thick covering of drift, were derived from all examinations which it is practicable to make within its limits alone, we should know very little with certainty about it; for so far as is now known only two exposures of rock in place are to be found within its boundaries. These are very slight exposures both belonging to the Upper coal-measures, and consist in each case of only a few layers of limestone. One of them is upon section 1, township 70, range 28, in the extreme northeast corner of the county, and the other is near its southern boundary on section 19, township 67, range 29. It is consequently more destitute of stone than any other county of southwestern Iowa. Judging from these exposures and from those observed in the adjoining counties, there is no doubt that all the strata which immediately underlie the drift belong to the Upper coal-measures. The drift here is very thick, amounting probably to two hundred feet in thickness over a great part of the county.

Surface Characters and Drainage. The reason of the great infrequency of rock exposures here is due to the unusual thickness of the drift which has covered up all the strata so deeply, that the streams, although their valleys are proportionally of more than average depth, have failed to reach and expose them, except in two instances befored named. The unusual accumulation of drift in this part of the State is an interesting fact, particularly when taken in connection with the further fact that the highest ridge of land in southern Iowa passes down into Missouri through this county. This interesting feature together with its connections is discussed more at length in the chapter upon the physical features of the State.

Ringgold county is drained by two of the upper branches of Grand river, and by the east branch of Platte river. These streams flow through the county in a southerly direction, having at its northern border already attained considerable size, and in their passage through it have eroded their valleys so deeply from the general surface of the uplands that the full grown forest trees which skirt the borders of the streams cannot usually be seen even at short distances from the valley-sides. These valleys are interesting as being the deepest and largest purely drift-valleys in the State. They are from one hundred and fifty feet to more than two hundred feet deep, from the general level of the uplands of the county; and yet, except at the two points before mentioned, nothing but drift material is to be seen in their valley-sides from top to bottom. It is from these and other indications that the Drift Deposit is estimated to reach a depth in Ringgold county of about two hundred feet. Its depth of course cannot be certainly known without digging shafts down through it.

The surface of the county is almost all prairie, and its general aspect is peculiar and interesting. A stranger passing through the county by the ordinary routes of travel is quite unconscious of the presence, within the range of his vision, of the deep valleys with their wooded banks, for the general surface which his vision falls upon is apparently all an undulating prairie. Upon approaching the streams he sees them winding through the rather narrow valleys, with a light border of trees upon their banks; and crossing them, they are soon lost to view again among the general undulations of the surface.

The whole county is so well drained that hardly a single pool of water can be found within its borders, but yet with its numerous streams it is practically well watered, and in addition to this, water may be readily obtained upon the more level surfaces of even the higher prairies.

Material Resources. It cannot be denied that at present, the only known resources of Ringgold county are almost wholly confined to its fertile soil. This is the usual deep, rich, drift soil, so characteristic of southern Iowa. It is not only capable of producing abundant crops of all varieties of farm products that are adapted to the climate, but also the fuel necessary to supply as dense a population as the soil will support, may be grown upon the same soil in the shape of forest trees.

For reasons frequently given upon previous pages it is thought probable that coal exists beneath the surface of this county at a not inaccessible depth. Should the explorations recommended for other counties in search for coal, be undertaken in this, and prove successful, in future times when the whole surface shall become covered with fine farms, and studded with rural villages and multitudes of groves of artificial planting, Ringgold county will hardly be recognized from the foregoing description.

7. UNION COUNTY.

Boundaries and Area. Union county is one of the second tier of counties from the southern boundary of the State, and is bounded on the east, south, and west respectively by Clarke, Ringgold, and Adams counties and on the north by

Madison and Adair. Like the greater part of the counties of the second tier, it is three townships in width from north to south, and four in length from east to west. It is thus a true parallelogram, containing four hundred and thirty-two square miles or two hundred and seventy-six thousand four hundred and eighty acres.

Drainage and Surface Characters. With the exception of half a dozen square miles of the extreme northeastern corner, which are drained into Clanton's fork and thence into the Des Moines, the whole of Union county is drained by the tributaries of the Missouri river, principally by Thompson's fork of Grand river. This stream, together with its branches, has a general course through the county from northwest to southeast. It will be seen that the Great Watershed which divides the drainage between the two great rivers, passes across the extreme northeast corner of Union county, yet the highest land of the county is not there; but upon a secondary watershed, that which divides the drainage of Grand and Platte rivers.

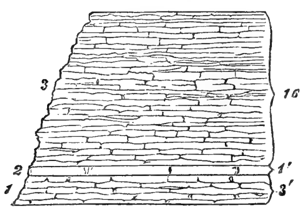
The profile in the first part of this report, prepared from notes of Mr. Thielsen, Chief Engineer of the Burlington and Missouri River Railroad, shows that Highland, near the center of the county, is the highest point on the line of the road between the two great rivers, being seven hundred and ninety-four feet above low water in the Mississippi at Burlington, and twelve hundred and eighty feet above the level of the sea. The lowest point along the line of this road within Union county is in the bed of Grand river, which is about three hundred feet lower than the surface at Highland. The valley proper of Grand river, however, is only from one hundred to one hundred and fifty feet deep from the general level of the upland in its neighborhood, and the great height attained at Highland is by a gradual rise of the general surface from the vicinity of Grand river valley.

The valley of Twelve Mile creek, the principal branch of Grand river, in this county, has a similar average depth and character, but it has no exposure of strata along its entire length, except near its confluence with Grand river, and consequently, it presents the usual characters of a drift valley, as do also all the other smaller streams of the county.

The surface in the immediate vicinity of the larger streams is somewhat broken and partially wooded, but much the greater part, even of the eastern half the county, has that gently undulating character of surface known as rolling prairie.

Geology. If Union county be divided into four equal parts by east-and-west and north-and-south lines, all the exposures of strata, with a single exception, so far as now known, will be found in the southeastern quarter. That exception is a small exposure in the banks of a creek about two miles northeast from Afton. All these strata belong to the Upper coal-measure formation, and nearly all of them are found in the valley of Grand river.

FIG. 22.



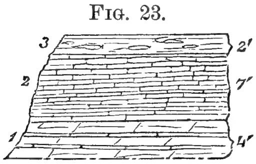
On section 36, township 71, range 28, just where Twelve Mile creek joins Grand river, the section represented by Fig. 22, was measured.

Section at the Mouth of Twelve Mile Creek.

No. 3.	Yellowish gray, thin bedded limestone....................	16 feet.
No. 2.	Compact, grayish limestone, (one layer)...................	1 foot.
No. 1.	Bluish, concretionary, marly limestone......................	3 feet.
	Total..	20 feet.

The base of No. 1 was not seen, nor were any lower strata found exposed there. The water being high at the time of our visit may, however, have covered some others. Going up Grand river valley, the next exposure of any importance is found in the right bank of the stream on section 14, township 71, range 28, at which point the following named strata appear and are illustrated by Fig. 23.

FIG. 23.

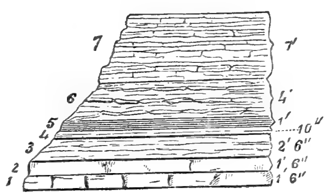


No. 3.	Light colored silicious shaly marl	2 feet.
No. 2.	Compact, thin-bedded grayish limestone	7 feet.
No. 1.	Hard, shaly, marly clay, with thin bands of impure limestone	4 feet.
	Total	13 feet.

The base of No. 1 was not seen, being covered by the water of the creek. About a mile further up the valley, on section 11 of the same township and range, and in the left bank of the river, about ten feet in thickness of uniformly bedded limestone is seen, resting upon about five feet in thickness of bluish, fragmentary, argillaceous, limestone; the latter very fossiliferous.

Continuing up the valley about three miles farther, at Emerson's mill, on section 31, township 71, range 28, the following named strata were found exposed in the left bank of the river and are represented by Fig. 24.

Fig. 24.

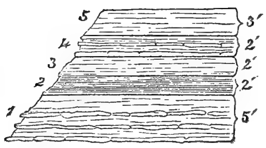


Section at Emerson's Mill.

No. 7.	Yellowish, impure limestone, with frequent partings of calcareo-silicious shale of same color	7 feet.
No. 6.	Bluish, clayey shale, with occasional thin concretionary layers of impure limestone	4 feet.
No. 5.	Black carbonaceous shale	1 foot.
No. 4.	Bluish shale, very fossiliferous	$\frac{10}{12}$ feet.
No. 3.	Bluish clayey shale	2½ feet.
No. 2.	Rough, greyish limestone	1½ foot.
No. 1.	Grayish, clayey, and concretionary limestone	1½ foot.
	Total	18⅓ feet.

The water in Grand river reaching No. 1, no strata were seen beneath it. This lowest member of the section is largely composed of the shells of a very small variety of *Fusulina cylindrica*, and the clayey partings of the layers of limestone are crowded with the same fossil.

Fig. 25.



The next exposure seen in passing up the valley of the Grand river, is represented by Fig. 25. It occurs in its left bank, on land belonging to Mr. Carter, and near the crossing of the Burlington and Missouri Railroad.

Section at Carter's

No. 5.	Light colored marly shale	3 feet.
No. 4.	Yellowish gray limestone in thin layers, with yellowish marly partings	2 feet.
No. 3.	Bluish, marly shale	2 feet.
No. 2.	Black carbonaceous shale	2 feet,
No. 1.	Blue clayey shale, alternating with thin layers of blue, hard and impure limestone	5 feet.
	Total	14

All the strata represented by the foregoing sections, together with all others found exposed in Union county, are of Upper coal-measure age, and all probably belong within a vertical range of thirty feet, so nearly do the slopes of the streams coincide with the southerly dip of the strata; and the stratigraphical equivalents of the whole of this vertical range are regarded as being included within the lower half of the limestone portion of the section at Winterset, in Madison county.

Material Resources. As has been said of a number of other counties, the material resources of Union county, so far as at present demonstrated, consist of its fertile soil, its stone, and the forest trees that skirt its streams. Referring to the preceding sections of the strata exposed at various points along the valley of Grand river, it will be seen that a large proportion of them consist of limestone. These, together with some others in the valleys of small creeks and ravines that come into that river, and not before mentioned, will be found to afford large quantities of building stone, besides any desired quantities of excellent lime.

All the strata found exposed in Union county belonging to the Upper or unproductive coal-measures, it will be correctly inferred from what has been before written, that the hope of finding coal within its limits should be based upon explorations at considerable depth beneath its surface, which, to save useless labor, should be commenced in the valleys. If such enterprises as have been recommended on previous pages for Madison county should prove successful there, those who shall commence similar labors in the valley of Grand river or elsewhere in Union county, will have additional reason to expect similar success.

The strata exposed in this county are referred to a horizon a little below the middle of the full series of Upper coal-measure limestone, as exposed near Winterset, and shown in the section measured near that place, which will be found represented on a previous page. They are also referred to about the same horizon which those strata belong to, that contain the thin bed of coal found there; but that bed of coal seems to have entirely thinned out to the eastward, so that it is not represented at all in the valley of Grand river, and will probably not be found at all in Union county. Thus, although strata in those counties that are geologically equivalent to these, do contain a bed of coal there, yet a supply of that valuable material, if found at all in Union county, should be sought for by deep mining.

There is a sufficient area of woodland in Union county to meet the present wants of the inhabitants for fuel, yet the proportion in the western half of it is small. In the eastern half, however, especially along the valleys of Grand river and its principal branches, the supply of wood is quite sufficient for present and prospective use. The county is well supplied with water from its numerous streams, and wells of water may be obtained almost anywhere at moderate depth, even upon the highest surfaces. The soil is of that variety known as drift soil, except the small proportion of alluvial soil in the valleys. It is everywhere of the same fertile and excellent character as that which characterizes the whole region of southwestern Iowa.

8. ADAIR COUNTY.

Boundaries and Area. Adair, like Madison, and also like the majority of the other counties of the third tier from the southern boundary of the State, contains sixteen congressional townships—four north and south and four east and west. Its superficial area is consequently about five hundred and seventy-six square miles, or three hundred and sixty-eight thousand six hundred and forty acres.

Drainage and Surface Characters. The Great Watershed passes through Adair county, entering it from the north a little east of its northwest corner, and leaving it a little southward of the middle of its eastern boundary. The Chicago, Rock Island, and Pacific railroad crosses the Great Watershed almost exactly at the point where it enters Adair county, which point, according to their levelings, is nine hundred and seventeen feet above low water in the Mississippi at Davenport, or about fourteen hundred and forty-five feet above the level of the sea. After passing southeastward, nearly as far as the center of the county, the watershed sweeps abruptly to the eastward between the upper branches of Grand and Middle rivers, and continues thus until it makes its exit from the eastern boundary. The broad ridge of upland that constitutes the Great Watershed, where it enters the county, continues southward into Union county between the East Nodaway and Grand rivers, both of which are tributaries of the Missouri, and, although it thus becomes a secondary watershed, it has actually a higher elevation than the Great Watershed, which passes further to the eastward, as before explained.

Thompson's fork, of Grand river, and both the East and Middle Nodaways, have their rise in Adair county, and both North and Middle rivers are only small prairie streams where they enter its northern boundary. Even a few rivulets of the upper branches of the East Nishnabotany reach within its western boundary line. It will thus be seen that this county, although not greatly elevated, is, nevertheless, a summit region in relation to the drainage of the surrounding country, and yet, unlike many similar summit regions, it is so perfectly drained that ponds and marshes are nowhere to be found.

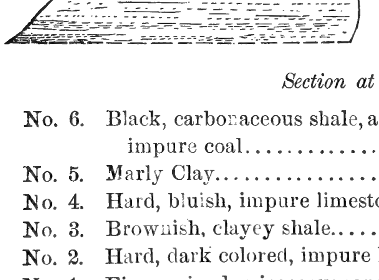
Like all the other counties that lie upon the Great Watershed, the drift of Adair county is very deep, probably two hundred feet deep in its central portion. Therefore, with the exception of that of Middle river, all its valleys are true drift valleys, and even that of the river named is only slightly modified by the few exposures of strata that occur along its course. Some of these valleys reach a depth of one hundred and fifty feet from the general level of the upland, and yet nothing but drift is to be seen within them.

The surface of Adair county, although almost all prairie, is very undulatory, and in many parts is quite broken by deep, yet grassy ravines. This unevenness of surface renders a part of it untillable by the ordinary methods now in use. The soil of these steep slopes, however, is almost as fertile as that upon the more level surfaces, and the time will come when they may be cultivated with profit. Much the larger part of the surface of the county possesses not only an excellent soil, but it is also adapted to convenient tillage. The drift of this county, like that of the others adjoining it, is almost entirely composed of comparatively fine material, so that the surface is never obstructed by boulders, or other impediments to agricultural operations, yet a few isolated boulders occasionally appear. A number of these granite strangers from the north are to be seen upon the surface near the head of Grand river, in the eastern part of the county.

Geology. The only strata exposed in this county are found in the valley of Middle river, and consequently are confined to the eastern and northeastern portions. These all belong to the Upper coal-measures; and, judging from our knowledge of the geology of the surrounding region, the same strata occupy the remainder of the county immediately beneath the deep deposit of drift, unless, which is possibly the case, the extreme border of the Nishnabotany sandstone may intervene in some parts.

The most northerly point in Middle river valley, at which an exposure of strata occurs, is near the right bank of the river, about three miles southward from the north boundary of the county. Below this, to the point where the river enters Madison county, similar strata are exposed in the banks of the stream at rather rare but gradually increasing intervals, until, near the eastern border of the county, the exposures are somewhat numerous. All these exposures are referred to the lower half of the series of limestone strata shown in the Winterset section. It will be remembered, also, that all the strata exposed in the valley of Grand river, in Union and Decatur counties are referred to the same horizon. It is believed, also, that all the strata exposed in the counties of Adair, Union, and Decatur, belong within a verticle range of less than one hundred feet. Nearly all the strata exposed along the valley of Middle river are limestone. They usually amount to only a few feet in vertical thickness, but one of them, on section 12, township 76, range 31, presents a vertical thickness of about twenty feet of limestone. More argillaceous strata exist beneath these, and are exposed in the banks of Drake's creek, on section 13, township 75, range 30. These are shown in the following section and illustrated by Fig. 26.

FIG. 26.



Section at Drake's Creek.

No. 6.	Black, carbonaceous shale, a few inches at top consisting of impure coal........................	2 feet.
No. 5.	Marly Clay..	½ foot.
No. 4.	Hard, bluish, impure limestone.........................	1 foot.
No. 3.	Brownish, clayey shale.................................	1 foot.
No. 2.	Hard, dark colored, impure limestone...................	½ foot.
No. 1.	Fine grained, micaceous sandy shale, becoming darker and more clayey at top..................................	22 feet.
	Total	27 feet.

No. 1 is regarded as equivalent to No. 2 of the Winterset section, although it differs from it somewhat in its more argilaceous character. In this respect it more closely resembles No. 2 of the section at Davis' mill in Decatur county, with which it is also equivalent.

Material Resources. Besides its fertile soil, the material resources of Adair county are unimportant. Sufficient supplies of stone for building purposes and for lime may be obtained along the valley of Middle river, but elsewhere in the county none of this important material is to be found.

If coal should in the future be obtained in Madison county by deep mining, according to the plan before suggested, it may also be expected by similar mining in Adair county.

Ancient Peat. On section 22, township 75, range 32, a bed of dark colored carbonaceous substance was found exposed in the bed of one of the upper branches of the Middle Nodaway river, which is there a mere prairie creek. This is evidently ancient peat, formed there before the surface had assumed its present well-drained condition at least, if it is not really of pre-glacial origin of which there are some indications. The owners of the land thinking it might prove valuable for fuel, sunk a shaft of a few feet in depth down to it from the bank of the rivulet, and the bed was found to be between two and three feet in thickness. The drift, apparently only slightly, if at all modified, rested directly upon it, and it was underlaid by a dull, bluish clayey bed. Although the proportion of ash in this ancient peat is only a little greater than that of some modern peat used as fuel, it is only slightly combustible and probably has no practical value.

9. ADAMS COUNTY.

Boundaries and Area. Adams lies immediately west of Union county before described, and is of exactly the same size, being three congressional townships in width from north to south, and four of the same in length from east to west. Consequently, it contains a superficial area of four hundred and thirty-two square miles, or two hundred and seventy-six thousand four hundred and eighty acres.

Drainage and Surface Characters. The county lies wholly upon the Missouri river drainage slope, the greater part of it being drained by the East and Middle Nodaways and their branches, which pass through it in a southwesterly direction. Some of the upper branches of Platte river drain the southeast corner portion, while the west fork of the One Hundred and Two river rises in, and its upper branches drain the southern part. Its deepest and most characteristic valleys are those of the two Nodaways before mentioned, and the scenery along each is always interesting and frequently beautiful in its kind.

If the county be divided directly through the middle, from north to south, it will be found that the eastern half is almost wholly prairie, there being interrupted belts of woodland along the banks of the East Nodaway and there only, besides a few clumps of trees upon the borders of the other small streams. In the western half, however, there are very considerable bodies of woodland along the valleys of both the Nodaways. The surface of the east is principally gently undulating prairie, almost every acre of which is excellent farming land. The western half is no less valuable for the same purposes, but it contains a somewhat greater, but still very small, proportion of land not easily tillable on account of its greater unevenness. This, however, is more than compensated for by the presence of stone and coal in its valleys, neither of which are found in the eastern half.

Geology. All the strata exposed in Adams county belong to the Upper coal-measure formation, and the exposures here enumerated are the principal ones to be found within its limits. A few feet in thickness of compact, bluish limestone, in somewhat regular layers, is found exposed in the right bank of William's creek, on section 6, township 73, range 34. A similar exposure is also found on section 19 of the same township and range. Crossing to the Middle

Nodaway, the next exposure to be found in this part of the county is near Harader's mill, three miles north of Quincy, where a few feet of clayey shales and impure limestone rest upon a bed of coal about eighteen inches thick. The stone is very small in quantity, and not of very good quality, but owing to the scarcity of stone in this region, it has been taken out to some extent for common use, and the coal has also been mined there, but not extensively. Three miles farther down the valley, and two miles west of Quincy, the same bed of coal has been quite extensively mined at several points within half a mile of each other.

The exposures are upon, or near the banks of the river; the following described strata being exposed in the left bank, near the bridge:

Section near Quincy.

No. 10.	Bluish, shaly limestone	20 inches.
No. 9.	Dark colored shale	8 inches.
No. 8.	Coal	20 inches.
No. 7.	Light bluish, shaly, fossiliferous clay	20 inches.

In the year 1866, Messrs. Barnett and Smith commenced sinking a shaft within a few rods of this locality, with the hope of finding a deeper and better bed of coal. The following is Mr. Smith's statement of the strata passed through:

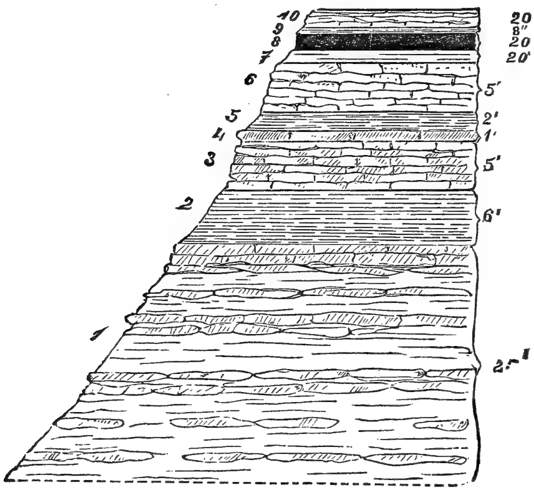
Barnett and Smith's Shaft.

No. 6.	Dark gray, clayey limestone	5 feet.
No. 5.	Dark colored carbonaceous shale	2 feet.
No. 4.	Dark colored fossiliferous limestone	1 foot.
No. 3.	Light, gray limestone, with dull fracture	5 feet.
No. 2.	Gray, clayey shale	6 feet.
No. 1.	Concretionary clayey limestone, alternating with clayey shale	25 feet.

The enumeration of the strata passed through at the shaft of Barnett and Smith, commences at the top (No. 6), with the stratum which immediately underlies the lowest member of the section measured upon the bank of the river, (No. 7).

The annexed diagram, (Fig. 27), is intended to illustrate the section just named, together with the measurements of the shaft:

FIG. 27.



The bed of coal represented in the foregoing section is the only one worthy of the name that has yet been found within the whole vertical range of the Upper coal-measure formation. Besides the opening of this bed by Mr. Harader, near his mill before mentioned, Messrs. Barnett & Smith, Mr. Thos. Nelson, and the Drs. Rawson, of Quincy, have all caused the same bed to be opened in the valley of the Middle Nodaway near that place, and the last named gentlemen have also caused the same bed to be opened a couple of miles farther down the valley on section 15, township 76, range 35. The bed of coal at all these points varies from twelve to twenty inches in thickness, and these are the only points thus far known at which it has been exposed within Adams county. It is an interesting fact that wherever this coal bed is found it occupies a position only a few feet above the water in the river, showing that the general dip of the strata is exactly coincident with the slope of the stream. The dip is so uniform that the same bed may no doubt be reached at about the same level at almost any point between Harader's mill and the south boundary of the county, except where it may have been disturbed and destroyed by the erosive action of the river in the bottom of its valley. There is no evidence whatever, as some of the inhabitants have supposed, that the bed of coal has been brought near the surface at the points where it has been discovered by an elevation of the strata there in the form of folds. On the contrary, besides the evidence that exists within the county, we have the additional evidence afforded by the strata exposed in the adjoining region, of a perfect uniformity of general dip of all the strata throughout the whole region, and of the almost exact coincidence of that dip with the southerly slope of the streams. The same bed is found in the banks of the East Nodaway from the northwest corner of Taylor county to the southern boundary of the State and beyond, and along the whole distance in that valley it holds about the same relative position above the river level as it does in the valley of the Middle Nodaway.

In the banks of the East Nodaway, a little below Corning, some slight exposures of very good common limestone are found, and two or three other similar ones exist in similar positions farther down the stream. The stratigraphical position of these strata is believed to be a little beneath the bed of coal found in the banks of the West Nodaway, and to be equivalent to the limestone strata of Barnett and Smith's shaft there. The latter, however, were not found naturally exposed anywhere in the valley of the Middle Nodaway.

So nearly does the general dip of the strata of this county coincide with the southerly slope of its streams, that all the natural exposures are referred to a vertical range of about fifteen or twenty feet. All these strata are referred to the horizon of the lower half of the series of limestones of the Winterset section.

Material Resources. Besides its universally fertile soil the material resources of Adams county are of considerable importance, the principal of which is its coal. The bed from which it is obtained, as before described, is very thin, and in other parts of the State would be regarded as of little value, but since it is the only one in the whole region at present accessible, it has an important local value. Although the amount of coal obtained from this bed will always be small, the quality is very good, and it will always be in demand until deeper and better beds are found.

It has been often repeated upon previous pages that there are good reasons for hope that profitable beds of coal may be reached beneath this part of the State by deep mining. While it is doubtless practicable to reach such beds of coal at any time, if they really exist beneath Adams county, by sinking deep shafts down to them, yet such an enterprise would be undertaken with much more confidence by most persons if the similar ones which have been suggested for Madison, Union, and other counties had already been prosecuted and proved successful.

The various exposures of stone before mentioned furnish considerable quantities of material for common masonry, walling wells, etc., and some of those on the East Nodaway furnish stone that is suitable for lime.

The soil is the usual deep, rich, loamy soil of the drift, and is everywhere excellent. The county is well watered by its streams, and wells of pure water are obtainable almost anywhere without difficulty.

10. TAYLOR COUNTY.

Boundaries and Area. Taylor is one of the southern tier of counties, and the third in order, counting eastward from the Missouri river. It is bounded on the north, east and west respectively by Adams, Ringgold, and Page counties, and on the south by the southern boundary of the State. It contains nominally sixteen congressional townships, but in consequence of the irregularity caused by the correction line which passes east and west near its center, and also of the obliquity of the southern boundary line, a part of the townships are not quite of full size. Its superficial area is estimated at about five hundred and thirty-seven square miles, or three hundred and forty-three thousand six hundred and eighty acres.

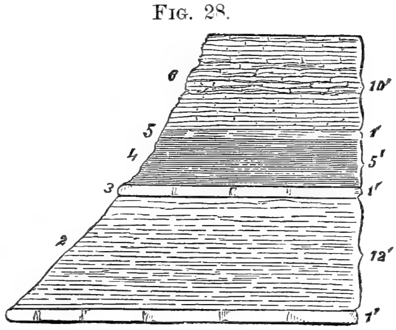
Drainage and Surface Characters. Taylor county is drained principally by the Platte and One Hundred and Two rivers, together with their upper branches, most of which have their rise within its limits. The East Nodaway crosses its northwestern corner, but drains only an inconsiderable part of its surface.

The general character of the surface is gently undulating, but it possesses considerable diversity, and even beauty, along the valleys of the larger streams. Its northeastern quarter reaches nearly to the highest land in this tier of counties, and having no large streams to traverse its surface, it is almost one continuous prairie. The southeastern quarter is also in great part prairie, but narrow belts of woodland exist there along the banks of the branches of the Platte, the East Fork of One Hundred and Two river, and of Honey creek. Both these portions, constituting the east half of the county, are destitute of any exposure of rocks in place.

The western half is also largely prairie, but it contains a greater proportion of woodland, which exists in narrow belts along the banks of the different branches of One Hundred and Two river, and the East Nodaway. In consequence of the presence of these larger streams here, it also has a greater diversity of scenery.

Geology. The only two places at present known within the limits of Taylor county where strata of any kind are exposed are, first in the immediate vicinity of Bedford, the county seat, and second, on land of Mr. J. R. Foster, in the northwest part of the county. In the first named vicinity there are several

FIG. 28.



exposures, the principal one of which is at the quarries of Mr. Edwin Houck, near the bank of the stream, almost within the village at Bedford. At this point the strata exposed consist of about ten feet in thickness of limestone only, but Mr. Houck had drilled down about twenty feet, and that portion of the annexed diagram, and section beneath, No. 6, is taken from his record of the drilling.

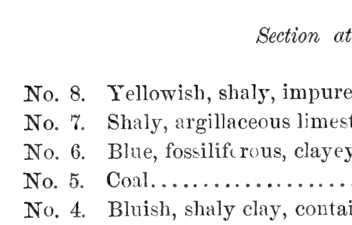
Section at Bedford.

No. 6.	Thin bedded, yellowish impure limestone	10 feet.
No. 5.	"Shaly clay"	1 foot.
No. 4.	"Black slate"	5 feet.
No. 3.	"Hard gray stone"	1 foot.
No. 2.	"Gray shale"	12 feet.
No. 1.	"Hard stone"	1 foot.
	Total	30 feet.

No. 6 contains an abundance of *Fusilina cylindrica*, and other characteristic fossils of the Upper coal-measures.

On Coal creek, just at the borders of the valley of the East Nodaway, on section 29, township 70, range 35, Mr. Foster has opened the same bed of coal that is mined at several points in the valley of the Middle Nodaway in Adams county. The following named strata were observed there in the bed and banks of the creek and are represented by Fig. 29.

FIG. 29.



Section at Foster's Coal-Bank.

No. 8.	Yellowish, shaly, impure limestone	3 feet.
No. 7.	Shaly, argillaceous limestone	2 feet.
No. 6.	Blue, fossiliferous, clayey shale	3 feet.
No. 5.	Coal	1½ feet.
No. 4.	Bluish, shaly clay, containing vegetable remains	4 feet.
No. 3.	Compact, impure limestone	½ foot.
No. 2.	Bluish, clayey shale, with occasional thin seams of impure limestone	6 feet.
No. 1.	Compact, impure limestone	1 foot.

It is thought that all the strata exposed in the vicinity of Bedford belong beneath all those at Foster's. If so, this gives a vertical range of between thirty and forty feet for all the exposed strata of Taylor county.

Material Resources. Except the great and uniform fertility of the soil, the material resources of Taylor county are not important, or, at least, they would not be so regarded in more highly favored regions in that respect. But in a region like this, where coal and stone are both scarce, the small supplies of both these articles, that Taylor county contains, have a great local value. The quality of the coal at Foster's bank is very good, and is much esteemed by blacksmiths.

As to the prospect of finding other and thicker beds of coal by deep mining in Taylor county, little more can be said than to repeat what has been said concerning the other counties adjoining it. There can be no reasonable doubt that the formation which contains the important beds of coal that are now mined in the valley of the Des Moines river, extends beneath Taylor county, and it is reasonable to infer that it contains beds of coal there as well as where they have already been discovered. There is reason, however, to believe that the strata which rest upon those coal-bearing formations, as well as those formations themselves, thicken gradually to the westward and southward, so that the beds of coal before mentioned, if they exist at all in the farther parts of southwestern Iowa, will require considerable capital and labor to reach them. This subject is discussed more at length at the close of the chapter on the Upper coal-measures in another part of this report.

The stone at Foster's coal-bank is not of the best quality, but it will serve for ordinary uses. That obtained in the vicinity of Bedford, makes good lime and is also useful for purposes of common masonry. Quite a number of buildings have been constructed from the stone obtained from Mr. Houck's quarries, and he has a market for his lime extending all over his own county and into those adjoining.

The soil of Taylor county is wholly drift soil, modified only in its valleys which are mostly small ones; it is all excellent, and almost every acre is tillable.

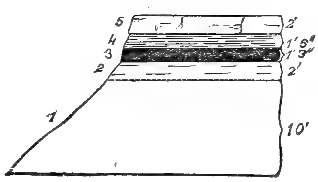
11. PAGE COUNTY.

Boundaries and Area. Page county is one of the southern tier, and second eastward from the Missouri river, lying between Fremont and Taylor counties and immediately south of Montgomery. It contains sixteen congressional townships, but, one half of them not being quite of full size, its area is estimated at about five hundred and thirty square miles, or three hundred and thirty-nine thousand two hundred acres.

Drainage and Surface Characters. The county is drained by the East and West Nodaways, the East, Middle, and West Tarkeos, and the East Nishnabotany. These streams run through the county in a direction a little west of south, and drain it very completely. Much the greater part of the surface is prairie, but the valleys present much pleasing diversity, particularly those of the larger streams. Indeed, the whole valley of the Nodaway, from the northern to the southern boundary of the county is very beautiful, and that of the East Nishnabotany scarcely less so. Narrow belts of woodland border the main Tarkeo, and also the west branch of the same river in the southern part of the county, but the other portions and branches of the Tarkeo within Page county are prairie streams. A somewhat larger proportion is found upon the borders of that portion of the East Nishnabotany that crosses the northwest corner of the county, and also in the valleys of the Nodaways in its northeastern portion. From the middle of the county southward, the valleys of these last named streams contain the largest bodies of woodland to be found within its limits, so that the southeast quarter of the county is well supplied with fuel. The remaining portions, or all outside of the larger valleys is prairie which has a gently undulating surface. The general character of the valleys of Page county, is that of the usual drift valleys, although the Bluff Deposit occupies a large part of its western half.

Geology. The Upper coal-measure strata alone have been found exposed in this county, but it is probable that some outliers of the Nishnabotany sandstone exist beneath the surface in the northwestern part. The strata thus far discovered are all referred to the horizon of the lower half of the series of limestones and shales of the Winterset section. At Hawleysville, just upon the east border of the county, there is an exposure of about five feet in thickness of bluish, argillaceous limestone, with partings of blue, clayey shale. These are no doubt the equivalents of a part of the strata associated with the coal bed at Foster's in the northwestern part of Taylor county, but no coal has yet been discovered in connection with the strata at Hawleysville. Crossing over to the valley of the West Nodaway, the next exposure of strata found were upon the left bank of the stream a little below Clarinda, the county seat. Here the same bed of coal is found again which is worked at various points in Taylor and Adams counties together with their associated strata. The coal is here of about the same thickness (from fifteen to twenty inches) as in the last named counties, and its associated strata have the same general characters. It has been mined just below the mill near Clarinda, and also at several points within a mile below the mill on the east side of the river. The following section, illustrated by Fig. 30, was measured there, commencing with the surface of the river as the base of No. 1.

Fig. 30.



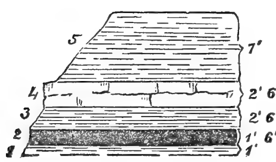
Section near Clarinda.

No. 5.	Hard, bluish, impure limestone..........................	2 feet.
No. 4.	Bluish, clayey shale....................................	1½ feet.
No. 3.	Coal...	1¼ feet.
No. 2.	Light, bluish, clayey shale, containing fossil plants and shells...	2 feet.
No. 1.	Unexposed to the water's edge..........................	10 feet.
	Total..	16¾ feet.

A short distance below this place, a quarry has been opened in some strata of hard, bluish, impure limestone that seems to belong beneath those of the foregoing section, but their actual relative position was not satisfactorily ascertained. Near this point a shaft of several feet in depth has been sunk with the hope of finding another bed of coal. It was reported that such a discovery had actually been made there, but no reliable account of the digging could be obtained, nor any evidence that any trace of coal had been found beneath the bed so well known.

Going southward about four miles from Clarinda upon the west side of the valley, the same bed of coal and its associated strata are again exposed in the banks of a small creek just before it empties into the Nodaway. The coal is mined there also upon land of Judge Ribble, and the following section, illustrated by Fig. 31, was measured there:

FIG. 31.

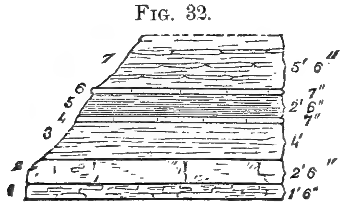


Section at Ribble's Coal-bank.

No. 5.	Yellowish, shaly, calcareous clay	7	feet.
No. 4.	Hard, heavy bedded limestone	2½	feet.
No. 3.	Bluish, clayey shale	2½	feet.
No. 2.	Coal	1¼	feet.
No. 1.	Light, bluish, fossiliferous shaly clay	1	foot.
	Total	14¼	feet.

Proceeding down the valley of the Nodaway, we find a very interesting exposure of strata in the right bank of the stream, just below the dam at Brady's mill. The locality is very near the south boundary of the State, and the exposure is represented by the following section, and Fig. 32.

FIG. 32.



Section at Brady's Mill.

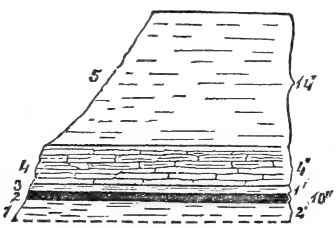
No. 7. Yellowish, shaly marl, with occasional thin layers of impure limestone .... 5½ feet.

No. 6.	Layer of compact limestone	½ foot.
No. 5.	Dark colored, carbonaceous shale, passing upward into light blue, clayey shale	2½ feet.
No. 4.	Layer of compact, bluish, impure limestone	½ foot.
No. 3.	Bluish, carbonaceous shale, with thin, calcareous seams	4 feet.
No. 2.	Hard, bluish, impure limestone	2½ feet.
No. 1.	Bluish, concretionary and shaly limestone	1½ feet.
	Total	17 feet.

These beds are all thought to belong beneath the horizon of the coal bed farther up the valley, and seem to have been elevated here by a very slight fold or undulation in the strata.

Going still further down the valley of the Nodaway, and about two miles within the borders of the State of Missouri, another exposure of strata is found in the banks of the stream in which the same bed of coal is recognized that had been so often seen farther up the valleys of the same stream and its branches. The following section and Fig. 23, represent the strata exposed there.

FIG. 33.

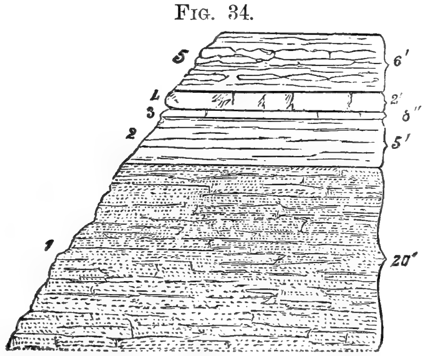


Section two miles below Brady's Mill.

No. 5.	Yellowish, marly shale	14 feet.
No. 4.	Shaly, impure limestone	4 feet.
No. 3.	Carbonaceous shale	1 foot.
No. 2.	Coal	$\frac{10}{12}$ foot.
No. 1.	Light bluish shale with remains of plants	2 feet.
	Total	$21\frac{10}{12}$ feet.

Going westward from the valley of the Nodaway, we find the next exposures of strata in the valley of the main Tarkeo. These are slightly exposed at intervals from the northern to the southern boundary of the county. The following section, illustrated by Fig 34,

FIG. 34.



was measured in the east valley-side of that stream, on section 7, township 70, range 37, near the residence of Hon. Joseph Cramer.

Section near Cramer's.

No. 5.	Yellowish, marly clay with occasional thin layers of limestone	6	feet.
No. 4	Compact, bluish limestone	2½	feet.
No. 3.	Reddish clay	2½	feet.
No. 2.	Bluish, marly clay	2½	feet.
No. 1.	Light bluish, sandy and clayey shales with thin layers of fine-grained micaceous sandstone, occasionally showing ripple marks	20	feet.
	Total	33½	feet.

The members of this section, from No. 1 to No. 3 inclusive, have a very strong lithological resemblance to, and are, no doubt, equivalent with No. 2 and No. 3 of the Winterset section, in Madison county.

Passing down the valley of the Tarkeo from this point we find the harder and more durable strata of the foregoing section occasionally presenting slight exposures in the valley sides, at a nearly uniform elevation above the stream. Going westward into the valley of the East Nishnabotany we find a few exposures of strata similar to those in the valley of the Tarkeo.

Material Resources. The soil of Page county is everywhere excellent, a considerable portion of it being Bluff soil and the remainder, except the small portion of Alluvial, is Drift soil. There is scarcely an acre of it all that may not be tilled with facility and profit. So far as the existence of mineral resources in this county has been demonstrated they consist entirely of its coal and stone.

The only bed of coal thus far discovered within the limits of the county is the one represented in the preceding section, and so often seen in the valleys of the Nodaway and its branches; and although it has not proved capable alone of supplying the inhabitants with necessary fuel, it has nevertheless thus far supplied a sufficiency of that kind of fuel for which there is no substitute for working iron, etc.

No reasonable doubt can be entertained that the Lower coal-measure formation with its beds of coal extends beneath Page county; and if the region were a densely populated one, and capital abundant, the facts in the case, whatever they may be, would soon be demonstrated. While, however, there are such good reasons for believing that coal actually exists beneath the county, it is proper to caution persons of limited means against undertaking the enterprise of sinking a shaft in search of it, with the hope of accomplishing the desired result with the expenditure of only a few hundred dollars. If beds of coal exist at all beneath the one now mined near the surface, a profitable one will not probably be reached at less than several hundred feet below the surface; but at the same time, there are good reasons for estimating the base of all the coal-bearing strata at a less depth than that at which coal is profitably mined in other countries.

Although none of the stone thus far found in Page county has proved to be suitable for lime, yet taking the county as a whole it is very well supplied with stone for ordinary purposes.

Page county possesses much that is interesting to the geologist, although the exposures of strata are fewer than they are in many other regions. Many interesting and characteristic fossils of the upper coal-measures have been collected at the several exposures. The only bed of coal in that formation worthy of the name is as well developed here as in Adams county. In the valley of the Nodaway near Clarinda some teeth of that huge extinct animal, the Mastodon, have been found.

12. FREMONT COUNTY.

Boundaries and Area. Fremont is the most southwesterly county in the state, being bounded on the south by the State boundary line, on the west by the Missouri river, and on the north and east respectively by Mills and Page counties. It is a little more than twenty-two miles across from its northern to its southern boundary, and about twenty-six miles from east to west across its widest part. Its outlier is a little more irregular than that of any of the other counties before described, on account of the meandering course of the Missouri river which forms its western boundary. It is estimated to contain about five hundred and twenty-four square miles or three hundred and thirty-five thousand three hundred and sixty acres.

Drainage and Surface Characters. The greater part of the county is drained by the Nishnabotany and its branches, the Missouri river itself draining the remainder, which is only a small portion. The last named drainage consists of ravines and small creeks which reach the great flood-plain from the uplands through the bluffs that border the flood-plain throughout the whole extent. All these creeks and ravines pour their waters out upon the flood-plain, and none of them, not even the largest, reach the river except by percolation through the earth, for they sink away and become lost soon after leaving the bluffs, although water may remain running in their beds among the bluffs during the whole year.

A very large part of the surface of Fremont county is prairie, but yet it possesses quite enough woodland to furnish all necessary wood to the inhabitants for fuel and fencing.

That peculiar lacustrine deposit described in another part of this report, under the name of Bluff Deposit, occupies almost the entire surface of Fremont county, except the bottoms of its valleys, constituting all its soil except that of its flood-plains, and even enters largely into the composition of the latter also, including that of the great flood-plain of the Missouri river. This remarkable deposit gives character to the entire surface of the county, which differs considerably, even in physical aspect, from any of those counties hitherto described. The bluffs which border the broad flood-plain of the Missouri river, form the most conspicuous feature of its surface, and they extend from its northern to its southern boundary. They reach a height of from one hundred and fifty to nearly three hundred feet from the level of the flood-plain. Although they are in most places composed almost entirely of that fine homogeneous material, designated as Bluff Deposit, they are nearly as steep and abrupt as the rocky bluffs of the Mississippi valley. In many cases, these bluffs of the Missouri river valley are so steep that they appear almost perpendicular, but this is far from being the case, appearances of this kind always being deceptive. The steepest fronts will average less than an angle of forty-five degrees with the horizon, and the boldest and most precipitous one observed, upon which the grass was growing, when tested by the clinometer, proved to have an angle of only fifty degrees. Some of the ravines which open into the flood-plain through these bluffs, are deep, wild gorges, such as one would hardly suspect the existence of, but they are usually short and end abruptly by slopes so steep that one can climb them only with difficulty.

Proceeding inland from the border of the valley the surface quickly becomes much less broken, although the material that constitutes the ground for a great depth is the same, in the higher parts of the county near the great river reaching a depth of two hundred feet. The more level inland surfaces are prairie, which present much the same general appearance that prairie surfaces elsewhere do, the peculiarities of the deposit being more especially shown where the surface is considerably broken.

Coming to the valleys of the East and West Nishnabotany's, which have their confluence into a common stream near the center of the county, although they have eroded their valleys out of this deposit almost alone, we find none of those bold, precipitous bluffs, such as border the valley of the Missouri river. On the contrary, they are bordered by valley-sides of moderate height which gently slope from the high general surface to the lowlands that more immediately border the streams. The lowlands of these two important tributaries of the Missouri river, although resulting as such from the same natural causes as the flood-plain of the great river, are nevertheless quite different from it in some respects. As one stands upon the uplands that border the valley, the lowlands at its bottom, which average about a mile in width, appear to be quite as flat as flood-plains usually are, but upon going down upon them he finds in almost all cases that they slope very gently and uniformly from the valley-side to the stream, so that those portions only that are immediately adjacent to the stream are reached by the floods. This being the character of the lowlands of these valleys they are nearly all tillable without drainage. The undulatory slope of the valley-sides to the higher surface being so gentle, the valley is broad and shallow, averaging from three to four miles in width. Thus, although their scenery is lacking in boldness, that portion of the county traversed by these streams is one of delightful and quiet beauty.

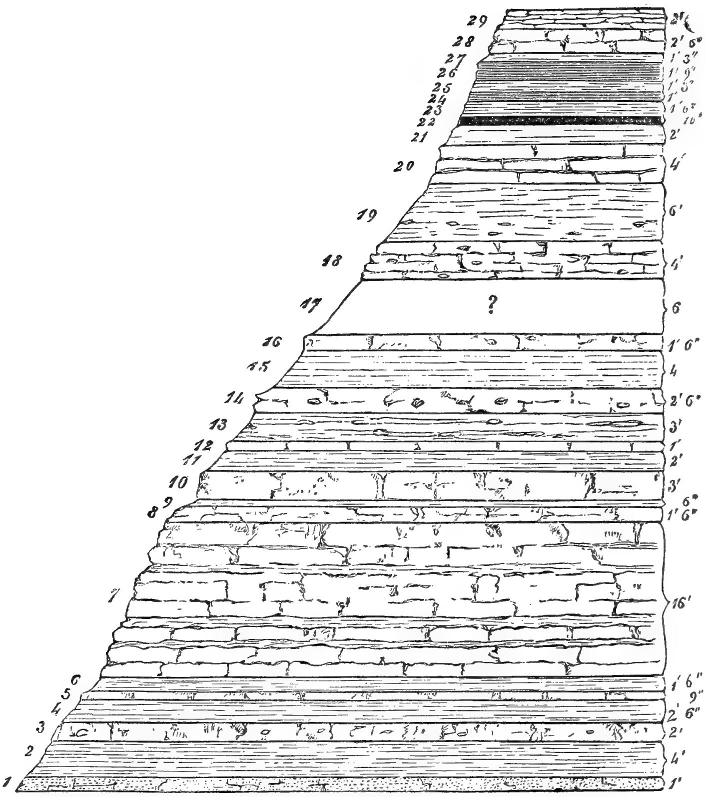
The usual narrow belt of woodland skirts the immediate banks of these streams as well as those of their larger branches. That part of the county lying east of the West Nishnabotany is with these exceptions, all prairie, including lowland, slope, and upland alike; but the part lying west of that river, and of the main stream below the confluence, is well supplied with timber for fuel, fencing, and common lumber. Besides the original forest trees that were of mature growth when the country was first occupied by white men, a dense growth of young trees of all the indigenous species have sprung up, covering large areas, and are rapidly encroaching upon the prairies wherever the fires have been incidentally or intentionally prevented from continuing their annual ravages. These trees are of the most vigorous and rapid growth, although the soil that supports them is entirely composed of that fine homogeneous material that everywhere forms the soil and subsoil, extending to a depth far beyond the possible reach of the rootlets of adult trees. This fact shows conclusively that the original absence of trees upon the prairies was not due to the fineness of prairie soil as some have supposed.

By referring to the descriptions of Ringgold, Union, Adair, and other counties to the eastward, it will be seen that the Drift Deposit there is stated to be very deep. Going westward from that region, we find the drift gradually diminishing in thickness until we reach the counties that border upon the Missouri river, where it is sometimes found not exceeding half a dozen feet in thickness between the stratified rocks beneath it, and the Bluff Deposit above it. The Bluff Deposit is so deep throughout Fremont county, and the drift so thin, it is only at a few points where the latter has been bared by the erosion of the valleys that it is seen at all. Thus, only the immediate beds of the larger streams contain any sand or gravel, while the banks of all of them, and the beds also of the smaller branches and creeks, are composed of the fine material of the Bluff Deposit, and are usually soft and muddy.

Geology. The strata only of the Upper coal-measures have been found exposed in Fremont county, and in consequence of the great thickness of the Bluff Deposit, the exposures of these are very few. None have been found in the valleys of either the Nishnabotany's, and, with the exception of a slight one in the valley of Walnut creek, the only exposures are to be found at distant intervals along the base of the bluffs that border the Missouri river flood-plain. They usually extend only a few feet in height above the level of the plain, and are then lost from sight beneath the Bluff Deposit, or the slight intervening accumulation of drift, but in the northwestern part of the county a few exposures reach considerable height above the general level of the flood-plain.

On land of Mr. John Wilson, section 23, township 70, range 43, there are some fine exposures of Upper coal-measure strata, which reach the greatest aggregate thickness of any yet known within the State, westward from Madison county. It is therefore a locality of great interest and importance in the study of that formation in southwestern Iowa. The strata observed there are represented by Fig. 35, and by the section following it.

Fig. 35.



Section at Wilson's.

No. 29.	Yellowish gray, impure limestone, in thin layers........	2	feet.
No. 28.	Limestone in two layers, with a three inch marly parting	2½	feet.
No. 27.	Yellowish, shaly marl	1¼	feet.
No. 26.	Black, carbonaceous shale..............................	1¾	feet.
No. 25.	Bluish, clayey shale....................................	1¼	feet.
No. 24.	Black, carbonaceous shale	1	foot.
No. 23.	Bluish, marly shale, with numerous fossils	1½	feet.
No. 22.	Impure coal	$\frac{10}{12}$	foot.
No. 21.	Light-bluish, fossiliferous, shaly clay...................	2	feet.
No. 20.	Compact, bluish limestone, with shaly partings	4	feet.
No. 19.	Marly clay, with calcareous concretions................	6	feet.
No. 18.	Light, gray limestone	4	feet.
No. 17.	Unexposed	6	feet.
No. 16.	Compact limestone.....................................	1½	feet.

No. 15.	Light yellowish, indurated marl	4	feet.
No. 14.	Yellowish, silicious limestone, with flinty concretions	2½	feet.
No. 13.	Yellowish, marly shale, with concretions of impure limestone	3	feet.
No. 12.	Compact limestone	1	foot.
No. 11.	Yellowish, marly shale	2	feet.
No. 10.	Gray limestone, in thick layers	3	feet.
No. 9.	Bluish, clayey shale	½	foot.
No. 8.	Yellowish, silicious limestone	1½	feet.
No. 7.	Compact, gray limestone, with marly partings	16	feet.
No. 6.	Bluish, shaly clay	1½	feet.
No. 5.	Compact layer of limestone	¾	foot.
No. 4.	Bluish, shaly clay	2½	feet.
No. 3.	Compact, bluish limestone	2	feet.
No. 2.	Bluish clayey shale	4	feet.
No. 1.	Fine-grained, micaceous sandstone	1	foot.
	Total	$80\frac{10}{12}$	feet.

The lowest member of the foregoing section, No. 1, is only a few feet above the general level of the flood-plain, and many of the other members appear successively above it in the face of the bluff that fronts the flood-plain near Mr. Wilson's residence, while the higher members are found in the bed and banks of a small rivulet that comes down from the uplands through the bluffs at this point. Along the base of the bluffs above this point, as far as the north boundary line of the county, frequent exposures are seen of strata which are equivalent to a large part of those that constitute the lower half of the section at Wilson's. Southward from Mr. Wilson's, along the base of the bluffs, several exposures of the lowest members of that section are seen at long intervals, always holding about the same relative position above the level of the flood-plain, all the way to the town of Hamburg, in the southwestern part of the county. The fine grained micaceous sandstone of No. 1, of the foregoing section, is seen at the village of Plum Hollow, a couple of miles below Mr. Wilson's, and also at Hamburg, and several intermediate points. A few strata were found resting upon it at all these points, but none were observed beneath it. It is therefore stratigraphically, the lowest stratum found in southwestern Iowa, if we except the lowest strata of Madison and Decatur counties. It is regarded as equivalent with No. 1, of the section in the valley of the Tarkeo in Page county; with No. 2 of the section at Winterset, in Madison county, and with No. 2, of the section at Davis' mill, in Decatur county. It will thus be seen that the lowest stratum exposed in Fremont county, is regarded as equivalent with strata that further eastward are known to be near the base of the Upper coal-measures. It is of course inferred that that stratum is also near the base of the same formation, unless those beneath it have thickened very greatly in their westward extension.

No doubt is entertained that the thin bed of impure coal represented by No. 22, of the section at Wilson's, is identical with the bed of coal that has been opened at various points along the valley of the Nodaway, from the centre of Adams county, to the southern boundary of the State. The horizon of this coal is referred to near the base of the series of limestone strata exposed near Winterset, in Madison county, and above No. 3, of that section, as represented on a previous page. If this reference is correct, it will be seen that there is a greater aggregate thickness of limestone strata in Fremont county, beneath the horizon named, than there is in Madison county, which seems plainly to indicate a thickening of the strata of the Upper coal-measures to the westward.

Some borings and excavations have been made at Nebraska City, on the west bank of the Missouri river, with the hope of finding workable beds of coal among the strata beneath. The boring is represented to have reached a depth of four hundred feet without passing through a workable bed of coal, although two or three thin coaly strata were pierced by the drill. It is always difficult to obtain from a boring a perfectly clear idea of the character of the strata passed through by the drill, but judging from the report we obtained from the one in question, all the strata seem to resemble closely in lithological characters, those of the Middle coal-measures. If this is really the case, it gives evidence of a still greater thickening of the strata of the Middle coal-measures than of the Upper. It can hardly be otherwise than that all three of the coal-measure formations have thickened in some degree at least from the middle of their outer border in Iowa, in which case the boring at Nebraska City evidently came much short of reaching the base of the Lower coal-measures, even if the drill entered that formation at all, where alone we may hope to find the thickest beds of coal. Even if no thickening of the formations occurs in that direction, the Nebraska City boring was carried hardly deep enough to reach the base of the Lower coal-measures, (in which relative position the heavy beds of coal exist in the valley of the Des Moines), because the aggregate thickness of the Middle and Lower coal-measures as actually measured in Iowa, is greater than the depth of the boring.

Material Resources. The soil of Fremont county is an inexhaustible source of wealth, for it is almost wholly composed of that fine lacustrine material known as the Bluff Deposit, which is perfectly homogenous from top to bottom, and when thrown out upon the surface from a hundred feet below it, its fertility is almost as great as that already upon the surface. Its mineral resources consist mainly of its stone so far as their existence has yet been demonstrated. Large quantities of stone may be obtained in the northwestern quarter of the county, the exposures being found only at the base of the bluffs that border the flood-plain of the Missouri river. The smaller exposures at Plum Hollow and below, as far as Hamburg, furnish considerable quantities of stone for ordinary use, but those extensive exposures at Wilson's, and at other points to the northward, contain much that is fit for dressing into caps and sills for buildings, and also excellent material for lime.

Brick clay, properly so called, is quite scarce in Fremont county, and yet, very good bricks are made from material obtained from the base of the Bluff Deposit, where it joins the drift and has received some admixture of its clay. Even although the clay contained may amount to only a small fraction of the bulk, the lime it always contains seems to act as a sufficient flax in burning to cement the minute silicious grains of the bluff material. Thus, very serviceable bricks are made, although they are lighter and more porous than bricks made from ordinary brick clay are. It is necessary, however, that this material should be entirely free from the limy concretions which are often found in it, because if present in the material when moulded, the burning of the bricks converts the concretions into quicklime. The slaking of this by moisture absorbed from the atmosphere, or from rains, shatters and destroys the bricks.

After what has been said in the preceding paragraphs, it is almost unnecessary to add that no hope is entertained of the discovery of a profitable bed of coal in Fremont county except by deep mining. For a further explanation of the veiws entertained upon this subject, the reader is referred to the closing section of the chapter on the Upper coal-measure formation.

None of the soil of Fremont county may be properly called drift soil, and only a very small fraction of it has any admixture of drift in its composition. The latter occurs only in the valleys where the drift has been reached by their erosion through the Bluff Deposit. Even the alluvial soils of the flood-plains are largely composed of material derived from the Bluff Deposit. As to the quality of the soil of this county, it may be confidently asserted that no country in the world contains soil of greater fertility and that no equal area contains a less proportion of untillable land.

13. MONTGOMERY COUNTY.

Boundaries and Area. Montgomery county is one of the second tier from the southern boundary of the State, and is of the same size and quadrangular shape as the majority of them. It is three townships, or eighteen miles across from its northern to its southern boundary, and twenty-four miles in length from east to west. Consequently, it contains four hundred and thirty-two square miles, or two hundred and seventy-six thousand four hundred and eighty acres.

Drainage and Surface Characters. Montgomery is eminently a prairie county, all the woodland it contains consisting principally of narrow belts bordering the larger streams. A young growth of forest trees begins to encroach upon the prairies from the valley-sides, wherever the annual prairie fires are made to cease, but all the space between the valleys is at present gently undulating or rolling prairie.

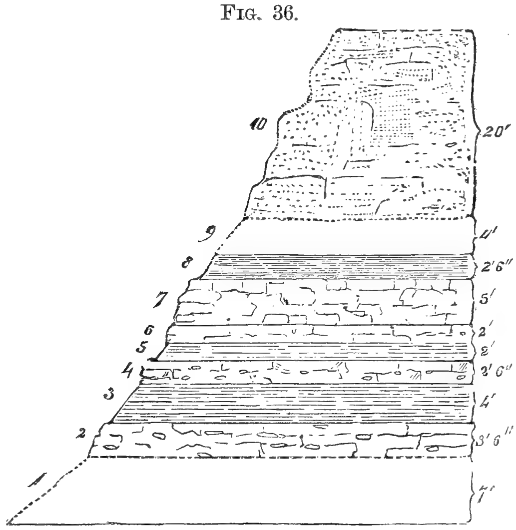
The two principal streams of the county are the East Nishnabotany and West Nodaway, but the Walnut and Tarkeo drain considerable portions. All these streams have nearly a southerly course through the county, which is thoroughly drained by them and their tributaries. Although the surface has a good degree of diversity, it is not so uneven as to render any considerable portion of it inconvenient for cultivation with the ordinary appliances.

The soil is of both drift and bluff origin, the Bluff Deposit thinning out upon the drift within this county, but both are very fertile and excellent. The valleys of the two principal streams mentioned, have the same general characters that they have in the other counties to the southward through which they pass, and which have already been described. Their sides are very gently sloping, which gives them the appearance of being shallow, although their depth will really average about a hundred and fifty feet from the general level of the adjacent uplands.

Geology. The geology of Montgomery county is especially interesting from the fact that besides the Upper coal-measure strata exposed in different portions, there are also important exposures of strata of Cretaceous age in the valley of the Nishnabotany, those at the village of Red Oak being the most southerly exposures of strata of that age yet known in Iowa. All the exposures of those strata in Montgomery county are of sandstone, and from the fact of their being most frequently seen in the valley of the Nishnabotany's, the name Nishnabotany sandstone has been applied to the formation. This formation constitutes the lowest Cretaceous strata yet known in this part of the continent, and in this county it is found resting uncomformably upon the Upper coal-measures. The principal exposures of strata occur in the valley of the East Nishnabotany, but a few are found in the valley of the Nodaway in the northwestern part of the county, and also in the valley of the Tarkeo, in the southern part.

The following section, illustrated by Fig. 36, was measured at and near Stennett's quarries, near the mouth of Pilot creek, on the east side of the valley of the Nishnabotany, and six miles north of the village of Red Oak. It is the most extensive exposure of strata to be found in the county.

FIG. 36.

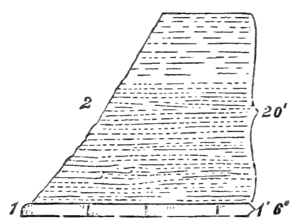


Section at Stennett's Quarries.

No.	10.	Coarse, ferruginous sandstone	20	feet.
No.	9.	Unexposed	4	feet.
No.	8.	Black, fissile, carbonaceous shale	2½	feet.
No.	7.	Fragmentary, marly limestone	5	feet.
No.	6.	Compact, gray limestone	2	feet.
No.	5.	Grayish, marly clay	2	feet.
No.	4.	Compact, gray limestone	2½	feet.
No.	3.	Grayish, calcareous clay	4	feet.
No.	2.	Compact, gray limestone, with dark nodules of flint	3½	feet.
No.	1.	Unexposed from the bed of the creek	7	feet.
		Total	52½	feet.

Going northward, from Stennett's into Cass county, both the Cretaceous and Upper coal-measure strata are again found exposed and will be represented in the geology of that county. Going southward, an exposure of the Cretaceous sandstone is found on land of Mr. Johnson, section 2, township 72, range 38. It occurs in the bank of a small rivulet which comes into the Nishnabotany from the eastward. It consists of about thirty feet in thickness of the usual coarse soft sandstone, resting upon variegated, or red and grey mottled clay. No other strata were found in connection with these at that locality. At Red Oak village a couple of exposures of the same sandstone are found, each measuring some eight or ten feet in thickness, and in the same vicinity Upper coal-measure strata are exposed which occupy both higher and lower levels respectively than the sandstone does, showing conclusively the unconformability of the latter upon the former. Those referred to as being above the level occupied by the sandstone are regarded as equivalent to the upper part of the section at Stennett's, beneath the sandstone there, while the lower strata at Red Oak are lower than any seen at Stennett's, and doubtless, the lowest exposed in the county. They are probably equivalent to the lower members of the section in the valley of the Tarkeo in Page county. Fig. 37 represents those lower strata in the banks of the Nishnabotany at Red Oak.

FIG. 37.



Section near Red Oak.

No. 2.	Fine grained sandy and clayey micaceous shale..........	20 feet.
No. 1.	Bluish compact impure limestone........................	1½ feet.
	Total..........	21½ feet.

No 1 was found exposed just at the water's edge. At the top of No. 2 reddish and bluish clays were obtained in a disturbed condition by weathering. They are very similar in character to those seen at Johnson's, beneath the sandstone; and on the banks of a small creek or rivulet near the abandoned town of Frankford another exposure of similar clay is found with no associated strata. There are some reasons for believing that these clays are of Cretaceous age like the Nishnabotany sandstone; but no positive evidence of it was obtained. Proof, however, of the Cretaceous age of the Nishnabotany sandstone was obtained at Red Oak in the form of fragments of fossil-leaves of Angiospermous trees of species that characterize Cretaceous strata elsewhere.

Mineral Resources. The mineral resources of Montgomery county are comparatively small and confined principally to its stone, the local value of which is very great. The same thin bed of coal that has been described as being frequently exposed in the valley of the Nodaway, is also found in the extreme northeast corner of Montgomery county, but although some good coal has been taken out there, the bed is too thin and poor to be worked with profit. With this exception, no other discovery of the kind has been made within its limits, and in view of the evidence we have that the Nodaway valley coal bed is the only one included within the strata of the Upper coal-measures, and that it thins out to the westward, it can hardly be expected that it will present a workable thickness in other parts of Montgomery county if it should be discovered there. Thus we have no present encouragement to hope that a workable bed of coal will be found occupying a position above the level of the bottom of its deepest valleys, and although it may be reasonably inferred that coal actually exists beneath that level, it is probable that a depth of several hundred feet must be passed through before reaching it.

The sandstone is of comparatively little value, as it is usually too soft for any practical use, but the limestone is of good quality for all ordinary purposes, and much of it makes excellent lime. The most important quarries are those of Mr. Wayne Stennett, about six miles north of Red Oak. The inhabitants of the whole of Montgomery county and many of those adjoining, are furnished with lime from these quarries, and also with a large part of their stone for common uses.

The clay before mentioned as occurring at the base of the sandstone exposure at Mr. Johnson's, a few miles above Red Oak, is very plastic, and is reported to have been used for common stone-pottery with good success. The red clayey bed before mentioned as occurring near Frankford, is so ferruginous that it may be very properly called clayey ochre. Mr. J. B. Packard, of Red Oak, has erected a small mill for grinding it into material for paint. When finely ground and mixed with linseed oil, it makes a serviceable paint without any other admixture where the color is not objectionable. It may of course be mixed with white lead, and the color thus modified. In chemical composition it somewhat resembles the paint known in the market as *pecora.*

14. MILLS COUNTY.

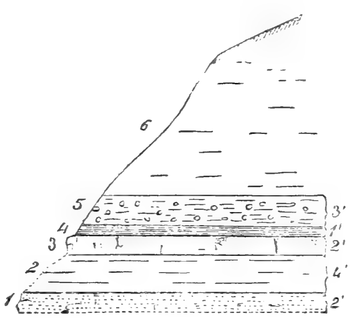
Boundaries and Area. Mills county lies immediately north of Fremont, west of Montgomery, and south of Pottawattamie counties, and is bounded on the west by the Missouri river. It is eighteen miles across from its northern to its southern boundary, and about twenty-four miles in its widest part from east to west. In consequence of the meandering course of the great river, it contains some small fractions above twelve regular congressional townships, and is consequently estimated to contain about two hundred and eighty-eight thousand acres.

Drainage and Surface Characters. The principal streams of Mills county are the West Nishnabotany, its tributary Silver creek, and Keg creek. The whole surface being occupied by the Bluff Deposit, their valleys have the peculiar characteristics which it everywhere imparts to those of the tributary rivers, somewhat resembling the valleys of the drift. That of the West Nishnabotany is of the same general aspect which it and its associate, that of the East Nishnabotany, have in the other counties before described; namely, a broad gently inclining flood-plain and gently undulating valley-sides, which slope very gradually to the adjacent uplands. The character of the smaller valleys is somewhat similar, but their flood-plains are proportionally smaller, or often almost entirely wanting. The larger streams have eroded their valleys through the Bluff Deposit down to the Drift in a few places, so that the immediate beds have a small proportion of gravel and sand, yet the banks are almost invariably muddy, being composed of the fine material of the Bluff Deposit. The character of the great flood-plain of the Missouri river has already been described in the early part of this chapter, and the character of the bluffs that border it have also been described in the chapter on surface deposits. The highest land in the county is almost three hundred feet above the level of the great flood-plain. The eastern two-thirds of the county is principally prairie, but the western third contains much woodland, a large part of it being covered with a thrifty growth of young indigenous forest trees that have sprung up spontaneously as soon as the annual prairie fires ceased by inhabitation of the region, and cultivation of a large part of its soil. The general aspect of the county is one of much beauty, particularly along the valleys of the larger streams; and the ranges of bluffs that border the flood-plain of the Missouri river are often very picturesque.

Geology. With the exception of two or three exposures of the Nishnabotany sandstone near each other in the north-eastern corner of the county, all the stratified rocks yet observed within its limits belong to the Upper coal-measures. The principal exposures of the Nishnabotany sandstone in this county are on section 23, township 73, range 40, and appear in the east valley-side of the Nishnabotany just below Farm creek. These exposures where opened for quarries, are from ten to fifteen feet in thickness, consisting almost entirely of coarse-grained ferruginous sandstone, somewhat irregularly bedded, with occasional slight intercalations of clayey material.

The only exposures of Upper coal-measure strata in the county are found in the valley of the Nishnabotany, or at or near the base of the bluffs that border the Missouri river flood-plain. Near the exposures of sandstone before mentioned there is a slight exposure of Upper coal-measure limestone, referable to a horizon nearly corresponding with the coal-bed in the valley of the Nodaway. On section 5, township 71, range 41, two or three small exposures of impure, yellowish limestone and calcareous shales were found, which are referred to about the same horizon. At Glenwood, in the valley of Keg creek, and not far from where it enters the great flood-plain, the following section was measured, which is referred to a horizon a few feet below that of the last named exposures. These are all that have yet been observed in Mills county, except those important exposures along the base of the Missouri river bluffs.

FIG. 38.



Section at Glenwood.

No. 6.	Bluff deposit	15	feet.
No. 5.	Drift	5	feet.
No. 4.	Dark-colored, carbonaceous shale	1	foot.
No. 3.	Compact, dark-colored limestone	2	feet.
No. 2.	Unexposed	4	feet.
No. 1.	Sandstone, (seen in a well)	2	feet.

The same layers of limestone represented in this section are also exposed together with a few others, about a mile further down the creek in the right valley-side. Going down the valley of the Missouri along the base of the bluffs we find some very extensive and valuable exposures of limestone in the face of the bluffs at their base. These exposures are six or eight miles southward from Glenwood and not far from the line of the Council Bluffs and St. Joseph railroad. The aggregate thickness of the strata exposed here varies at the different points where they are seen, but the highest are not quite so high in the series as the upper part of the section at Wilson's, in Fremont county, and only six miles below here. They comprise only the equivalent of about the lower two-thirds of that section, the greater part being limestone. There is evidence that in this part of Mills county the equivalents of the upper portion of the section at Wilson's, once existed here in their order above the others, but that they have been removed by glacial action.

Near the house of Mr. Joseph Shaw, on section 16, township 71, range 43, very distinct glacial scratches were seen upon the upper surface of an upper layer of limestone. The natural inequalities of the bedding surface had been removed, leaving a plain and level surface upon which there were two distinct sets of striæ that are fully described in another part of this report.

A good idea of the general character of the strata exposed in this vicinity, may be obtained by referring to the section at Wilson's, in Fremont county, and only a few miles distant, therefore no illustration of them is given here. Besides these and the other exposures before described, there are a few small ones of the same limestone at the base of the bluffs, a little above the point at which Pony creek enters the great flood-plain. These are all the exposures yet observed in Mills county, the deep deposit of bluff material having generally covered the strata from sight.

Material Resources. The soil of Mills county is almost wholly bluff soil, except that of the flood-plains of the rivers, and this also is largely composed of the same material. It is all of remarkable fertility, and the resources to be derived from it in the future are in no danger of being over-estimated. The other resources of the county consist almost entirely of its stone and wood. The most important stone quarries are those along the base of the bluffs in the southwestern part. The other exposures, although small, have a great local value, but these of the southwestern part of the county, are of such a character that they would be valuable in any region. All of the stone is suitable for ordinary purposes, and for the production of lime, and many of the layers also furnish blocks suitable for bridge building, and for dressing into caps and sills for buildings. The localities in this vicinity may be made to furnish an abundance of the material mentioned.

Mr. Peter Cooper has quarried and dressed considerable quantities of the Nishnabotany sandstone at the exposures before mentioned, in the northeastern part of the county. This stone serves a very good purpose for some parts of buildings, if selected with care, but it is too soft, even after it has received its usual hardening by exposure, for those structures which require great strength of material.

Although the vertical range of the Upper coal-measure strata of Mills county includes the horizon of the Nodaway valley coal-bed, yet the coal itself has not yet been found within its limits. Consequently, if coal is ever obtained, it must be sought by deep mining beneath the level of its deepest valleys. As to the probabilities of finding it by such mining, the reader is referred to the closing section of the chapter on the Upper coal-measures in another part of this report.

The county is well supplied with fuel from its woodlands, and the young growth of indigenous forest trees before mentioned, is increasing so rapidly that there is no cause to fear that the supply from this source will become exhausted.

15. CASS COUNTY.

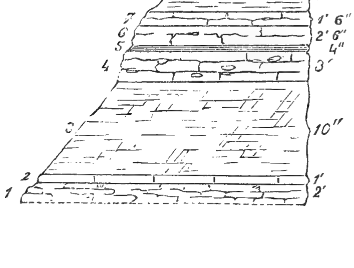
Boundaries and Area. Cass, is the second county eastward from the Missouri river in the third tier from the southern boundary of the State, lying east of Pottawattamie and west of Adair counties. It is exactly square in outline, being twenty-four miles from east to west and the same from north to south. Consequently, it contains five hundred and seventy-six square miles, or three hundred and sixty-eight thousand six hundred and forty acres.

Drainage and Surface Characters. It is drained principally by the upper branches of the West Nodaway and the East Nishnabotany. These upper branches are designated as creeks in this county, as such small streams should always be, and have separate names applied to them. Thus, the main branch of the Nodaway, which drains the southeastern part, is called Sixteen Mile creek, while in the northeastern part the East Nishnabotany becomes divided up into Indian, Buck, Troublesome, Turkey, and other creeks and loses its identity in them. These creeks drain the county completely, and give considerable diversity to its surface. The whole of the county lies within the area drained by the tributaries of the Missouri river, but its extreme northeastern corner reaches almost to the Great Watershed. It is estimated from the neighboring levels along the line of the Chicago, Rock Island, and Pacific Railroad, that this corner of the county is about nine hundred and twenty feet above low water in the Mississippi river at Davenport, or one thousand four hundred and forty-eight feet above the level of the sea.

Much the greater part of the surface is prairie, and between the valleys of the larger streams it is, as usual, gently undulating. The character of the valleys of its creeks is almost entirely that of the drift valleys, the sides being gently sloping, and nowhere steep. A few exposures of rock in the valley of the Nishnabotany, produce some steepness of its sides at a few points, but these are rare exceptions. The Bluff Deposit thins out upon the surface of the uplands in the western part of the county, so that the greater part of the soil is the fine drift soil of the prairies. The general aspect of the eastern half of the county is that usually presented by the gently undulating prairies of southwestern Iowa, but the western half, in the vicinity of the streams, is rather more diversified. The valley of the Nishnabotany still retains its characteristic beauty in this county, until it becomes subdivided into the numerous creeks before mentioned. The valleys of these creeks produce a pleasing diversity of surface in that part of the county drained by them.

Geology. The stratified rocks of Cass county, which immediately underlie the surface deposits, are of Upper coal-measure and Cretaceous age. Those of the latter age are the lower strata of Nishnabotany sandstone, and rest unconformably upon the Upper coal-measure strata. Their exposures are isolated, comparatively small, and have the general appearance of outliers separated by denudation from the body of the formation as they doubtless are. The most important of these exposures is at the the town of Lewis, in the east valley-side of the Nishnabotany, where it reaches a known thickness of about sixteen feet, but is doubtless much thicker there further beneath the drift. Besides several smaller exposures of it within a few miles of Lewis, it also appears on section 5, township 76, range 35; section 33, township 75, range 36; section 22, township 74, range 35, and on section 3, township 74, range 37. This sandstone, like that of the same formation in Mills and Montgomery counties, is usually too soft for any practical use, but at Lewis it is bedded with considerable regularity, and possesses a good degree of firmness. At the last named locality it is darker than usual, being mostly of a dark brown color. At Lewis, and also at other localities, the Nishnabotany sandstone contains occasional isolated lumps of clayey shale imbedded in the stone. They were evidently rounded by attrition in water, and imbedded in the mass, while the whole was in the form of moving sand. It is suspected that these clayey lumps were detached from coal-measure strata, but no fossils were found in them which might have proved it.

Fig. 39.



The most important exposures of the Upper coal-measure limestone are also found in the immediate vicinity of Lewis. The accompanying section, illustrated by Fig. 39, was measured just below the mill at that place, in the right bank of the Nishnabotany.

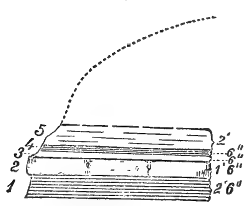
Section at Lewis.

No. 10.	Yellowish, marly clay, with occasional thin calcareous layers	2	feet.
No. 9.	Grayish, compact limestone	⅔	foot.
No. 8.	Marly clay	4	feet.
No. 7.	Fragmentary limestone, with flinty nodules	1⅓	feet.
No. 6.	Grayish, compact limestone	2½	feet.
No. 5.	Dark colored carbonaceous shale	½	foot.
No. 4.	Dark colored, concretionary, and very flinty limestone	3	feet.
No. 3.	Yellowish, and bluish marly clays	10	feet.
No. 2.	Grayish limestone	1	foot.
No. 1.	Yellowish, marly clay	2	feet.
	Total	27	feet.

No. 1 was partially hidden beneath the water of the river, and upon its shores numerous fragments of black, laminated, carbonaceous shale were seen, doubtless derived from a bed of that material in the bottom of the stream.

There are frequent exposures of these strata of limestone and shales in the valley-sides of the Nishnabotany, at intervals, for three or four miles below Lewis. Going up Turkey creek, northward from Lewis, three or four miles, several exposures of limestone, marly clays, and shales were observed, all of which are regarded as belonging within the vertical range of the section at Lewis.

Fig. 40.

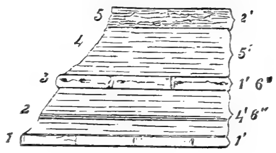


The following section was measured in the bank of a small creek called "Chapman's branch," about a mile above Lewis. It is illustrated by Fig. 40.

Section at Chapman's Branch.

No. 5.	Yellowish, marly clay	2	feet.
No. 4.	Black carbonaceous shale	½	foot.
No. 3.	Clay, resembling fire clay	½	foot.
No. 2.	Bluish, compact limestone	1½	feet.
No. 1.	Black carbonaceous shale	2½	feet.
	Total	7	feet.

FIG. 41.



About a mile further northward from Lewis, on section 1, township 75, range 37, the following measurements were made of strata exposed in the left bank of Turkey creek and illustrated by Fig. 41.

Section on Turkey Creek.

No. 5.	Yellowish, calcareous clay, containing small masses of limestone, almost entirely composed of *Fusulina cylindrica*..	2	feet.
No. 4.	Yellowish, calcareous shale...........	5	feet.
No. 3.	Limestone with flinty concretions	1½	feet.
No. 2.	Yellowish, marly clay, with one thin band of black carbonaceous shale......................	4½	feet.
No. 1.	Bluish, compact limestone.............................	1	foot.
	Total....	14	feet.

No. 1 of this section is regarded as equivalent with No. 2 of the section on Chapman's branch, and both of these, equivalent with No. 2 of the section near Lewis.

A number of exposures of strata, belonging within the same vertical range, also occur along the valley of Indian creek, a few miles westward from Lewis.

In the southern part of the county, in the valley of Sixteen Mile and Seven Mile creeks, there are also considerable exposures of Upper coal-measure strata, principally limestone. They are usually small and unimportant, but some seen on section 31, township 74, range 35, were about thirty feet in vertical thickness, yet they were so incompletely exposed in the valley-side that no satisfactory measurement of them was made. They are, however, referred to about the same stratigraphical horizon as that of the strata exposed near Lewis. Thus, all the strata exposed in the county, except the Nishnabotany sandstone, are all referred to the Upper coal-measure formation, and all, apparently, confined to a vertical range of forty feet at most. This range is regarded as about equivalent to the lower half of the limestone strata above No. 3 of the Winterset section, and also includes the horizon of the Nodaway valley coal-bed.

Material Resources. It is possible that the Nodaway valley coal-bed may yet be found in Cass county, but if ever discovered, it will probably be much too thin and poor for profitable working, and the only hope of obtaining a supply of coal, within the limits of the county, is by deep mining. Should such explorations along the valley of Middle river, as have been suggested, ever be made and should prove successful, similar enterprises might be undertaken along the valley of the Nishnabotany, in Cass county, with great confidence of success.

The stone of Cass county is of considerable value, particularly so, as large regions lying adjacent to it in other counties are destitute of stone and must be supplied from this. The exposure of Nishnabotany sandstone, at Lewis, is the only one at which it has proved to be of any practical value. Here considerable quantities of it have been used for the construction of houses and for other purposes. For ordinary dwellings, its dark-brown color gives the structure a sombre and gloomy aspect, but this color would not be objectionable in buildings of other styles of architecture, such, for example, as a small gothic church or chapel.

Any desired quantities of stone for common building purposes and for the manufacture of lime may be had at and in the vicinity of Lewis. Some of the strata there will also furnish good blocks for dressing into caps and sills for buildings. Large quantities of the same material may be also obtained in the valley of Sixteen Mile creek.

The soil of Cass county is of that abundant fertility which characterizes the soil of the whole region, and will always prove the constant and principal source of wealth to the inhabitants. The western and southern portions are tolerably well supplied with fuel from the woodlands there, and the growth of young forest trees is so rapid that abundant future supplies may be derived from this source.

16. POTTAWATTAMIE COUNTY.

Boundaries and Area. With the exception of Kossuth, as that county, up to the present year, has been organized, Pottawattamie county is the largest one in the State. The meanderings of the Missouri river, which forms its western boundary gives a slight indefiniteness to an estimate of its superficial area, but it is not far from nine hundred and sixty square miles, or six hundred and fourteen thousand four hundred acres. Its greatest breadth from east to west is forty-three miles, while its width is twenty-four miles, the same as that of the majority of the counties of the third tier from the southern boundary of the State, Pottawattamie being the most westerly one of that tier.

Drainage and Surface Characters. The principal streams of the county are the East and West Nishnabotany rivers, and Pigeon, Mosquito, Keg, Silver, and Walnut creeks. These all have their courses more or less to the west of southward, and drain the county very completely.

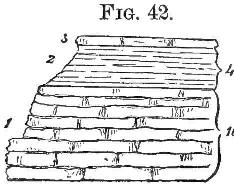
All except a fraction of the surface of Pottawattamie county is, or originally was, prairie, but the opening of farms and the encroachment of the young growth of forest trees is fast changing its primitive aspect in this respect. The general surface is of the usual undulatory character common to the prairie region occupied by the Bluff Deposit, which includes the whole of Pottawattamie county. The Bluff Deposit becomes very thin in the eastern part, but is gradually thickened to the west. The drift very rarely appears anywhere in the county, but in the beds of the streams and larger creeks its gravel and sand is to be seen at low water, and slight exposures of it also appear beneath the Bluff Deposit, at the base of the bluffs that border the great flood-plain. In the latter case, it is usually altered drift. The East Nishnabotany has but a short portion of its course lying in this county, and that in its extreme southeastern part. Its valley here retains the beauty which characterizes it in the counties to the southward, and the same may be said of the valley of the West Nishnabotany, which also traverses the county from its northern to its southern boundary. The northern half of that portion of the latter valley which lies within Pottawattamie county, however, is merely that of a prairie stream, but there are considerable bodies of woodland in the southern half of it.

The greater part of the surface of the county has a considerable degree of monotony in general aspect, owing to the extensive prairie surfaces, but the region adjacent to the valley of the Missouri river, along the whole western border of the county, is one of strange and interesting beauty, the most conspicuous features of the landscape being the broad fertile flood-plain of the Missouri river and the continuous range of bluffs that border it, all of which have been already described.

Geology. Owing to the great depth of the Bluff Deposit, exposures of strata are very few, but all the strata of the county immediately beneath the surface deposits are, without doubt, of Upper coal-measure and Cretaceous age. Only one exposure of rocks of the latter age has been observed within its limits. This is in the valley of the East Nishnabotany, near the southeast corner of the county, on section 36, township 75, range 38. Its full exposed thickness at this point is about thirty feet, and the continuous front of the exposure is several hundred feet in length. The stone is the usual yellowish, coarse-grained sandstone, too soft here for any practical use.

No exposures of Upper coal-measure strata were found in the valley of the East Nishnabotany in this county, although several extensive ones occur in the same valley in Cass and Montgomery counties, not far distant. In the southern part of the county, on section 21, township 74, range 40, near the left bank of the West Nishnabotany, there is a small exposure of the Upper coal-measure strata. The exposure is near Macedonia post office, and a little below Stutsman's mill, and is represented by Fig. 42.

Fig. 42.



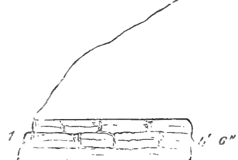
Section at Stutsman's Mill.

No. 3.	Layer of grayish limestone	$\frac{10}{12}$ foot.
No. 2.	Light bluish, shaly clay..................................	4 feet.
No. 1.	Grayish limestone..	10 feet.
	Total	$14\frac{10}{12}$ feet.

Going up the east side of the valley about a mile above the old mill, several exposures of limestone are seen in the valley-side, comprising six or eight feet in thickness of grayish limestone, crowded with the shelly remains of *Fusulina cylindrica.* At the water's edge in the same vicinity, and of course holding a position beneath the limestone, some slight exposures of carbonaceous shale and calcareous fossiliferous clay were observed. The inhabitants report the existence at the last named locality of a thin seam of coal near the bank of the river. This was not seen, but since the strata there occupy about the same horizon as the Nodaway valley coal-bed, it is not improbable that such a seam exists there, yet it is thought improbable that it will be found of profitable thickness.

Going westward to the valley of Mosquito creek we find in its left bank, about three miles west of Council Bluffs, some important exposures of limestone with marly partings, presenting a vertical thickness of about seven feet, all of which are referred to the same horizon as the exposure below the mill near Lewis. Important quarries have been opened here for obtaining building material and for lime-burning. Some of the upper layers are flinty, like some of those at Lewis, and considerable quantities of flint are mixed in the very slight deposit of drift that occurs here, which has a thickness of only two or three feet in some places between the Bluff Deposit and the limestone.

FIG. 43.



Six miles north of Council Bluffs, there is another exposure of the same limestone, and apparently representatives, in part, of the same layers just mentioned. The exposure is at the base of the bluffs that border the great flood-plain of the Missouri, and near the railroad track a short distance below the town of Crescent. The following named strata are found there:

Section near Crescent.

No. 3.	Light, brownish gray limestone	1 foot.
No. 2.	Light gray oolitic limestone	2½ feet.
No. 1.	Impure concretionary limestone	1 foot.
	Total	4½ feet.

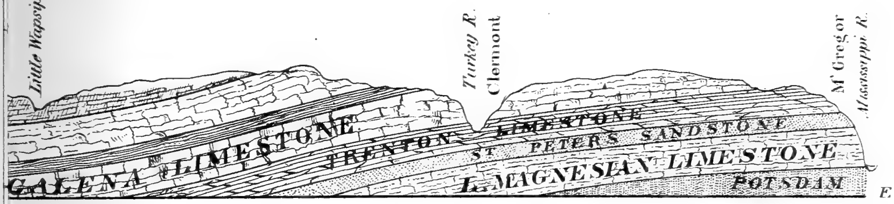
Near the place were these strata are exposed, a shaft was sunk about twenty feet in depth, which passed through much yellowish, marly shale and occasional layers of impure limestone. Near the bottom, a layer of black laminated carbonaceous shale was found, which has the same general character as that so often found among the strata of all the coal-measures. These exposures of strata hitherto mentioned are the only ones that have been observed within the limits of this great county.

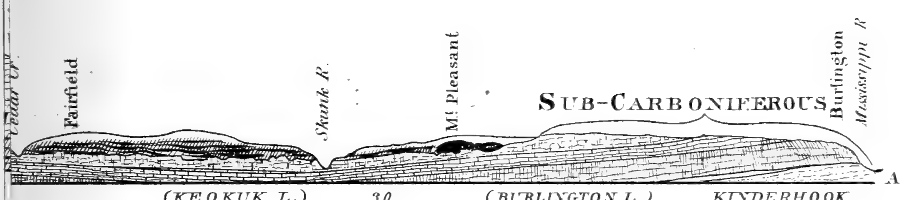
Material Resources. Almost every acre of the surface of Pottawattamie county is not only very fertile, but tillable; and when it is remembered that it contains more than half a million of acres of tillable land, some idea may be obtained of the magnitude of the resources that may be annually drawn from its soil. Its other resources, at present available, consist of its stone and forest trees. Its stone, as will appear from the foregoing paragraphs upon its geology, is not abundant; but good lime has been prepared from the limestone at Stutsman's mill, on Mosquito creek, and near Crescent; and the stone at all these places is also suitable for ordinary building purposes, and some of it for dressing. The Nishnabotany sandstone, before mentioned as being exposed in the East Nishnabotany, is there much too soft for any economic purpose.

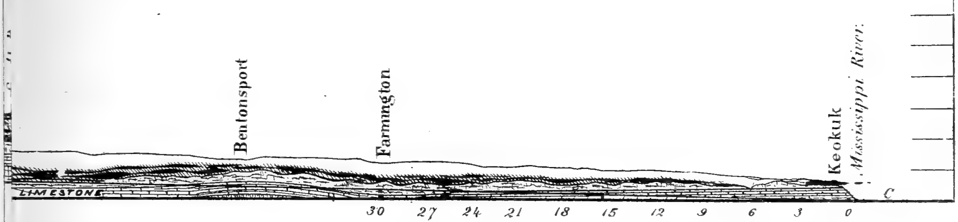
Along the base of the bluffs, between Crescent and Council Bluffs and elsewhere, the altered drift, consisting of more or less distinctly stratified sand and gravel, has become cemented in some cases into a stony mass by the lime of the limy water which percolates from the higher surfaces through the Bluff Deposit. These, although sometimes quite firmly cemented, are practically worthless, and are mentioned here from the fact only that some have supposed them to be parts of regular ledges of stratified rocks. This is not the case, because the cementing process has usually extended only few feet inward from the surface.

Wood is not in sufficient abundance in this county to supply at once a population with fuel that its soil is capable of supplying with food, but that soil may itself be made to supply all desired quantities of fuel in the form of forest trees within a few years after planting them.

Some very good bricks are made from a mixture of the Bluff and Drift materials in the vicinity of Council Bluffs; but good brick clays are nowhere abundant in this county.







ORNER *of the* STATE
S.

IOWA GEOLOGICAL SURVEY

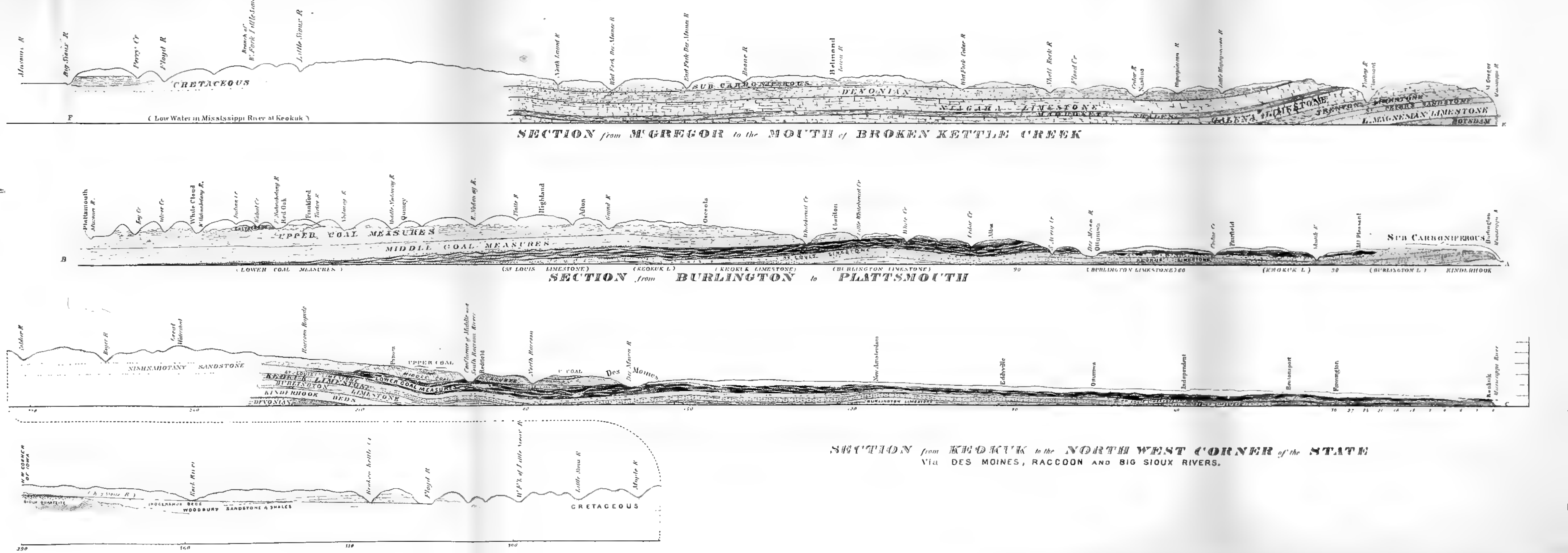
1870

GENERAL SECTIONS ACROSS THE STATE

Scale:

Distances 12 miles to the inch

Elevations 1200 feet to the inch.



GLOSSARY.

ACERVULARIA, a genus of fossil corals.
ACTINOCRINUS, a genus of crinoids.
AGARICOCRINUS, a genus of crinoids.
ALLORISMA, a genus of fossil bivalve shells.
ALLUVIAL, pertaining to floods of rivers, or to alluvium.
ALLUVIUM, deposits caused by floods.
AMPLEXUS, a genus of fossil corals.
ANTHRACITE, hard mineral coal, not bituminous.
ANTICLINAL AXIS, a given line or ridge from which strata dip in both directions.
ANTLIODUS, a genus of fossil fishes.
ARCHIMEDES, a genus of Polyzoans with a spiral axis.
ARENACEOUS, sandy, containing sand.
ARGILLACEOUS, clayey, containing clay.
ATHYRIS, a genus of fossil bivalve shells.
ATRYPA, a genus of fossil bivalve shells.
AULOPORA, a genus of fossil corals.
AULOSTEGES, a genus of fossil bivalve shells.
AVICULA, a genus of bivalve shells.
AVICULOPECTEN, a genus of fossil bivalve shells.
AXOPHYLLUM, a genus of fossil corals.
AZOIC, literally, without life.
AZOIC STRATA, those believed to have been formed before life existed upon the earth.

BELLEROPHON, a genus of fossil univalve shells.
BEYRICHIA, a genus of minute crustaceans.
BOTTOM, the low flat land of river-valleys, flood-plains.
BOULDER, a transported mass of rock, usually rounded.
BRACHIOPODA, a class of mollusks.
BRECCIA, rock composed of angular fragments of rock or other substances consolidated.

CALAMITES, a genus of fossil plants.
CALCAREOUS, limy, containing lime.
CAMPOPHYLLUM, a genus of fossil corals.
CEPHALOPODA, the highest class of mollusks.
CHÆTETES, a genus of fossil corals.
CHERT, coarse, fragmentary, flinty material.
CHOMATODUS, a genus of fossil fishes.
CHONETES, a genus of fossil bivalve shells.
CLADODUS, a genus of fossil fishes.
COAL-FIELD, a region in which coal is, or may be found.
COAL-MEASURES, (see page 231.)
CONFORMABLE STRATA, those lying parallel upon each other.
CONGLOMERATE, pebbles and sand consolidated into rock.
CONIFER, a sub-class of plants, including the pines and cedars.
CRANIA, a genus of shells.
CREEK, a name commonly applied in America to small tributaries of rivers.
CRETACEOUS, chalky, the formation of the same geological age as the chalk of Europe.
CRINOIDS, a family of radiates, related to the star-fishes.
CRUSTACEANS, an order of animals, including lobsters, crabs, crayfish, etc.
CRYPTACANTHIA, a genus of fossil bivalve shells.
CYATHOPHYLLUM, a genus of fossil corals.
CYRTIA, a genus of fossil bivalve shells.
CYTHERE, a genus of minute crustaceans.
CYTHERINA, a genus of minute crustaceans.

DEBRIS, broken or comminuted fragments of rocks.
DELTODUS, a genus of fossil fishes.
DENUDATION, the wearing away of some portions of strata, or deposits from the principal portion.
DETRITUS, fragments, or comminuted material worn from rocks.
DILUVIAL, pertaining to floods.
DISCINA, a genus of shells.
DOLOMITE, magnesian limestone.
DRIFT, the deposits which contains the boulders.
DRIFTING, (a miner's term), digging a way horizontally into or within a mine.
DREPANACANTHUS, a genus of fossil fishes.

ESCARPMENT, a steep or precipitous exposure of strata.
EUOMPHALUS, a genus of fossil univalve shells.

FAULT, an abrupt break in the continuity of strata, by elevation or depression upon one side or the other of the break.
FAUNA, (as used in geology), all the animal remains of a formation, group or system.

FAVOSITES, a genus of fossil corals.

FERRUGINOUS, containing iron.

FIRE-CLAY, a common name for the clay beneath the beds of coal. It is very seldom suitable for fire-brick.

FISSILE, easily cleft into thin pieces.

FLORA (as used in geology), all the remains of vegetation of a formation, group, or system.

FLUVATILE, belonging to rivers.

FORAMINIFERA, an order of Protozoan shells.

FUCOIDES, sea-weeds.

GANOIDS, an order of fishes.

GASTEROPODA, a class of mollusks.

GEODE, a hollow, concretionary, stony mass, lined with crystals.

GLACIAL, pertaining to glaciers.

GLACIER, a very slowly moving body of ice upon the earth of great thickness and covering a large area.

GRIT, coarse sandstone.

HELODUS, a genus of fossil fishes.

HEMIPRONITES, a genus of fossil bivalve shells.

HOLOPTYCHIUS, a genus of fossil fishes.

INOCERAMUS, a genus of fossil bivalve shells.

IN SITU (Latin), in place, that is, as applied to rocks not disturbed from the position in which they were formed.

LACUSTRINE, belonging to lakes.

LAMELLIBRANCHIATA, a class of mollusks.

LAMINATED, composed of very thin layers.

LEPIDODENDRON, a genus of fossil trees.

LITHOSTROTION, a genus of fossil corals.

LINGULA, a genus of bivalve shells.

MARLITE, marl which has become somewhat stony in character.

MEEKELLA, a genus of fossils shells.

METAMORPHIC ROCKS, those which have become much hardened, crystaline, or otherwise much changed from their original texture.

MICACEOUS, containing mica.

MOLLUSKS, the sub-kingdom of animals which includes all the so-called shell fish.

MURCHISONIA, a genus of fossil univalve shells.

MYALINA, a genus of fossil shells.

ORACANTHUS, a genus of fossil fishes.

ORODUS, a genus of fossil fishes.

ORTHIS, a genus of fossil bivalve shells.

ORTHOCERAS, a genus of fosssl shells related to the nautilus.

PALÆONTOLOGY, the science which treats of fossil remains.
PENTREMITES, a genus of fossils related to the star-fishes.
PHILLIPSIA, a genus of trilobites.
PINNA, a genus of bivalve shells.
PLATYCRINUS, a genus of fossil crinoids.
PLEUROTOMARIA, a genus of fossil univalve shells.
POLYZOA, a low class of mollusks.
PRODUCTUS, a genus of bivalve shells.
PROTOZOANS, an indistinctly defined branch of the animal kingdom, including the lowest forms.
PSAMMODUS, a genus of fossil fishes.
PTEROPODA, a class of swimming mollusks.

QUARTZITE, metamorphic sandstone.

RECEPTACULITES, a fossil coral-like body, probably foraminiferous.
RETZIA, a genus of bivalve shells.
RHODOCRINUS, a genus of fossil crinoids.
RHYNCHONELLA, a genus of bivalve shells.

SANDALODUS, a genus of fossil fishes.
SELACHIANS, an order of fishes including the sharks and others.
SEPTARIA, argillaceous stony masses, traversed in different directions by veins of purer mineral substance; usually lenticular in form and probably called "petrified turtles."
SHAFT, a perpendicular way into a mine.
SMITHIA, a genus of fossil corals.
SPIRIFER, a genus of fossil bivalve shells.
STRATUM, (plural, strata), a layer or bed as applied in geology.
STROPHODONTA, a genus of fossil bivalve shells.
SYNCLINAL AXIS, a given line *toward* which strata dip in both directions.
SYRINGOPORA, a genus of fossil corals.

TRILOBITE, a family of fossil crustaceans related to the horse-foot crab.
TUFA, calcareous, stony masses, usually very porous, formed by deposition from water of springs holding carbonate of lime in solution.

WALDHEIMIA, a genus of fossil bivalve shells.

ZAPHRENTIS, a genus of fossil corals.

INDEX.

ERRATA.

Page 93, 16th line from top, for "glacial-scored," read "glacier-scored."
Page 122, 6th line from the bottom, for "analysis," read "analyses."
Page 195, 13th line from the top, add "in Washington" before "county."
Page 201, 10th line from the top, for "Brachiopa," read "Brachiopoda."
Page 201, 18th line from the top, for "Tavosites," read "Favosites."
Page 201, 4th line from the bottom, for "ENCRIMTAL," read "ENCRINITAL."
Page 220, 3d line from the bottom, for "Holoptychins," read "Holoptychius."
Page 221, 2d line from the bottom, for "canadeuse," read "Canadense."
Page 241, 9th line from the top, for "canda-galli," read "cauda-galli."
Page 262, 8th line from the top, erase the word "there."
Page 271, 4th line from the bottom, for "species," read "spines."
Page 301, 9th line from the top, for "None." read "Some."