FIRST AND SECOND ANNUAL REPORT

OF PROGRESS BY THE

STATE GEOLOGIST

AND THE

ASSISTANT AND CHEMIST

ON THE GEOLOGICAL SURVEY OF

THE STATE OF IOWA

TOGETHER WITH THE SUBSTANCE OF

POPULAR LETTERS

CONTRIBUTED TO THE NEWSPAPERS OF THE STATE DURING THE YEARS 1866 AND 1867, IN ACCORDANCE WITH LAW; ALSO EXTRACTS ORIGINALLY CONTRIBUTED TO SCIENTIFIC JOURNALS AS A PART OF THE WORK OF THE SURVEY.

DES MOINES:
F. W. PALMER, STATE PRINTER.
1868.

GEOLOGICAL SURVEY.

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 said State Geologist, as well as the copy-right 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 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 assistants, 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

* Extract of Chapter 73, Laws of the Eleventh General Assembly.

the General Assembly. That the 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 can not 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.

FIRST ANNUAL REPORT

OF

CHARLES A. WHITE, M. D., STATE GEOLOGIST.

IOWA CITY, January 3, 1867.

To His Excellency, William M. Stone, Governor of Iowa:

SIR: In accordance with section four of chapter seventy-three of the laws of the Eleventh General Assembly, I herewith submit to you my first annual report of the progress of the Geological Survey of the State. Upon your approval of the law referred to, March 30th, 1866, I repaired to the capital for the purpose of being legally qualified, and then entered immediately upon the duties of my office. I appointed Mr. Chandler Childs, of Dubuque, as my field-assistant, and Prof. Gustavus Hinrichs, of the State University, as chemist of the survey. The first work done was a review of the older rocks of the eastern half of the State, from the oldest fossiliferous formations to the sub-carboniferous limestones inclusive. This was accomplished by visiting various localities in company with my field assistant, making measurements and collecting specimens for study, and for the State Cabinet.

The principal object of this review was that we might obtain as complete a knowledge as possible of the full series of the formations of the State, in their regular order, and thus enable us to study with greater precision the coal-bearing strata, to which it is proposed to devote the greater part of each season's labor. After accomplishing this, it was found necessary to make some comparative examinations of the coal-deposits of the neighboring States, and also along the northern border of our own coal-field. Then preparing an outfit consisting of a pair of horses with a covered wagon, tent and other necessary articles, we proceeded to the southwestern part of the State by the way of the southern tier of counties, and subsequently carried on careful examinations over the three southern tiers, from the Missouri River to those counties which border the valley of the Des Moines River, comprising Decatur, Ringgold, Taylor, Page, Fremont, Mills, Pottawattamie, Cass, Montgomery, Adams, Adair, Union, Madison, and parts of Clarke, Wayne and Appanoose counties. It was considered of great importance that we should know the extent of our coal-field in that direction, as well as just to the people of the western part of the State, because the examinations of the previous survey did not reach them.

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Wishing to accomplish all that was possible for the development of fuel for our State, early in September last I sent my assistant to the counties of Franklin, Wright, Cerro Gordo, Hancock, Worth and Winnebago, for the purpose of examining that region for deposits of peat, while I continued the examinations in relation to the coal-field. Peat will no doubt be found in large quantities in other parts of the State, but for reasons suggested by the character of the surface in relation to the streams of that region, climate, &c., it was thought to be one of the most favorable for present investigations of this kind; beside which, it is entirely beyond the limits of the coal-field, and within it no other fuel except wood may be expected.

My instructions to my assistant were that he should report to me at the end of every week, that I might give the results to the people through the public press as soon as they were ascertained, but I regret to say that I have received no report from him for more than three months, in consequence of which I have been obliged remove him, and have appointed Mr. Orestes H. St. John, of Waterloo, Black Hawk county, in his stead. I continued my field-work until the 10th of November last, at which time the weather became too inclement to prosecute it further for the present season.

The more prominent results of the field-work may be briefly stated as follows: That formation known among geologists as the coal-measures consists in our State of a succession of strata of sandstone, limestone, sandy, clayey and carbonaceous shales, marls and coal; and is divided into the upper and lower series. The lower series only is found along eastward and northward of the Des Moines River Valley, and consists principally of shales and sandstone, together with the coal. Very little limestone is found associated with them, and that is always more or less impure. This series contains all the productive coal-beds, and consequently furnishes nearly all the coal now obtained in the State. The upper series consists principally of limestone, with some fine-grained sandstone and marly shale. It is not known to exist at all northward and eastward of the Des Moines River, but to the southward and westward of that river it reaches a maximum development of one hundred and seventy-five feet in thickness. There are at least two carbonaceous horizons in this series, one of which embraces the only bed of coal yet found in the western part of the State. The other is of limited extent, usually showing a thin seam of highly carbonaceous matter, but in the form of shale, and entirely worthless. The bed of coal referred to finds its greatest development along the valleys of the Nodaways, in the counties of Adams, Taylor and Page, and is there, at most, only twenty inches in thickness. Its horizon has been recognized in most of the counties referred to, but the coal-bed is found to diminish in thickness to the eastward, westward and southward, so that in these directions little is seen except a thin band of carbonaceous matter of no economic value, as its representative. The strata of this series are nearly horizontal in an easterly and westerly direction, so that one, in passing from Madison or Clark to Fremont or Pottawatamie counties, would be, in geological language, constantly upon the line of strike, the dip of all the strata being to the southward, and nearly coincident with the fall of the streams.

In all that region of the south-western part of the State, comprising the thirteen or fourteen full counties, named, the only accessible rocks are those of the upper coal-measure series, which in the deeper valleys of Madison county at least, I found resting upon the upper part of the lower series, as at present understood; eastward from which point, the upper series rapidly disappears, and the lower, with its coal, becomes accessible.

This determination of the relative position of the strata of the western and central parts of the State, which was first made known by my labors during the past season, becomes a matter of very great economic interest to the people, for upon it depends the direction of intelligent effort in future investigations for coal. It is known that the upper series, in the region referred to, contains too little coal for the uses of the inhabitants, *but it is not contrary to any known principles of geology to expect to find the lower series, with its coal-beds, extending beneath the upper series to the western part of the State, by sinking shafts of not impracticable depth down to them.*

During the progress of the field-work, I wrote frequent articles for the public press, explanatory of its results, in accordance with the law. I herewith transmit to you printed copies of the same, thirty-three in number, as a part of my report.

The desire on the part of the principal newspapers of the State to obtain these communications has been so great that I have prepared from two to four manuscript copies of each one of them, and sent them simultaneously to as many newspaper offices for publication. These have again been copied into other papers of the State; in addition to which the leading newspapers of the neighboring States have frequently made copious extracts therefrom.

A large quantity of material has been collected, consisting of minerals, fossils, soils, clays, fuels, samples of building-rocks, mineral waters, &c., &c. I have not yet had time to fully investigate and arrange these collections, but they are known not only to comprise much that the State Cabinet has never before contained, but also a number of species not before found in the West, some of which are yet new to science. My first care will be to label and arrange these collections in such a manner that a knowledge of their ownership, geological position and location can not be lost. Those of which it is desirable to have chemical analyses and investigations made, are in the hands of the chemist. By reference to his report, herewith annexed, it will be seen that he has entered upon his work with an earnestness and care which give promise of the most satisfactory results. It is proposed to devote a considerable part of the time during the winter months to the critical investigation of these collections, and whenever it may be necessary to secure to the State the credit of priority in those labors, the results will be published in some of the scientific periodicals of the country in advance of my final report. After this has been done, the specimens will be distributed according to law.

The Faculty of the State University have generously given me the free and exclusive use of their large cabinet room for an office, and in which to study and arrange the collections. The railroad-companies of the State give me free access to the records of their surveys, and offer me all facilities for investigation that can

be desired. I find the people much interested in the progress of the work, and everywhere kind and obliging. As soon as the weather will admit of field operations in the Spring, it is proposed to take up that work where it was left at the close of the season just passed, giving especial attention to the subjects of coal and peat.

All of which is respectfully submitted.

CHARLES A. WHITE,
State Geologist.

REPORT OF THE CHEMIST.

To Dr. C. A. White, *State Geologist:*

Sir: I herewith submit the following as a report of progress of the chemical investigations connected with the survey: Up to date, two hundred and thirty-two numbers of specimens have been received at the laboratory for examination; many of these numbers representing duplicates. The material thus accumulated by you during the first season of the survey, is not only large in amount, but also of great intrinsic value for the scientific and economic mineralogy of the State. The specimens have all been labeled by numbers, which numbers are here used to designate them.

I. MINERAL WATERS

Have been received from Mt. Pleasant (114), Ottumwa (121), Bloomfield (24), and near Salt Creek, Davis county, (72); also, water and its peculiar sediment from the Missouri River (187.) Of these, the first four have been analyzed. These analyses, together with one of a spring water made for the Iowa Hospital for the Insane, constitute the only analyses yet made of the waters of the State.

II. ROCKS AND SOILS.

A considerable number have been received. No. 8 from Burlington, Nos. 77 and 78 from Madison county, and No. 79 from Adair county, have been examined; No. 10 from Clarke's quarry, near Iowa City, has been analyzed, and found to owe its dark color to phosphate of protoxide of iron. As phosphates are especially fertilizing, it will be important to investigate other rocks in the same direction. Of soils, none have been as yet analyzed; such analysis can be more expeditiously and accurately made when a larger number of samples shall have been collected.

III. COAL AND PEAT.

The analyses of coals made by Prof. Whitney, the former State Chemist, have been discussed. These analyses plainly show, that the combustible part in the Iowa coals is very nearly uniform, consisting of forty-five per cent of bitumen, and fifty-five per cent of fixed carbon; the great variation observed in the difierent coals analyzed being due to the varying proportions of ashes and moisture associated with the combustible part. The theoretical bearing of these results upon the formation of coal is apparent. Their practical importance is also very plain, for a determination of the amount of ashes of the dried coal is

equivalent to the more elaborate analysis. It will be important to make many further analyses, in order to ascertain whether the same law will hold good for all Iowa coals.

Of new analyses, the following have been made: (124) cannel coal from Mt. Pleasant, Henry county; (136) coal from Bentonsport, Van Buren county; (123) peat from Solon, Johnson County; (125) peat from Mason City, Cerro Gordo county; (126) the same condensed.

IV. MINERALS.

Celestine. The specimens brought by you from Fort Dodge proved to be sulphate of Strontia or Celestine, which according to Whitney has not before been recognized in any locality west of Ohio.— *Wisconsin Report, page* 113.

Gypsum. Nos. 9, 29 and 35, from Dubuque; No. 23 from Fort Dodge; the latter white, *and almost chemically pure.*

Barytes or Heavy Spar. Nos. 4 and 5, from Bremer county; No. 7, from Decatur county; Nos. 40, 42, and others, from Dubuque.

Epsomite or Sulphate of Magnesia. (Nos. 167 and 168) discovered by you some years ago near Burlington.

Calc spar in many varieties, as No. 16. Dog-tooth spar: geodes from Waverly, Bremer county; No. 17, the same with Brown spar covering; Nos. 33 and 48, Spars, and other varieties from Dubuque; Nos. 2 and 3, *Anthraconite* in fine columnar masses from Waverly, Bremer county. Nos. 60 and other, Rock Milk, from Dubuque; 177, Dog-tooth spar, from Iowa Falls.

Manganese, has been found in dendrites on slabs from Anamosa, (Nos. 13 and 14) on calcareous spars from Waverly, (No. 17) and Iowa Falls, (177.) It has also been detected as Wad (60, 61, 67) and Pyrolusite (47) from Dubuque.

Zinc, lead, and *iron* ores have been received and determined, but not yet analyzed.

The fine collection of geodes from Bentonsport has been partially investigated. The full investigation of this mineralogical treasure will require much further labor.

The specimen No. 121 from Red Rock, Marion county, will probably prove to be a new mineral species.

A full analysis has been made of clay from Iowa Falls; No, 20 is a remarkably pure marly clay; No. 21, a fire clay containing some ferruginous sand, and well adapted to various kinds of fine pottery.

From the work already done, both in regard to the material collected in the field, and the study in the laboratory, I may venture to predict that your final report will contain a chapter on the scientific and economic mineralogy of Iowa, consisting of the results of investigations, hitherto only barely commenced.

GUSTAVUS HINRICHS,
Chemist.

POPULAR LETTERS

OF

THE STATE GEOLOGIST

FOR 1866.

INTRODUCTORY.

By reference to the law of the Eleventh General Assembly, on the opening page, it will be seen that provision was made for the publication of *newspaper reports* of the observations made during the progress of the State Geological Survey.

This provision, although a novel feature of law relating to geological surveys, and adding largely to the labors of those in charge, has nevertheless become very popular with the people of Iowa during the last two years, and it is believed also that they have been much benefitted by its fulfillment. Instead of making records of observations to be filed away in the office until a future General Assembly should provide for their publication, and when, through lapse of time, many opportunities to take practical advantage of such information would have been lost to our citizens, these results have been made immediately available to all by the frequent publication of letters from the field and from the office, in the various State newspapers.

These letters were almost always written in "manifold," and one copy invariably sent to the newspaper of the neighborhood where the observations recorded were made; and the others, from two to ten in number, were sent simultaneously to other papers in various parts of the State, amounting in all to between forty-five and fifty, in all of which they have appeared as original matter.

Many of those letters were written by the light of the camp-lantern, after the field-labors of the day were over, and were consequently unsatisfactory to the writer, because it was inevitable that minor errors should be admitted into communications made before the observations were complete. Again, many of them having been written for different readers, while the subjects of each were similar, it was often necessary to repeat in one what had already been written in another; for it was the aim of the writer to present the information contained in those letters in such a form as to be readily understood by all, and also to present such other matter as should be attractive to the general readers, and thus awaken popoular interest in geological subjects.

By request of the Committee of the Senate who ordered the printing, such errors and repetitions have, to a great extent at least, been excluded, so that what is said of many of the counties appears somewhat changed from the form in which it originally appeared in the newspapers. An exception to the rule of excluding repetitions is made in favor of what has been said in relation to the growth of forest trees. This is a matter of so much importance that too much

can not be said to encourage the people to plant largely of all kinds of our native trees, which it is now known will grow as thriftily upon prairie soil as any where else. It is to be regretted that time would not allow the arrangement of the matter contained in those letters according to the various subjects discussed. Instead of this, the subject matter is left in the order of time in which the observations were made, or according with the progress of the work.

The scientific reader will thus understand why it is that official reports of the survey are presented in this unusual form, but he must not for a moment suppose that any scientific principle will be sacrificed to popular prejudice or preference. All matters that are more abstractly scientific in their character are receiving their full share of attention as the work progresses, and several papers of this character have already been published in various scientific journals, two of which are herein re-printed. It is of course expected that a comprehensive final report will be published in standard form, in addition to these preliminary papers and reports.

Considering the fact that only a few years ago geology was not made a part of even a liberal education, it is thought advisable to give a few words of popular explanation of its principles so far as relates to the geological structure of our State. All the rock formations of Iowa are stratified; that is, they have without doubt been formed at the bottom of the sea in more or less regular layers, and now, since their elevation from the sea, they extend, as it were, in broad sheets, lying the one above the other, beneath the whole surface.

In Iowa the order of superposition of the formations is comparatively simple, because no great disturbance of the strata has taken place here, as has been the case in some other regions. The characters and composition of our rocks are various, being limestone, sandstone, magnesian limestone, shale, clay, coal, &c., for whether hard or soft, geologists call them all rocks. Even the coal, since it lies in beds parallel with beds of rock, is practically itself a stratified rock, whether the theory of its marine origin advocated by the chemist in his letters is the correct one, or not.

Nearly all stratified rocks are found to contain fossil remains, which in ours are principally shells and corals of many kinds; and by the study of these, geologists find that certain sets of strata are characterized by certain fossils that are found in them, and nowhere else. It is this which gives collections of fossils their great value, for without the information they thus afford they would be of no more value than broken crockery. By studying the fossils of all the formations we are able to determine the relative position of any one of them, even if but a small part of a single one is found exposed; for this relation, when once ascertained, is found in all cases to be constant and reliable. The strata thus studied are divided into contiguous groups and variously named in an order indicative of their relative ages, as Lower Silurian, Upper Silurian, Devonian, Carboniferous, &c.; the lowest in the series being the oldest, and the others successively of later and later origin. The strata of our State do not now lie in a perfectly horizontal position. If they did we could find little more than the upper ones, but by a change in the

surface which probably went on slowly while they were being deposited, they have been elevated so that their slightly upturned edges come to the surface as one goes from the southwest to the northeastern corner of the State, where the oldest, and geologically the lowest are found. It will thus be seen that the plane of any of the geological formations beneath the surface have no necessary relation to the plane of that general surface. For instance, of the rocks exposed along the Mississippi river, those in Alamakee and Clayton counties are the lowest geologically, although topographically the highest, and as one goes *down* the Mississippi, he goes *up* in the geological scale.

Through the politeness of Dr. Mark Ranney, Superintendent of the State Hospital for the Insane at Mount Pleasant, Henry county, who presented a series of carefully preserved specimens of the borings of their Artesian well, we obtained very satisfactory proof of this order of superposition of the strata.

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 those characters, having studied the same rocks as they successively make their appearance at the surface northward.

At the depth of 1125 feet, the bottom of the boring, we identified the rock as the same as that which forms the tops of the hills at Dubuque, more than a hundred miles northward; and if the boring had been continued, the drill would have reached those rocks which come to the surface still further to the northward. The record of that boring says that the drill passed through no coal. This could have been predicted, because the first rocks pierced by the drill were those of the sub-carboniferous limestone which is found to form the floor, so to speak, of the formation which contains the coal. If they had commenced this boring in Jefferson, the next county westward, they would doubtless have passed through at least a portion of the coal-measure strata before reaching the limestone upon which they started at Mt. Pleasant. If they had commenced their boring in the southwestern part of the State they would have been obliged to pierce many hundred feet of barren and probably also productive coal-measure strata before their drill reached the limestone which is at the surface in Henry county where they began to bore. From what has been said it will be seen that the general dip of all the formations is to the southward, although it is so slight that is not perceptible to the eye; so that the oldest formation is in the northeast corner of the State, and the newest in the southwest corner. This is true with one exception. A formation newer than all the others, the Cretaceous, is known to occupy a large area in the northwestern part of the State, where a large part at least, of the other formations dip beneath it to the northwestward.

We have evidence which is admitted by all as conclusive, 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 country, was covered with ice, as Northern Greenland is at the present time. The ice is believed to have existed as an almost continuous glacier, moving 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 into the fine material that now constitutes our soil and subsoil, and which now covers those formations like a mantle, so that we seldom see them in place except when they have been bared by the streams while they were cutting out their own valleys. The granite boulders and pebbles so common in all parts of the State were brought down from the north by the same means, for we have no other granitic rocks within our borders, and these with the material ground up by the glaciers were mixed into a heterogenous mass which now occupies the surface every where, and is called "drift" by geologists. Lumps of copper, doubtless from the Lake Superior region, and masses of lead ore probably from the Dubuque lead region are sometimes found in the drift of the different parts of the State, where they happened to be released by the melting ice as the glacial epoch passed away. In Northern Iowa also, quite beyond the limits of our coal-field, lumps of coal have been found in the drift which the inhabitants sometimes regard as an indication of the existence in their neighborhood of a bed of coal. But these lumps were probably brought down by the ice from a thin bed of coal which is believed to exist in Southern Minnesota, and which belongs to rocks of Cretaceous age, and consequently having no connection with the Iowa coal-field. The subject of the drift formation will be found further discussed in the following pages under the heads of "Drift phenomena in Southern Iowa," and "Lakes of Iowa, past and present."

The term "coal-measures" is one introduced from England, and simply means the formation which contains the coal. It was once believed that all the coal of the earth is contained in the formation of that particular geological age, but subsequent investigation has proved this view to have been incorrect. We have now much evidence tending to prove that all the coal yet found in the far West, as we in Iowa understand those words, is of much later origin than our own, and with which ours has no connection by continuity of formations.

The coal-measures of Iowa are properly separable into upper, middle and lower divisions. The first lies wholly to the southward and westward of the Des Moines River, occupying the surface in the southwestern part of the State over an area equal in extent to that of the State of Vermont. The second doubtless underlies the whole of the first, but it occupies the surface only along its northern and eastern borders, including the greater part of the region of the Raccoon Rivers, which region is more particularly referred to in Mr. St. John's report, on another page. The lower coal-measures occupy the surface of a large area, averaging some fifty miles in width, and about one hundred and seventy-five miles in length, through the middle of which the Des Moines River runs longitudinally in a southeasterly direction, from a little above Ft. Dodge, nearly to Keokuk. Over nearly the whole of this large surface coal may reasonably be sought for. To the northward and eastward of it, it is useless to look for coal except in small "patches" or outliers. These are almost always unproductive of a workable bed of coal; the large outlier extending from Muscatine nearly to Davenport being an exception. To the southward and westward of this region it is believed that coal will be found by sinking shafts to a greater or less depth.

The lower coal-measures contain all the heaviest beds of coal, and by far the

largest part to be found in the State. The middle measures contain some workable beds, but the upper series are believed to contain only one bed of coal, the greatest thickness of which is only twenty inches.

The lower coal-measures are made up principally of sandstone, shales, clay and coal, with very little limestone; the middle, of similar materials, but has more limestone, less sandstone, and less coal, while the upper coal-measures are composed largely of limestone, which in Madison county alone is found to reach a thickness of more than a hundred feet, beside the other strata exposed there.

The lower coal-measures disappear beneath the middle and upper measures to the southward and westward, but we may confidently expect to reach the continuation of those strata by sinking deep shafts in the western part of the State. It is not absolutely certain that coal will be found in those strata when they are so reached, but when a similar condition of the strata are found to exist in densely populated countries, capitalists do not hesitate to invest their money in such enterprises, and the time will doubtless come when it will be done in Western Iowa.

However, since coal-beds are liable to thin out as the distance increases from any given maximum point of development, and that all formations are expected to be thinnest at their borders, it will be less hazardous as well as less expensive to commence such enterprises in the valleys near the eastern or northern border of the upper or unproductive coal-measures, say in the counties of Decatur, Clarke, Madison and Adair; and if successful at those points it would encourage similar enterprises still farther and farther to the westward. Yet we do not know that the maximum development of the coal beds may not be to the westward of the Des Moines river region.

People throughout the State very often ask the following questions by letter and otherwise: What relative position does coal hold to limestone, sandstone or other strata? What is regarded as "coal-blossom," or a sure indication of the presence of coal beneath the surface? The term "coal-blossom" is not used by geologists, but those who use it appear to mean the presence of per oxide of iron, or simple iron-rust in the water of springy places, and impregnating the earth around where it issues. So far as that appearance is concerned it amounts only to this: The strata associated with the coal, and also the coal itself, almost invariably contain more or less iron, which being oxidized passes out with the water which finds its way over or through them. But while this is true, other strata which have no possible connection with coal, also at times are found to contain iron in a similar form, which of course presents similar appearances at the surface.

As to the relative position of coal-beds with other strata, the rule is that a bed of clay, commonly called fire-clay, *underlies* a bed of coal, while a bed of shale, often called soapstone by the people, almost always *overlies* it. Sometimes, however, sandstone, or even limestone, has been found to rest upon, or to underlie, a bed of coal.

In the following pages, a limestone will be referred to which underlies all the

coal-measure strata, and beneath which it is useless to search for coal. This is the sub-carboniferous limestone, and is usually found to belong to that division which geologists have named the St. Louis limestone, because the same formation is well exposed near that city. It is by no means meant that limestone is never found above the coal, for the upper coal-measures are largely composed of limestone, and the general appearance of the rock of these two limestone formations is often almost identical, yet when one is acquainted with the fossils which characterize each, he will know without hesitation whether a given exposure belongs above or below the productive coal-measures. Since the lower coal-measures contain almost no limestone, any such rock found in the region occupied by that formation, as for instance along the Des Moines River, may almost certainly be referred to the sub-carboniferous formation; because the streams, in cutting out their own valleys, have bared the limestone after they had cut clear through the coal-measure strata. From the fact that this limestone is so often exposed near the streams which run through the region occupied by the lower coal-measures, it is evident that no very deep mining will be requisite in that region, to reach all the coal that exists there, because all the coal lying above the limestone will usually be obtained by drifting into the edges of the beds which crop out at the sides of the valleys. Strictly speaking, there are no 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 nearly a uniform plane, one may often make very satisfactory calculations as to its presence or absence. Thus, if a bed of coal is found cropping out in one side of a valley, one may expect to find the same bed cropping out of the other side of it; and if a similar exposure should be found in another valley a few miles distant, it is reasonable to suppose, in our coal-field at least, that the two exposures are parts of the same bed, and that it is continuous beneath the whole intermediate space, and further, that it may be reached at an estimated depth by sinking a shaft down to it from the high land between the two valleys. Beside this, it will be seen from what has been said that the geologist is able to draw a line, at least approximately, and say "beyond this line it is useless to explore for coal, while within it there is a reasonable prospect of finding coal."

Mining in our State will always be mainly confined to coal, as will be seen by reference to descriptions of the extent and character of the coal-field on the following pages. Next in importance comes the lead mines of Dubuque, which although very important, occupy a very limited area. The present prospect that other mineral substances will be found in paying quantities is not encouraging. Occasional masses and small deposits of iron ore are often found, but none have yet been discovered that will warrant the erection of a furnace, and even if it were so, as soon as our northern and southern railroads are built, iron from the Iron Mountain region in Missouri would doubtless be brought here more cheaply than we could manufacture it from our own scanty ores.

AUTHORSHIP.

The articles on "Surface Geology of the Middle Region of Western Iowa,"

"The Geology of the Raccoon River Region," and the report which bears his name, are the work of the Assistant. The articles on "The Fuel of Iowa," "Waters of Iowa," "Rocks of Iowa," "Valuation, composition, and proximate analysis of coals," "Mineralogy of Iowa," together with the reports which bear his name are the work of the Chemist. All the remaining matter is by the State Geologist. As usual in such cases, each author is to be considered as responsible for his own work.

SURVEY OF COUNTIES.

BLACK HAWK AND BREMER COUNTIES.

HYDRAULIC CEMENT.

In April of 1866, while making the examinations referred to in the preceding report, a communication was sent to the *Waterloo Courier*, which contained the following paragraphs:

"Throughout the northeastern portion of the State, the prevailing character of nearly all the formations is magnesian limestone, which character extends to the Devonian rocks of your county, although the same formation in Johnson county, and elsewhere in the State, is but very slightly magnesian. It is a well known fact that rocks quite various in their chemical composition will nevertheless make, when properly prepared, excellent hydraulic cement, and among the rocks from which this cement is prepared are the very kinds of magnesian limestones which are found in the northeastern portion of the State. Those of your own vicinity are as well worthy of a trial for this result as any known to me in the Mississippi Valley, and specimens were collected from various quarries in your region with a view to having them analyzed and tested. It must be remarked, however, that the only reliable tests are those which may be made at an ordinary lime-kiln, by properly burning the rock, and afterward grinding it *very fine*, and then by practical trial of the substance produced. When it has been determined that any rock will make the cement desired, the necessary skill can be readily acquired by any one for producing it in any quantity.

"It is the intention of Mr. McIsaac, of Waterloo, to make some practical tests of the magnesian limestones of your vicinity to which I have referred."

Within the last two months, Mr. McIsaac informed me that although

a press of business had prevented him from making the proper experiments, Mr. Robert B. Brown, of Waverly, Bremer county, had been conducting a series of experiments with evident success. A short time afterward Mr. St. John called on Mr. Brown, and obtained for the State collections a full suite of specimens illustrating his experiments, and from which it seems almost certain that he is just upon the eve of complete success in the manufacture of hydraulic cement of excellent quality, although the practical test of its use must be made before such a decision can be given. In view of the energy with which Mr. Brown is conducting his experiments, we may hope to know the full result before the close of the present year.

Similar references were made to the magnesian limestones in the vicinity of Cedar Falls, in a communication about the same time to the *Cedar Falls Gazette*.

Very little time was spent in Black Hawk county, but it was seen to be well supplied with building-stone, brick-clays, forest-wood, excellent water, almost unlimited water-power, and as to its soil, it is already high praise when it is said that it is a part of the Valley of the Cedar.

HARDIN COUNTY.

Crossing from the Cedar to the Iowa river, the extreme northeastern corner of the coal-field was visited, in the vicinity of Eldora, Hardin county. Commencing examinations at Iowa Falls in the northern part of the county, the following was soon after communicated to the *Iowa Falls Sentinel:*

The rocks exposed along the river near Iowa Falls belong to the lower portion of the sub-carboniferous group, and are consequently older than, and below the coal. Standing at the mill in the village and looking across the river, you will see that the strata dip from that point both eastward and westward, their most elevated point, which geologists call an anti-clinal axis, being just where you stand. The eastward dip does not probably extend far, before the strata gradually rise again. The westward dip is so great that a little above Talbott's mill, three miles from town, all the strata which you can see in the village have passed nearly out of sight beneath the river, and begin there to receive the coal-measure deposits upon them, but that

any coal exists among them, remains to be decided by boring or digging. My opportunity for examining this locality was not satisfactory, but judging from the fact that it is just upon the border of the coal-field, and in a local depression, since the Iowa Falls strata rise and appear again at Alden, the prospects for obtaining coal in paying quantities at or near Talbott's mill, are not believed to be promising.

The close proximity of the Eldora coal, however, and the existence of the large body of timber westward of Iowa Falls, give you a great advantage over many other towns of the State, in a plentiful supply of fuel. Considering the large tracts of country on which no stone, certainly no limestone, is to be seen, you possess another great advantage in the large exposures of excellent limestone, which, figuratively speaking, nature seems to have lifted out of the earth just at that point for your especial benefit, but in doing this she deprived you of the coal which was bestowed upon your neighbors of the southern part of the county. All the strata exposed along the river in the village are composed of a good and comparatively pure limestone, all of which will make good lime, and many of which furnish excellent stone for dressing. The rough, fragmentary stone of a yellowish color, seen in the hills around, and to the southeastward of the village, are magnesian limestone, although they look like, and are frequently called sandstone. This stone is probably useless except for the roughest masonry, but since good stone is so abundant, this is not needed.

The following is a part of a communication to the *Eldora Ledger*, communicated June 6, 1866:

The rocks exposed along the river at Iowa Falls, as do also the rough fragmentary layers in the hills around, and southeastward of the village, which overlie them, all dip to the southward, in which direction the lower ones soon disappear, but the upper portion, which is highly magnesian and at Hardin City, contains considerable iron and some sand, can be traced as far as the village of Steamboat Rock, where they suddenly disappear and the coal-measure sandstone as suddenly makes its appearance.

Within a mile of this first appearance of the sandstone, it presents a perpendicular front of some seventy-five feet on the left bank

of the Iowa river; and within two miles on a straight line from the locality where the coal-measure rocks first appear, they reach a development of nearly or quite two hundred feet in thickness, as seen in the hill, and by the boring at Buckner's coal mine. This is a very remarkable development of strata so near the well defined border of the coal-field, and causes some hesitation in giving a positive opinion as to the relative position of the underlying rocks of the immediate neighborhood, before a very careful examination is made. And there are also evidences of a slight local and irregular dip of the whole region, to the southward. Just at Buckner's mine there seems to be a local longitudinal depression, extending thence a little east of south, so that the strata probably dip slightly both east and west toward the axis of it. Along this axis the bed of coal appears to be below the level of the river, but elsewhere it is doubtless above it.

Exposures of coal-measure strata were observed in the region surrounding Buckner's mine indicating that they underlie a surface of some two square miles, and doubtless more, but how far the bed of coal now worked extends, and what is its thickness, in continuation, has not been determined, except at the few points where it has been mined. To prove this I have suggested to some parties interested, to bore down to the coal in various places as the only practicable method of determining the facts, and one that will be decisive.

Experience has shown that the quality of a bed of coal is generally better beneath a high unbroken hill, than where the overlying material is thin and uneven. In view of this, and the fact that the coal-bed seems to thicken to the northward at Buckner's mine, I have suggested that several borings be made on the hill in different directions and at various distances from the mine.

It is equally desirable also, to prove in the same manner, the region to the westward and southward to the distance of about a mile in each direction, and it is not at all improbable that a bed of coal may be found beneath Eldora, but if so, it will be at a considerable depth. If one exists there, nothing can be known of its character without boring.

Judging from the indications observed, I was led to believe that the best prospect for obtaining coal in this region, is found along the left bank of the river, from a point somewhat west of Buckner's mine, to about a quarter of a mile below it; but boring at various points from a mile below Steamboat Rock, to the mouth of Pine Creek, may reveal as good or better indications elsewhere.

Mr. Buckner is now boring for a lower bed of coal at his mines, having reached a depth of nearly a hundred feet below the bed he is now working. The drill has passed most of the way through a blue shale common to the coal-measures. Should the drill reach limestone, the boring ought to be stopped at once, for there is no doubt that it would prove to be sub-carboniferous limestone, below which it is useless to look for coal.

The quality of the coal at Buckner's mine, the only one now worked, is fair, and if properly separated from the sulphuret of iron, it is as good as Western coal will average. About a foot of the lower portion of the bed is very good, and carefully selected, will be suitable for working iron, and the preparation of illuminating gas. The bed is four feet in thickness and the working is now done along two narrow passages which have not yet penetrated far into the hill. It is the intention of those who are conducting the operations to carry the work in the same direction all along the inner side, thus proceeding beneath the hill, letting most of the roof fall in behind them as they remove the temporary supporting-posts. This plan gives them an opportunity to assort the coal in the mine, and throw the refuse behind them. They can also remove the coal more expeditiously and cheaper in this way than in any other.

Within a few days after the foregoing communication was published, Mr. Buckner resumed his boring, and his drill soon reached the limestone referred to, when he promptly stopped the work without finding any coal beneath the bed he was then working.

The advantage possessed by the owners of the Eldora coal mines is very great, from the fact that they are situated in a prominent angle of the coal field, which gives them an unusually extensive market. Besides these coal mines, Hardin county has a plentiful supply of wood for fuel also. Upon the sandstone cliffs in the vicinity of the coal mines, the white pine and white birch are both

observed, which are very unusual in this part of the State, and is believed to be the southern limit, at least of the birch. Hon. C. F. Clarkson has successfully transplanted quite a number of both of these trees to the grounds around his residence, a few miles away, where they are growing thriftily upon prairie soil, and where he has already proven, if proof be needed, that all kinds of our indigenous trees will thrive upon our prairies, if they are protected from the annual fires.

HAMILTON COUNTY.

Proceeding westward, the next examinations were made along Boone River, in Hamilton county. It was desirable that the exposures of coal along the northern border of the coal-field should be examined, for the purpose of comparison with those of the southern, central and western parts, the better to understand the character of the different beds, and their mode of occurrence. Our coal-field is a very large one, and it is intended to devote the greater part of the field-labor of the next two years to its examination. The results of that trip were quite satisfactory, because a better development of the coal-measure strata was found along the northern border of the coal-field, and the coal found to be more abundant and of better quality than might reasonably have been inferred before examination. While at Webster City I was informed that a thin bed of coal had been found a few miles north of town, but no examinations were made in that direction. It is not impossible that coal should be found there, but since the sub-carboniferous rocks, below which no coal can be expected, are seen in the river banks half a mile below town, and the general dip of the strata being to the southward, Webster City is evidently very near the northern boundary of the coal-field, and consequently a large expenditure of money in the search for coal in that direction could not be recommended.

To the southward, however, along Boone River and some of its tributary creeks, the case is quite different, for here large quantities of coal exist, as may be seen by any one who will take the trouble to go to the localities, where it is to be seen in natural exposures in the hill sides.

Going down Boone River, the first exposure seen was on the right bank, in the hill side, about four miles from town. The coal is of good quality, has been worked to a considerable extent, and the bed is said to be four feet thick, which no reason was seen to doubt. Between this point and Sternberg's mill, which is six miles from town, the same bed of bituminous coal again appears, as does a bed of cannel coal, two feet in thickness and of fair quality. The latter bed lies several feet beneath the former, and is, of course, no way connected with it. Near Sternberg's mill and also at various points for a number of miles below the mill, the coal makes its appearance in the banks where they are rendered steep by the washing of the river. These beds are doubtless continuous in broad continuous layers beneath the surface, over a large area, and have become exposed to view in places by the deepening of the river valley by its own stream. They may doubtless be reached with comparatively little labor from the gentler slopes of the river valley, and when the demand will warrant it, as it probably will in the future, they may be mined by sinking shafts to them from the higher lands away from the river. As much attention as possible was given to the quality of the coal, and the conclusion arrived at is, that the coal along Boone river is fully equal to the average of Western coal. None was seen in this region which contains so much sulphur and other impurities, as many beds do which are profitably worked in other places. It was noticed that very few of the inhabitants were using coal for fuel, but this was fully explained by the fact that no regular system of mining is adopted, and the supply is consequently too uncertain to be depended on.

This supply is also at present rendered somewhat unnecessary by the abundant growth of excellent timber which the region affords, but with its present rapid settlement, and the prospect of the early extension of the Dubuque and Sioux City Railroad, the case will soon be different, and large quantities of coal will then be demanded for the regions eastward and northward of Webster City. This want must be supplied in great measure by the Boone river coal-mines.

WEBSTER COUNTY.

After going down Boone river about twelve miles from Webster City, we crossed over to the Des Moines, examining a number of coal exposures along that river and its tributaries on our way up to Fort Dodge. Near this place the coal and gypsum were briefly examined, but since the region was subsequently examined with more care, a fuller account of its resources will be found on another page.

One can not visit the valleys of the rivers referred to in the preceding pages without being impressed with the fact that they are destined to be soon filled with a wealthy and prosperous population, and to be the seat of thousands of happy homes; and there seems no reason to believe that future bards may not arise to sing the beauties of the Cedar, the Iowa, the Boone and Des Moines, since many a stream has become famous in song which does not possess half their native beauties.

Returning to prepare the outfit for the work in the western part of the State, a short time was spent in

JONES COUNTY.

Time would not permit the full examination of Jones county at the time it was visited, but the long and favorably known quarries near Anamosa received an examination, and the following account of them was sent to the *Anamosa Eureka* in May, 1866:

Although Jones county is entirely beyond the limits of the great Iowa coal-field, yet the large bodies of timber along the Wapsipincon and Maquoketa rivers will yield a plentiful supply of fuel for all time to come. The supply is now more than sufficient, and the tendency of the forests to encroach upon the prairies where the fires are kept out, is apparent to every one, so that the increase in this respect will supply the demands of an increasing population.

An examination of the brick of several houses in your place shows that you have a supply which is good, and no doubt abundant, of this indispensable building material.

The soil, as far as seen, is a rich dark loam, containing just enough sand to make it warm and mellow, without approaching barrenness; and that much of the material having a sandy appearance, is really not silicious in its composition but results from the disintegration of the magnesian limestones which underlie the county.

Those who have visited the lead mines of Dubuque, have seen

large quantities of material thrown out of the diggings near the surface, which has the appearance of sand, but in reality contains none at all; for it is composed of the disintegrated rock from which the lead ore is obtained, which is also a magnesian limestone, although it belongs to a different geological period from that which underlies Jones county. Some of your readers, who learned their mineralogy from Comstock's manual, will remember that under the head of Magnesian Limestone he has the following paragraph: "Where magnesia exists in considerable quantity in the soil, it wholly destroys vegetation." This statement is now known to be entirely without foundation in fact, of which the people of the northwestern part of our State have the fullest evidence from the fact that, although their soil is almost entirely underlaid by, and largely derived from magnesian limestone, it is nevertheless, as a whole, as productive as any with which a beneficent Creator has spread the earth. However, since the world owes so much to the labors of scientific men, we ought in justice to forgive their occasional errors and strive to correct them.

Nearly all the rocks of Jones county, belong to the Upper Silurian age, and those in the vicinity of Anamosa are believed to be geologically the highest of that age occurring in the State, but I had not time to satisfy myself fully upon these geological questions, and consequently felt constrained to devote all the time at my disposal to matters of immediate practical importance to the people. The beds of rock exposed along the river in your city, are thought to be continuous with those at the quarries three miles distant, although the stratification is quite different. Notwithstanding this difference, the chemical composition and contained fossils are nearly or quite the same, and the peculiar stratification which is so valuable a character at the quarries, seems to be confined, so far as could be ascertained, to an area not much, if any, more than three miles in extent.

Although this area is thus limited, the supply of excellent stone is practically unlimited. It would surprise one who knows the reputation that this stone has already obtained abroad, to visit the quarry and learn the fact that all the stone which has yet been taken

out for the home and distant markets, has only just opened one quarry to a degree that lays bare the best and most profitable layers, and two or three others which can hardly be said to be yet opened.

This principal quarry is now owned and worked by Messrs. Haines & Co., and is generally known as the "Anamosa Quarry." Two and a half miles northeast of this point, Mr. John Burham has long had a quarry in operation, but I did not get time to visit it.

Messrs. Parsons & Webb have just commenced opening a quarry one and a half miles west of the "Anamosa Quarry," adjoining the railroad, with good indications of procuring a large supply of excellent stone. These gentlemen have also commenced the erection of a large kiln for the manufacture of lime from their broken stone. Samples of mortar prepared from lime made from this stone were seen which were equal in quality to any. It is intended to have some of the layers tested for the purpose of learning whether it may be used for the preparation of hydraulic cement. It will be remembered that some of the best of these cements are prepared from magnesian limestone.

For a description of the character of the Anamosa stone, I shall be obliged to confine myself to that of the quarry of Messrs. Haines & Co., because it is the only one which has been worked to a sufficient extent to disclose the full value of the material; yet there is every reason to believe that at almost any point in the hills in the immediate vicinity the same quality of stone will be obtained, for the layers extend horizontally irrespective of the unevenness of the surface, the only questions to be decided are as to the amount of labor required to remove the superficial material, and the convenience of shipping the stone when quarried.

The common character and appearance of magnesian limestone in a natural exposure, of whatever geological age, is rough and picturesque, like the exposure seen on each side of the Wapsipinicon just below your mills; but the stone of the quarries, although magnesian, is a remarkable exception in its stratification. It is fine grained, evenly and horizontally bedded, some of the layers splitting readily into slabs from half an inch to one, two, three or four inches in thickness, and of almost any desired size; *many of which are as even in thickness and surface as a board from a planing machine*

The surface of a few of the layers is slightly rough, but they are very uniform in thickness. Some of the layers will furnish blocks four feet in thickness if desired; and from very many of them are obtained almost perfect ashlars for caps and sills, water-table, store-front columns, &c. The bedding surfaces are so smooth and true in many instances as not to require to be touched with a chisel.

The whole front exposed at this quarry is about ninety feet above the river, giving just room enough for the railroad between it and the quarry. From fifteen to twenty feet of the lower beds are more porous in texture than those above, but they are harder, heavier, and doubtless fully as durable. The stone of the upper layers is rather soft when first taken out, but in a couple of days it becomes quite hard and firm.

The weight of a cubic foot, as given me by Mr. Philip Haines, is, when quite dry, 140 lbs. for the upper layers, and 160 lbs. for the lower.

Of the present and prospective value of these quarries, it is not easy to form a correct estimate, but there is little danger of placing it too high. The present market for dressed stone and slabs extends from Cedar Rapids to Dubuque, and also so far as Independence in Buchanan county; and as the population increases the demand will be more extended and much greater than now, for there are no similar quarries within a long distance from this, if any others exist in the State.

The broken stone for common walls finds a ready market at the various stations along the whole length of the Dubuque Southwestern Railroad, although the ordinary rough stone can be obtained at those points.

The great advantage of these stones for cellar walls is that they can be readily joined so closely that rats can not burrow through them; they require less mortar to bed them, less labor to lay them, and make a firm and stronger wall. The broad slabs make the best walks that can be desired, and will outlast brick for that purpose.

BURLINGTON AND ITS VICINITY.

The name of Burlington will be known wherever American geology is studied, because the "Burlington limestone" has produced a greater

variety of interesting fossils than any other known locality in the world. Of crinoids alone, more than three hundred species as at present classified have been found in the limestones of that vicinity. Beside this, more than one hundred species of other fossils have been obtained from the strata which underlie the Burlington limestone at the same locality. The rocks which constitute the framework of the high bold hills around Burlington belong to the two lower members of the sub-carboniferous group, namely, the Kinderhook series, and the upper and lower Burlington limestone. The former consists of five or six distinct beds of limestones and fine-grained sandstones, none of which are of much economic value. The two groups of strata composing the Burlington limestone contain material of the greatest value in building the city. The Kinderhook series here reaches a thickness of about one hundred and forty feet, sixty feet of which was ascertained by boring, while the limestones rest upon it and form the bold exposures which constitute so prominent a feature of the scenery around the city. The Burlington limestone, as well as a part of the series beneath it, are to be seen in the bluffs across the river in Illinois, and with which those of the Iowa side were no doubt continuous before the river had cut its valley down to its present depth, and to a width of six miles at this point. At the base of the lower Burlington limestone is a bed of light gray limestone, about four feet in thickness, which upon close inspection will be found to be composed of minute rounded grains, and is called in geological language oolitic limestone. It is quarried and wrought with facility, and has a good appearance when cut, but it is as worthless for any purpose, except the preparation of lime, as the friable sandstone beneath it; for it is sure to disintegrate rapidly and completely upon exposure to the frost. It has so good an appearance when taken from the quarry, and can be obtained in such desirable shapes, that it has been used for paving and curbstones in various parts of the city, as well as for capping embankment walls, &c., and in every instance it has been broken up and destroyed by the action of the frost alone within a year or two.

The heavy beds of limestone at the brow of the bluffs furnish a great part of the paving and building stone used in the city. It is unlimited in quantity, is not affected by the action of the frost, and

is a good stone for ordinary purposes, but the upper beds of limestone which overlie this, although they do not appear at the brow of the hills within the city limits, furnish so much fine material for hewn stone that the former is not so often used for that purpose as it otherwise would be. These upper beds are seen to cap the bluffs below the city a few miles, but many of the quarries opened in them are in the southern and western part of the city, and also beyond its limits in those directions. This stone, when hewn, closely resembles in color the worthless limestone before referred to, but close examination will show that it has none of that peculiar structure resembling the roe of a fish, which the worthless stone has. The stone of these upper beds is of a pleasing appearance, as durable as the everlasting hills, and unlimited in quantity.

The quarry of Mr. Nat. Irvin, in these beds, has furnished a large quantity of excellent hewn stone, and those of Mr. Peter Smith, farther to the southwest in the same beds, are noted for the excellent quality of lime obtained from them. The quarries of Mr. Parr, a few miles below the city, are in the lower beds of limestone, continuous with those at the brow of the bluffs, within the city limits, the lime from which has had a first-class reputation. But good stone is so abundant here, and quarries so numerous, that it is unnecessary to make more definite reference to them. The brick-clays upon the hills are abundant, and of as good quality as any to be found in the State. Aside from the materials mentioned, there is little probability that mineral substances of economic value will ever be found here.

Since the rocks of this vicinity are older than the coal-measures, and consequently *geologically* below them, there is no hope of finding coal here, but in both an easterly and westerly direction they pass beneath the surface, and have received the coal-measure deposits upon them, and it is in these directions that one must go to procure a supply of coal.

The coal-measure rocks do not appear until Skunk river is passed, going in a westerly direction, but other higher members of the subcarboniferous group are found to lap on to the Burlington limestone as one goes in that direction. The Keokuk limestone is next in the series above the Burlington limestone, and on Long Creek, seven

miles west of the city, some important quarries in that limstone are worked. The principal quarry is located near the mouth of a small branch which empties into Long Creek, a few hundred yards north of the ford, and consists of three or four massive layers from six or eight inches to two or three feet in thickness. Both above and below those layers other stone is seen, but it is of little or no economic value. Although the stone of these quarries is so different in lithological character and appearance from the Keokuk limestone, as seen at Keokuk and Nauvoo, they are nevertheless a part of that formation which, extending northward from the places named, laps upon the Burlington limestone, as the latter formation dips beneath it to the southward and westward, its nearest approach to Burlington being on the Poor-House Farm, four miles from the city. It is quite different, also, from that of the same beds in the immediate vicinity, which, although continuous, present a marked change within a few rods. While in the city, a few weeks ago, I procured a specimen of the rock and had it analyzed. Prof. Hinrichs reports it to be highly magnesian. It is much more so than any rock of the same formation in this vicinity or elsewhere, but less so, however, than the dolomites of northeastern Iowa; while at the typical localities of the same formation, Keokuk and Nauvoo, it contains little, if any, magnesia.

This stone has been introduced within the last few years, and has been found to withstand the action of frost better than any other stone obtained in this vicinity. It presents a pleasant appearance in a building, and is much used for caps, sills, water-tables, store-fronts, &c. It is hewn rather more easily than the light grey stone of the quarries in the upper portion of the Burlington limestone, before mentioned, and which has heretofore furnished the best accessible material for such purposes. It is generally of a uniform texture, and without doubt a durable and valuable stone, perhaps the best yet found near the city. Yet it has occasionally, but not frequently, soft places in it, which should be avoided in hewing, as it will ultimately crumble in these places and thus deface and injure the structure. Although the exposures of stone of this peculiar character are limited in extent, yet they will furnish large quantities of excellent material for many years to come.

We are accustomed to regard limestone as one of the most indestructible of all our building materials, which it doubtless is, yet the best limestone is subject to more or less erosion by "the tooth of time," which popular expression the chemist takes the poetry out of, by telling us that it is caused by carbonic acid taken out of the atmosphere by the falling rains, coming in contact with the limestone, which is a proto-carbonate, constantly changing minute quantities of it to a bi-carbonate, which is soluble in cold water, but the lime becomes precipitated again as a proto-carbonate, or common limestone, when exposed to the atmosphere, or to an elevated temperature. We find it thus deposited as stalactites, and stalagmites in caves; as a rough porous limestone where some springs issue from the earth, and also often forming a heavy white lining to our tea-kettles. Thus it will be seen that when even the rocks are disintegrated they are not destroyed, but new combinations are formed from the same materials. It is not in the laboratory alone that chemical changes are produced, but they are constantly going on around us, and it is always interesting, and sometimes profitable to trace them.

Those who are scientifically or curiously inclined may observe some interesting results of such chemical changes in nature, beneath the overhanging bluffs at Starr's mill, three miles northwestward from Burlington. That portion of the strata which is seen to be more rapidly disintegrating than the other, and leaving the solid limestone projecting above contains considerable quantities, both of carbonate of magnesia and sulphuret of iron. The oxidation of the sulphur produces sulphuric acid, which uniting with the magnesia by displacing the carbonic acid, forms native sulphate of magnesia. This substance is, no doubt, formed in other places, but being very soluble it is usually carried off by the rains, and thence by the streams to the sea, the waters of which are known to contain large quantities. But here the overhanging cliff prevents the rain from reaching it, beneath which it is found as a white encrustation upon the stones among the fine substance resulting from the decomposition of rock. By re-dissolving some of this native sulphate of magnesia, and allowing it to crystalize, as fine a sample of epsom salts was produced as can be purchased at any of our drug stores. It is

proper to say, however, that this substance is obtained so cheaply by artificial means, that small quantities of it may be regarded only as interesting specimens in mineralogy.

Des Moines county is abundantly supplied with building-stone which crop out in almost one continuous exposure along the Mississippi river bluffs, from the northern to the southern line. Also scarcely less abundantly, along Skunk and Flint rivers, Brush, Spring and Long creeks.

Its other advantages are too well known to need mention here.

DAVIS COUNTY.

Davis and Appanoose counties received only partial examinations at the time they were visited, because the plans adopted for the season contemplated the special examination of the southwestern portion of the State first.

Upon Salt creek, near its junction with Soap creek, where the Bloomfield road crosses the former, there are several "salt-licks" or springs, from which samples of the water were obtained for analysis. In consequence of previous continued rains they were flowing freely. Therefore the water was proportionally less saline than usual. Mr. S. D. Wells afterward sent samples from another spring on his land in the same neighborhood, (Section 15, 70, 13,) and the following is the result of a preliminary examination by Prof. Hinrichs, a fuller account of which will be found in the Professor's report on another page:

The water of the first named spring was found to contain soda, potassa, lime, iron, alumina, and a little magnesia; also, chlorine and sulphuric acid. These substances of course exist in combination with each other, and the water may, from present indications, be regarded as common spring water, containing common salt, alum, a little copperas, and, as is usual with nearly or quite all the spring waters of the State, a considerable proportion of lime.

The spring on Mr. Wells' farm was similar to the other, in the character of its water, except that it did not contain so great a proportion of the substances named, particularly of potassa, while the presence of iron and magnesia were not detected in it.

These waters have some characters in common with those of some

of the mineral springs resorted to for medicinal purposes, but in detail they vary considerably from those commonly used. The spring on Salt creek contains a considerable proportion of salt, but probably not enough to make it valuable for that purpose.

The springs, like many similar ones in other parts of the coal-field of the State, issue from the shales, limestones and clays associated with the coal.

These springs are a favorite resort for cattle and horses, which drink the water with a great relish. The early settlers of Davis county used to shoot many deer here, where they came in great numbers to drink, and doubtless long departed generations of Indians did the same.

It is commonly believed that springs which animals resort to with unusual avidity *always* contain a considerable proportion of salt. But this is not the case, for many springs are known which contain an amount of sulphuretted hydrogen that renders the water quite disagreeable to most persons, but no salt; yet animals become very fond of such water, and drink with as much eagerness and evident relish as they do saline water.

Davis county is known to contain large quantities of excellent coal, but the only exposures seen were one nearly four feet thick a few rods below the spring before mentioned on Salt Creek, and another half a mile above the mill of Mr. Peter Hendricks, on Soap creek.

A foot or two above the bed of coal at this locality, a four foot bed of compact, bluish limestone is found, from which Mr. Hendricks, some years ago, manufactured considerable quantities of hydraulic cement. Some of this cement was used in the construction of the locks on the Des Moines River, and is said to be satisfactorily tested. No definite analysis of this rock has yet been made, but it is supposed that its hydraulic property is due to alumnia and not to magnesia, like that of the northern part of the State.

Beside an abundance of coal, Davis county is bountifully supplied with fuel in the form of forest trees.

PETROLEUM.

During the year 1865, and also a few previous years, there was much excitement and speculation throughout the country in relation to petroleum. This excitement extended even to our own State, and resulted in much useless expenditure of money in the search for oil. In reply to numerous inquiries concerning the probabilities of finding petroleum in Iowa, the following article, slightly modified in the wording, but not in character, was sent to three or four of the newspapers of the State on June 15, 1866:

"With the successful boring of the first well for petroleum in Titusville, Pa., a spirit of speculation was aroused, or rather was given a new direction, which went on increasing as one success followed another, in that and adjoining States, until it has extended not only over those portions of our country where the search for petroleum was likely to be attended with success, but also to regions where success could not possibly reward those who expended their money and and labor in such enterprises. Some of our own citizens caught the same spirit, and commenced the search for this valuable product, but thus far with invariable failure, so far as the ultimate result has been learned. In view of these facts my opinion has been often solicited as to the probability of finding petroleum in paying quantities in our own State, which I now take this public method of stating, together with the reasons for entertaining it. The importance of this question, as well as of the responsibility which my official position imposes upon me, are well considered; but it is believed that the true interests of the people of Iowa are as well served by informing them where it is useless to expend their money as they would be by directing them to opportunities of making profitable investments.

"The great majority of the men engaged in the search for petroleum, have commenced the enterprise in good faith, but in too many instances with their visions blinded by bright hopes of sudden wealth; honestly inducing others to join in the expense and share with them the great profits which they believed themselves sure to obtain. But this is not the worst feature of these profitless enterprises. Designing men have induced others to furnish capital for prosecuting the development, or purchase of reputed oil lands which perhaps they themselves had "salted," or rather *oiled;* or concerning the great value of which they had obtained a report from some geologist of

easy virtue, or one who was better known for his connection with such schemes than for his scientific attainments."

These remarks are not to be understood as in any respect of a personal character, but that such practices have been committed, is too true to be doubted. Neither have I any words of disrespect to offer concerning those geologists who are in the habit of examining such lands for the purpose of giving an honest scientific opinion of them. The world owes much to such men, and their labors are often underestimated.

First then, expenditures of money and labor, should be made with great caution in our State, because it has been estimated, and I think with some reason, that every dollar's worth of petroleum obtained in the United States has cost a dollar in its production. If this is true the State at large will be the loser, even if some individuals are successful, because there is no reason to believe that our State will produce at best even an average amount of petroleum. The primary origin of petroleum, is believed to be without doubt in fossilized vegetable substances, — probably marine — which existed and accumulated in the sediment which now forms the rock from which it is derived. All rocks in which it has its origin as such, are highly bituminious, or at least carbonaceous, yet it is often obtained in the more porous rock above that in which it actually originated.

In all known instances where petroleum has been obtained in paying quantity in the United States, it has had its origin in *heavy* deposits of these carbonaceous strata; no slight deposits having been known to produce any considerable quantity, even when very rich in the carbonaceous ingredient. Sometimes the material of these slight deposits will yield petroleum by distillation, but as a natural product, the conditions required seem in all cases to be in connection with heavy deposits of carbonaceous strata, and at considerable depth beneath the surface.

Although the illuminating oil formerly obtained by the distillation of coal is the same in its chemical composition as that obtained from petroleum; and sometimes petroleum is found in a natural state associated with coal-bearing strata, yet in the great majority of instances it has in its origin no connection whatever with coal. In

the United States far the greatest amount of petroleum has its origin in strata of Devonian age,— the age preceding that in which the coal was formed. It has in several instances been found in rocks of more ancient date than the Devonian, but in those early ages it is not probable that vegetation existed in sufficient amount to produce the carbon which is believed to have been necessary to give origin to large quantities of petroleum.

Now, in applying these general remarks upon the origin of petroleum to our State, it is not forgotten that it has not yet been carefully examined in all its parts, but enough of its general geology is known to decide the fact, with scarcely a doubt that we have no heavy deposits of carbonaceous strata, except the coal, underlying its surface which precludes the probability of obtaining petroleum beneath our surface.

Again, when it has been found in connection with coal, it has been with cannel, and not bituminous coal. We have a few beds of cannel coal in Iowa, but the greater part is bituminous. Although we have coal enough in Iowa to serve a crowded population for many generations, yet the development of our coal strata is not thick enough nor rich enough in carbonaceous matters, I think, to produce petroleum in paying quantities. That what are usually regarded as favorable indications, and that small quantities of it have and may yet be found, there seems no reason to doubt. Mr. H. T. Woodman, of Dubuque, has shown me some light-brown carbonaceous shale from the Lower Silurian rocks (Trenton limestone) near Dubuque, and also some similar shale from the same beds at Shullsburg, Wisconsin, which will burn with a flame equal to the best cannel coal. Similar shale is also found in the northeast portion of the State in the so-called Hudson River strata, but these are of too slight development to yield any considerable amount of petroleum. Both of these deposits doubtless extend beneath the surface of the State to the southward and westward, where they may probably be reached by boring, but it is not believed that any petroleum would be obtained from them if they were reached, because the carbonaceous deposit, if it exists there, is doubtless too light to have developed it. Time, and a further collection of facts, may cause a change in the opinion here

expressed; but with the possession of present information, I am not disposed to encourage the search for petroleum in Iowa."

The excitement in regard to petroleum was decreasing when the foregoing article was written, and now nothing is known of its existence anywhere in the West.

APPANOOSE COUNTY.

The geology of Appanoose county may, for my present purposes, be summed up in these few words. It lies wholly within the great Iowa and Missouri coal-field; the coal, limestones, sandstones, and clays of which, underlie a drift deposit of varying depth, from twenty to perhaps fifty or sixty feet upon the higher lands; upon which the beautiful and fertile soil is spread, and through which the streams have eroded their way down to the series of coal-measure rocks just mentioned.

The rocks exposed near Centreville are believed to belong to both the upper and middle series of coal-measure strata as sub-divided by some geologists, the limestones belonging to the former, and the coal and its associated shales, to the latter. If this is the case, more coal may be expected to exist beneath the bed now worked by Mr. Talbot at his mill a mile from town. It may also be reasonably sought for on the lower slopes of the Chariton valley, particularly in the northern and northwestern parts of the county.

Coal has been mined from a three-foot bed at several points in the vicinity of Centreville. The only mine visited was that at Talbot's mill, the coal of which was found to be of superior quality.

Appanoose county is well supplied with everything necessary to make a community prosperous and wealthy, such as wood, coal, building-stone, brick-clays, and fertile soil. The latter seems to have been largely free from the blighting curse of non-resident land owners.

WAYNE COUNTY.

Those whose homes are in less beautiful lands than Iowa, and who desire to understand in all its broad expansiveness, the meaning of the word "Prairie," should visit Wayne county, for here these beautiful lineaments in the features of our mother earth are to be seen in all

their loveliness. It is difficult for one who has never seen them to form a correct idea of their character, and indeed to do this, one must see them in many different regions, for they vary much in this respect, although in general appearance they are so much alike. Scientific men have entertained various opinions concerning their origin, many of which were circumscribed by their want of opportunity to observe all their varieties. Those of Iowa are nearly all such as are known as "rolling prairies," and yet those of the northern and western parts of the State differ from each other in character. This difference is due, in part at least, to the more complete drainage of the southern portion, and this drainage is due to the deeper erosion of the river valleys than those of their tributaries farther to the northward. When the continent was finally raised from the diluvial sea, that portion of it which is now our state doubtless presented a surface which was only slightly undulating, the longitudinal depressions of which were in the same direction of, and gave origin to the course of the rivers and streams.

Wayne county presents an excellent example of a well-drained prairie region, lying as it does where the Medicine, and the South Fork of Chariton rivers take their rise. As one stands upon the prairie in the central part of the county, its rolling character is somewhat obscured by the distant view which is only broken by lines and groves of forest trees that reveal the presence of the streams into which the surface waters are gathered by the multitude of gently sloping and gradually deepening ravines which give the prairies of the region their characteristic rolling appearance.

The fact that this county lies about the head waters of the streams indicates a considerable elevation, but this is not definitely known. That of Corydon, however, is probably not far from the same as Chariton, the county seat of Lucas county, which is, according to Mr Thielson, five hundred and twenty-four feet above the level of the Mississippi at low water at Burlington. This, added to four hundred and eighty-six feet, the elevation of that point above the Gulf of Mexico, would give to Corydon, in round numbers, an elevation of about one thousand feet above the level of the sea. The soil of Wayne county is of excellent quality, and it is doubtful if an equal area can be found any where having so little waste and untillable

land. The only elements of prosperity wanting here are a sufficient supply of stone and timber. The heavy deposit of drift, which underlies the deep soil, renders the beds of stone inaccessible, which no doubt exist at too great a depth to be profitably quarried. This want must be supplied from other places, and by the manufacture of brick.

Timber can be profitably cultivated, as is being demonstrated very extensively, in different parts of the State; besides which the natural growth of forest trees will rapidly encroach upon the prairies as soon as the fires are kept out. Coal of good quality has been found in the northeastern part of this county, and a few exposures of stone are also seen in Wright, and South Fork townships, but depending on these alone, little could be said of its geology, except that it is known to lie within the great Iowa and Missouri coal-field, as do also all of those which surround it. This renders it entirely reasonable to prospect for coal by boring at almost any point within it. Owing to the small number of exposures of the series of strata which are generally found associated with the beds of coal, little more can be suggested, than that borings might be made in almost any part of the county with the reasonable hope of finding coal within two or three hundred feet if they are commenced in the deeper valleys. It is probable also that the upper beds of coal may be reached within one hundred and fifty feet. In case such borings are undertaken, it is probable that a considerable thickness of limestone would be passed through.

DECATUR COUNTY.

Passing westward from Wayne to Decatur county, one observes a marked change in the general aspect of the country, which is due to a greater proportion of timber in the latter, together with the existence of more numerous and larger streams. Some portions also of Decatur county are more uneven, but this unevenness is principally confined to the wooded lands in the vicinity of the rivers, while much of it is covered with prairies of that peculiar beauty which characterizes Wayne.

The same geological formations also underlie both counties, but in Decatur the rivers have eroded their channels deeper into them

than they have in Wayne, where the streams are comparatively small. It is this alone that has produced the difference in the character of their surfaces.

All the rocks of Decatur county, at least those above the level of Grand River Bottom, are understood to belong to the upper or unproductive coal-measures. Thus far no coal has been found in this county, but there are good geological reasons for believing that it does exist there at considerable depth beneath the surface. Should explorations be made, it should be done by sinking shafts. These ought to be commenced in the deeper valleys, for it is believed that the higher strata do not contain any coal; and since the strata of the county are practically level, by commencing in the valleys the labor and expense of digging through the upper strata, which are largely composed of limestone, would be avoided. The upper coal-measure limestone just referred to affords a great abundance of excellent building-stone, more particularly along Grand River and its tributaries. Should coal never be found in Decatur county, its inhabitants will never want for fuel, because it is well supplied with a thrifty growth of forest trees. The county is well watered by its springs and numerous streams, and its soil has no superior for fertility.

Little has heretofore been said of the natural beauties of the regions thus far passed through. It is not because they were found below the average in this respect; but upon this bright June morning, in our journey down the west side of the valley of Grand River, our eyes have been resting upon views of impressive loveliness. The wooded hillsides, sloping down to the river from the prairied highlands; the bottom prairie, level as a floor; the belts of heavy timber skirting the stream, are characters in the landscape peculiar to the West, and around which the affections of the children reared amid these scenes will cling as long as memory lasts.

RINGGOLD COUNTY.

Wayne has been described as a prairie county, while Decatur, adjoining it on the west, is found to possess a well-proportioned diversity of prairie and timber land. Proceeding still further westward, Ringgold county again presents us with extensive and almost continuous prairies which, however differ somewhat in character from

those of Wayne; in consequence of the difference in the drainage systems of each, and not to any material difference in the character of their formations.

The drift-deposit in Ringgold county is very thick, and its distinctive topographical features are produced by the great depth to which its streams cut their valleys into that formation.

Wayne county is drained in almost all directions from its central portions, by the upper branches of Chariton and Medicine rivers, most of which pass out of the county before they have increased to any considerable volume, and before they have eroded their valleys to so great a depth that the tops of the trees which skirt them can not be seen peering above the general surface as one stands upon the higher prairie levels.

The streams of Ringgold county, however, pass through it from a northerly to a southerly direction, having at the northern border of the county already attained considerable size, and in their passage through it, have eroded their valleys so deeply that the full-grown forest trees which skirt their banks can not be seen from the higher prairie surface. Indeed they could not be thus seen in many cases if they were three times as high as they are, for the valleys are usually narrow, with somewhat abrupt slopes to the prairie level, and from one hundred to two hundred feet deep.

Timber is usually scarce in this county, but along the Platte, and East and West Grand rivers there are considerable bodies of forest trees consisting of oak, elm, maple, linden, cottonwood, hickory, buckeye, black walnut, box elder, &c.

Most of the roads are excellent, being located upon the "divides," and as the traveler passes over them there is very little upon which the eye can rest to relieve the monotonous expanse of prairie; and if a stranger he is quite unconscious of the presence within the range of his vision of these deep valleys with their wooded banks, until he approaches to cross them, which being done they are again hidden from view, and the course of the valley itself obscured by the general undulatory character of the surface.

It is difficult, if not impossible, to ascertain accurately the depth of the drift deposit in this county, but it is probably not less

than one hundred and fifty feet deep where none of it has been removed by erosion. Indeed it can not be certainly known that it is not fully as deep as the full depth of the valleys before mentioned, for no other material appears upon the slopes, and the only exposures of rock to be found in the county are a few small quarries of upper coal-measure limestone near the Missouri border, on section 19, township 67, range 29, together with a few similar exposures in the extreme northeast corner of the county. There are at least five hundred and fifty square miles of this county upon which no rocks appear except the very few boulders associated with the drift. It will be thus seen that a geological examination of such a county alone, disconnected from adjoining territory would give very unsatisfactory results, except of the character of the surface. In view of this a detour was made to the northward into Union, Madison and Adams counties, thence southward into Taylor. Examinations there, together with those within the county, leave no doubt that the first stratified rocks beneath the drift-deposit in Ringgold are the upper coal-measure limestone; the inference from which is that if coal is ever obtained here, it will be found at considerable depth below the surface. It is not at all improbable that one or more beds of coal underlie the county, but if so, further and more extensive examinations are needed to give even an approximate estimate of the depth at which it may be found.

The county is so well drained that hardly a single pool can be found within its borders, yet water is abundant in the streams, and also easily obtained at a moderate depth anywhere upon the high lands except upon the narrow ridges, and immediately upon the slopes. The prairies are covered with a luxuriant growth of wild grass, and the cultivated varieties succeed admirably. Consequently this is destined to be an important one for stock-raising as well as for purposes of general farming.

TAYLOR COUNTY.

Taylor county is similar in the general character of its surface to those which adjoin it. It has rather more timber than Ringgold, but not so much of either timber or stone as Decatur county. The streams flow to the southward through it as in Ringgold, but they

will not average quite so large, and their valleys are consequently not quite so deep nor their slopes so abrupt. The county is perfectly drained by its rivers and creeks, so that not a marsh nor pond was anywhere seen. These streams afford good water for stock, and springs are not uncommon in depressions upon the prairies. Excellent water is also readily obtained anywhere upon the prairies at a very moderate depth.

Timber enough for present use can be found in the vicinity of the streams, which rapidly encroaches upon the prairie where the fires are kept out. These trees also grow rapidly when planted upon the prairies. Hon. L. W. Hillyer, of Plattville, has some cottonwood trees about his residence which he had planted five years ago, and which measure twenty-three inches in circumference at the root. His method of propagating them is so peculiar and successful as to deserve particular mention, and thorough trial by others. He procured freshly cut poles of that wood from the timber, chipped them with an ax at short intervals, and then planted them, end to end in shallow trenches. Vigorous sprouts soon sprung from each of the chipped places which grew much more rapidly than the young trees which were transplanted with their roots at the same time, and soon exceeded them in size. They have also a much more healthy and thrifty appearance. Whether other trees may thus be propagated, remains to be tested. It is very desirable that other trees, particularly the White Maple, which grows vigorously, should be extensively propagated, but the cottonwood grows more rapidly than any other, and is consequently sooner available as fuel, although the quality is not so good as that of most others. Mr. Hillyer thinks that if he had planted ten acres in trees at the time he planted his grove, he might now have drawn all his supply of fuel from that source.

Considerable portions of this county, particularly the northeastern and southwestern parts are destitute of stone. Several good quarries are opened in the upper coal-measure limestone on the One-hundred-and-two river in the vicinity of Bedford. There are also a few exposures of the same rock along the river between Bedford and the southern boundary of the State. In the northwestern part

of the county, on several points on the East Nodaway, above where that river enters Page county, a blue argillaceous limestone is found, and beneath it a fifteen-inch bed of coal is being worked on land of Mr. J. R. Foster, section 29, township 70, range 35, which is thus far the only bed of coal worked in the county. It was at first believed that this bed of coal belonged to the upper part of the lower coal-measures, but subsequent examinations leave no doubt that it belongs quite within the upper series and is believed to be the only bed which that series contains. Connected with this change of opinion is also the belief that although other beds of coal may be expected beneath the one now worked, they lie at considerable depth.

The coal of Mr. Foster's mine is of good quality, and having a large market for it, he finds it profitable to have it mined although the bed is so thin.

Mr. Edwin Houck is making a good quality of lime from his quarries at Bedford, for which he finds a ready market, as well as for his quarry-rock.

The soil of Taylor, is of the same excellent quality as that found in the counties before named.

The marketable products of its citizens consist at present of live stock, for which buyers reach them from both the eastern and western borders of the State.

PAGE COUNTY.

Within the memory of some now living the growing wheat crop of the Genessee valley was watched with lively interest by the whole country, because success or failure there effected the market far and near. This was before the Great West had begun to send forward for the world's consumption, her surplus store amounting to millions of bushels of grain every year. That vallay, is still fertile and beautiful, but now, in the growing greatness, of our country, it has dwindled into insignificance compared with the fame it once possessed. Other valleys have been settled and cultivated as the tide of civilization rolled westward, which vie with that in everything that makes a region desirable, but being themselves in the

midst of boundless productiveness, their excellence has become known only to the passing traveller, and to those who dwell there. There are yet others in our State of surpassing beauty and fertility, which have only just begun to be settled, and which will in a few years produce more bread, and be the seat of a greater number of happy homes than the far famed valley of the Genessee.

Page county possesses one of these lovely regions in the valleys of the Nodaways. These streams ought to receive separate names, but in the meagre nomenclature of the pioneer, each large branch of a stream retained the name of the principal one, with the distinctive prefix East, West, or Middle, as the occasion required. Thus we have a multiplicity of Chariton, Grand, One - hundred - and - two, Nodaway, Tarkeo and Nishnabotony rivers. The West Nodaway stretches entirely through the county from north to south, a distance of nearty twenty - five miles, but which is only a small portion of its entire length, while the East Nodaway has a length of only about twelve miles in this county, having entered it near the middle of the east line, from Taylor, which received it in turn from Adams: but more particular reference is here made to the West Nodaway. The character of the approaches to this stream is somewhat different from those which drain the counties to the eastward of it. The stream itself lies about as far below the general prairie level as those of similar size in Taylor county, about one hundred and fifty feet, but the valley slopes are more gradual, commencing about a mile from the stream on either side. These slopes are themselves undulating like the higher prairies, the drainage system of which is here repeated in miniature. Shallow, grassy ravines come down to the stream at intervals, gradually diminishing branches of which extend outward on either side and up the slope, multiplying and draining the land completely, and giving it a very pleasing appearance when viewed from the opposite side. This is the general character of the valley in its whole extent through the county, but yet it possesses diversity enough to make it pleasant for the eye to rest upon it at every point. Although the eastern part of Page county contains more timber than any other of the southern tier, thus far seen west of Decatur, yet these approaches to the Nodaway are principally prairie slopes, which

allow their features to be seen with admirable distinctness. Immediately bordering the stream, more or less timber is always found. Sometimes, it is true, it amounts to but a very narrow belt, but at other places it is a quarter of a mile or more in width. Beside this, where its tributaries meet it, as well as at some other points also, still larger groves extend upward upon the slopes; and in the space between the East and West Nodaways, opposite Clarinda, there is a body of timber four miles in width.

At this season of the year (last of July) the ripened heads of one species of prairie grass gives the surface a sere and barren aspect in the distance, and in looking down upon this valley one sees the immense fields of green luxuriant corn, and yellow, ripened grain, standing upon the surface like rectangular oases in a desert of grass. This desert is one only in appearance, for it only needs the plow to convert every square rod of it into fields fertile as those which are now there smiling with a plentiful harvest.

The other rivers of the county are two small streams, the East and West Tarkeo, both of which traverse it from north to south; and the East Nishnabotony, which crosses the northwest corner. A narrow belt of timber skirts the latter river; a little is also found on the East Tarkeo, but from the latter stream to the west line of the county, stretches one almost unbroken, but deeply undulating prairie, all of which is as fertile as any soil in the State, as occasional fields of grain will testify, which are being cultivated wherever a grove of trees forms the nucleus for a settlement.

Limestone of good quality for building purposes is quarried at various points along the East and West Nodaway, from Hawleyville in the east part of the county, to the Missouri line; a very good supply being obtained within a few miles of Clarinda. A persistent ledge of a few layers, of a hard, ponderous, bluish limestone, two or three feet in thickness, is found cropping out at frequent intervals on the prairie - points, and in small streams bordering the East Tarkeo. It shows itself a little above the level of the narrow bottom bordering the stream, and extends quite through the county from north to south, and dipping to the southward at about the same rate that the water falls in the stream, it appears at about the same elevation

above it at all points. This stone seems well adapted to all the purposes for which stone is usually required, except the manufacture of lime. Thus far efforts with it in this direction have failed, although it seems to be composed principally, at least, of carbonate of lime. It very much resembles in physical characters the rock which has been successfully used in Davis county for the manufacture of hydraulic cement.

The only bed of coal yet found in this county is worked at various points near Clarinda, and is identical with the one which is worked at Quincy in Adams county, and also on Mr. Foster's land in the northwestern part of Taylor county.

The soil is everywhere fertile, and almost everywhere covered with a luxuriant growth of grass. Along the valleys of the rivers of this county, the "blue joint," one of the most nutritous of the wild grasses, is very abundant, making it one of the best natural stock-raising regions in the world. Large numbers of cattle, horses and sheep are now raised by the citizens of the county, but thousands of acres of this excellent grass dies annually, hardly a mouthful of which is consumed. The streams of the county afford abundant water for stock, and pure cold water can be obtained at a moderate depth almost anywhere upon the prairies, as well as in the valleys. Beside which, excellent springs are not unfrequently found along the slopes of the streams.

FREMONT COUNTY.

This county is more distinctly marked in its surface features than any of those between it and the Des Moines river, which difference is due to two distinct causes not possessed by any of those. The first of these causes is the great Missouri river which courses along its western border, and which, aside from the effects produced in its own immediate vicinity, has also had a modifying influence upon the drainage of the county by the Nishnabotany and its tributaries. The second cause is the existence over a great part of the county of a peculiar deposit which forms the soil where it exists, as well as much of the material beneath it, all resting upon the drift, the finely pulverized upper portion of which forms the soil in other portions of the State.

This deposit has been called by Prof. Swallow, State Geologist of Missouri, "the bluff deposit," which term will also be used in these communications from the field. It is composed of very finely comminuted silicious matter, with much clayey and limy material, a part of the latter having formed into stony concretions, from the size of a nut to a forty pound shot. With the exception of these concretions, which form a very inconsiderable part of it, the whole mass is very uniform in its color and composition from top to bottom, even where it is more than two feet thick. It is of a slightly yellowish ash color where it has not been rendered darker by decomposed vegetable matter resulting from the profusion of grasses and plants, which grow upon it in every favorable situation.

Resting upon the drift, which it will be remembered contains the water-worn pebbles, boulders and sand, it has of course been formed at a subsequent period, and bears within itself the evidences of its origin in a fresh water lake which was doubtless anciently an expansion of the Missouri river. *

There is reason to believe that this deposit does not extend eastward of the Nishnabotanys in Fremont county, but its exact limit in this direction is not clearly defined, from the fact that the fine material of the upper portion of the drift forms a soil almost identical in appearance in most places, with that formed by the bluff deposit, supporting the same profusion of grasses and plants, and presenting but little to the eye of the casual observer to indicate a change of composition in the soil-material. It is along the border of the Missouri river bottom, and in excavations such as cellars and wells, that the strange peculiarities of this deposit are seen. Excavations are made in it with less labor than in the drift, and when moist a strong man can thrust a spade into it without difficulty. Yet wells dug in it and walled only just above the water line, remain unchanged for years, the sides showing the spade marks upon them as when they were first dug. Very good cellars are also made in it, the perpendicular banks of which remain without a wall or other support, and sometimes even the steps are carved out of it, which when dry, as it usually becomes, remain serviceable for a long time with a little care.

* See the article entitled "Lakes of Iowa, Past and Present," on another page.

Bordering the Missouri river bottom — which, with the exception of a narrow belt of timber along the river, is in this county a nearly level prairie from three to six miles wide — the bluff deposit ends as abruptly as the rocky cliffs of the Mississippi, and viewing the fantastic shapes into which it has been carved by fluvatile and meteorological erosion, one can hardly rid himself of the idea that these too, are supported by a frame-work of rock. But this is not the case, for not a stone of any kind is to be found in the whole mass save the limy concretions above referred to. Along the base of these bluffs between the northern and southern line of the county, ledges of the upper coal-measure limestone and sandstone are found, resting upon which a comparatively thin deposit of drift is seen with its boulders, gravel and sand, which in turn bears upon itself the bluff deposit. This towers up above the drift in some places more than two hundred feet, and upward of two hundred and fifty feet above the general level of the river bottom.

Frequent springs of pure cold water issue from the drift at the base of the bluff deposit, and there are also evidences of the former existence of many which have ceased to flow or that have sought other channels. These springs have doubtless had some effect in producing the peculiar outline which the face of the bluff presents, particularly in forming the beautiful little natural ampitheaters, containing from a few square rods to an acre, covered with box-elder and other trees, opening toward the river, but nearly surrounded by high buttresses and undulating precipitous slopes which are covered sparsely with prairie grass to their tops. From some of these, springs still issue, making them delightful nooks in which to hold pic-nics, or for the matter-of-fact farmer to shelter his stock. In many places the bluffs are so precipitous that they appear almost perpendicular, but this is far from being the case, since appearances of this kind are always deceptive. The steepest fronts will average less than an angle of forty-five degrees with the horizon, and the boldest and most precipitous one we found, upon which the grass was growing, when tested with the clinometer proved to be only fifty degrees. There are occasional places in some of the more prominent fronts where the material has fallen down, which present bared faces for a short distance, which are in reality nearly perpendicular,

and these stand there year after year, with little or no change, becoming so dry that no grass can grow upon them, and giving the appearance in the distance of a rocky cliff. There is a peculiar rounding to the summits of these bluffs many of which resemble the artificial mound raised by a departed race of Indians upon those which border the Mississippi, but their great number would undeceive one in this respect if their shapes were not more varied, and their ridges and slopes also did not partake of the same character. Being destitute of trees upon their summits, and stretching northward and southward so far as the eye can reach, they present a strange and impressive aspect quite different from that produced by any other formation in the State.

Proceeding inland from the great river, the surface becomes much less broken although the material is the same, and a great portion of that which is not occupied by fertile farms, is covered by a thrifty growth of timber; and approaching this county from the prairies which lie to the eastward of it, one sees for the first time since leaving Decatur county, the horizon serrated with forest trees growing upon the high lands and slopes.

The Missouri river bottom is, in this county at least, somewhat different in character from that of the Mississippi. Here are none of the definite terraces which are often seen there, and the whole is more nearly level from the river to the bluff. The greater part of it is prairie, and much of it is never reached by the highest floods of the river, perhaps excepting those which occur at intervals of many years. The soil here is of the most extraordinary fertility. Wells dug in it show a depth of more than ten feet, every inch of which is as fertile as that turned by the plow. There are some farms upon this bottom which have yielded a bountiful crop of corn every year for fifteen years, without rotation of crops, without manure, and almost without care. The formation of this bottom land was long subsequent to that of the bluff deposit, from which much of its material was derived, which, as already explained, was deposited at a period subsequent to that in which the drift with its own productive soil was formed. Thus we perceive that this county presents excellent, and, indeed, remarkable examples of soil of diluvial,

lacustrine, and fluvatile origin, each succeeding the other in order of time; all of which are also of remarkable fertility.

The northeastern and southeastern portions of Fremont county are nearly all prairie, but the region along the Nishnabotany and its tributaries, as well as a great part of the county west of that river, furnishes much more than the average amount of timber. In the description of Page county, considerable space was devoted to a description of the valley of the Nodaway, but the great length of this letter makes it necessary to close it without doing full justice to the valleys of the Nishnabotany and its tributaries. A few words, however, must be said concerning its general features, and these will be confined to the West river, which extends from the northern to the southern line of the county, almost directly through its middle. It is a larger stream than the Nodaway, and its valley occupies a much wider area, but nearly all that was said of that valley is also applicable to this. The approaches to the stream, however, are longer and more gradual; the valley is wider from the highest land on either side, averaging four miles or more in width, and then it has also a distinct bottom, which is not so marked a feature of that of the Nodaway.

A dweller by the Mississippi, viewing this valley from the high lands for the first time, would be likely to mistake the real character of its bottom, for it is not in reality so flat as those he is accustomed to see there. Far the greater portion of it is never reached by the highest floods which swell the river in wet seasons. Standing near the river, and looking toward the slopes on each side, the bottom land will, in most cases, be seen to rise without a terrace towards them, at the rate of about forty feet in the mile, the distance from the foot of the slope to the river being often as much or more than this. There are occasional low places which are reached by the high waters, but most of them are drained when the waters subside, leaving no pond, and the surface becomes covered with grass every year. The soil of these places, and that closely bordering the stream is composed of the disturbed material of the bluff deposit, while the higher portions of the bottom land are composed of *unaltered* bluff material like the high lands along the border of the valley and to the westward of it. The view of this valley from the high lands is everywhere so delightful

that it is not easy to select any one region which greatly excels another in this respect, but no person capable of appreciating the beautiful can pass over the road from Sidney to Hamburg without being thankful that his eyes were permitted to rest upon scenes so lovely as those which meet his view all the way.

The deep drift in the eastern part of the county, and the deeper bluff deposit of the middle and western portions have covered from sight all, or nearly all the stratified rocks which exist beneath it, except along the base of the Missouri river bluffs, the most southern exposure of which is seen on the town lot of Mr. Allen near his saw-mill in Hamburg. This is now nearly obscured by grading, but enough was seen to indicate several layers of upper coal-measure limestone with marly partings, resting upon a fine grained, micaceous sandstone, at an elevation of thirty or forty feet above the general level of the river bottom. Following up the base of the bluff along the bottom road to Plum Creek the exposures, particularly of the limestone, become more frequent, and afford good quarry-rock. At about two miles above Plum creek, and extending thence some two miles further along the base of the bluffs, there are very full exposures of limestone, which afford the finest and most extensive quarries yet seen west of Madison county. The stone closely resembles those obtained from the quarries of that county, in quality as well as in the excellence of its lime. It can be obtained here in almost any desired quantity, and with not greater than the ordinary amount of labor in quarrying.

Near the residence of Mr. John Wilson, on Section 14, township 70, range 43, this gentleman kindly pointed out a place where a ten inch bed of coal has been exposed by excavation; an examination of which, together with the strata above and below it, leaves but little, if any doubt, that it is a continuation of the same bed which is being worked in Adams, Taylor and Page counties. It is hardly probable that this bed will be found thick enough to be profitably worked in this county.

The brick made in this county are of very fair quality, the clay for which was obtained from the drift, at the base of the bluff deposit, at the only yard where it was examined. The bluff material would itself probably make very fair brick were it not

that the small limy concretions which it contains, are changed to to quick-lime when the bricks are burned, and then when exposed to moisture the slaking of the lime bursts them.

MILLS COUNTY.

The counties of Mills and Fremont are so similar in geological character, as well as in those topographical features which distinguish them from the counties lying to the eastward of them that much of the description of one would be equally applicable to the other. In view of this, and of the unusual length of my letter on Fremont county, some of the topics discussed therein will be continued in this, and others will now receive attention which were omitted in that.

Although Mills county seems to contain proportionally a little less timber than Fremont, yet it has more than the counties eastward of those on the Missouri watershed will average; the principal portion of which is found in the western half of the county. Wherever the fires are kept from the prairies the young timber grows up with great rapidity, so that one frequently sees considerable bodies of forest trees of the various kinds common to the State, large enough to use for fuel, which have grown up since the country was settled. These trees, as well as the osage orange also, succeed well when planted upon the prairies that rest upon the bluff deposit, as well as those which rest upon the drift.

The beautiful and fertile valley of the Nishnabotany extends through the county from north to south, and is almost identical in character with that part of it lying in Fremont, and the smaller but no less beautiful valleys of Silver and Keg creeks traverse large portions of the northern and central parts. These valleys with their tributary depressions are not as deep as the valleys of similar streams are in some of the counties to the eastward and the approaches to them are so gentle that they can all be as easily cultivated as the more level land. This character of the valleys began to be distinctly perceptible upon reaching the Nodaway, and at the same time, that clearly defind ocean-like horizon of the prairie level observed in Wayne and elsewhere began to be less distinct, and these changes, particularly the former, are more readily

recognized, as one passes westward into Fremont and Mills counties; the nearest approach to a definite prairie horizon being seen in the northern part of Mills. The eastern border of the bluff deposit was not recognized in this county, and it doubtless extends over the whole surface, except where the streams have eroded their valleys through it, reaching the drift with its gravel sand and boulders beneath, but by this means it was seen to be much thinner in the western part of the county.

The Missouri river bottom extends the full length of the county as in Fremont, the character of it being similar, and the width averaging about the same, for the river nowhere approaches the bluffs in either of these counties. The bluffs of Mills, generally slope more gradually to the bottom lands, and are more frequently wooded than in Fremont; and where the timber does not exist the slopes are more thickly covered with grass. This results, not from any change in the character of the material, but wholly in consequence of the more gradual sloping of the hills, thus retaining the moisture; for where the peculiar material of which they are formed is exposed in such prominent and precipitous masses as are sometimes seen, it becomes too dry to support vegetation; yet under more favorable circumstances every part of it, even when thrown out of deep wells, produces a luxuriant growth, both of plants and trees. Thus many of the bluffs of Mills county are wooded upon their slopes, while their prominent, rounded summits are destitute of trees, reminding us of the waning locks of our honored sires.

The material composing the bluff-deposit has some physical characteristic which are very remarkable. One of the most striking of which is the constancy with which it remains unchanged by atmosphere or frost, in any shape which has been given to it by natural or artificial forces, while it can be readily excavated by the spade alone. It is this which maintains the bluffs in their strange and peculiar shapes as unchanged in form as those are in other parts of the country which are supported by a framework of rocks. Wells dug in it do not need walls above the water line; stock shelters dug in the hillsides are serviceable for many years; roads upon it become hard and do not wash easily by the rains,

and thus the roads of this region are among the best in the State, for there is not a stone to jar the wheels, nor deep ruts to impede them. It dries so readily that lime and pottery kilns are dug out in the prominent points, and used as well and as long without walls, as they can be with them in other places. And yet the soil formed from the same material will endure a drouth as well as any other, and those who till it claim that it is better than the average in this respect. The water of springs and creeks run perfectly clear upon it much of the time, and where they have finally cut their narrow channels down, the banks remain precipitous and the ravines very short beyond the issuance of the spring.

All that was said of the excellence of the soil of Fremont county is also applicable to that of Mills, and the stratified rocks of both counties bear the same relation to the productive coal-beds of the Des Moines River Valley. Large quantities of excellent limestone are found along the base of the bluffs in the southwestern part of the county. The exposures are almost identical in character with those in the northwestern part of Fremont, and the quality of the rock, about the same. A couple of quarries of limestone also exist on Silver Creek, in the south part of the county, and in the northeastern corner, there are considerable exposure of sandstone, some of which is quarried by Mr. Peter Cooper, and wrought into various shapes for building purposes.

Some of the layers of limestone both in Mills and Fremont counties, closely resemble, in physical characters, a stone which has been successfully used in Davis county for the preparation of hydraulic cement. Even if these should be found upon trial to produce a good quality of that valuable article, any person contemplating the manufacture of it, should satisfy himself of the existence of a large and constant supply of the stone, and also that its character is uniform; for that of the various localities which furnish the best cement, is almost never identical in composition, and sometimes they are widely different in this respect, while furnishing equally good cement. It thus becomes necessary that the stone of each locality should be studied and experimented with independently of others.

At various points along the base of the bluffs, both in Mills and

Fremont counties, where springs issue or have issued in former times, considerable masses of porous stone are seen, which are always of limited extent, and have been formed entirely by the spring water giving up a portion of its lime upon coming in contact with the atmosphere. This is found in various parts of the world, and is called calcareous tufa. Another curious fact observed there is the formation of small masses of sandstone by the same natural process, the lime from the water forming a cement as it has percolated through the sand often found in the drift, at the base of the bluffs. At a point not far from St. Mary's, in Mills county, a mass of natural "concrete" was found, formed in the same manner. This mass was identical in appearance with that used in the construction of "concrete houses," so much recommended a few years ago. The granite and greenstone pebbles it contained, prove it to have been derived from the drift. But these substances are merely curious, and not of any economic value, and are only mentioned here to correct the impression that they are parts of large masses of stone extending beneath the surface.

The brick manufactured in Mills county, are very good, far better than any seen in the prairie region lately passed over. The material from which they are made at Glenwood, is taken from the base of the bluff deposit, four or five feet of which, at the base, contains more clay than that above. It is the practice there to mix the whole together, since they find that the upper portion has not coherence enough to hold the bricks together while drying, and the lower portion cracks by the same process.

POTTAWATTAMIE COUNTY.

The great thoroughfares of the earth, around which wealth and civilization cluster, and along which property is always most valuable, are not arbitrarily located by man, but their routes are in a great measure determined by geological features, themselves the result of geological causes which completed their operations long before he was created. It is from such causes as these that the continents have their outline, mountains range their elevation, the sea its bounds, and the rivers their volume and direction; and now, while the rapid tide of civilization is setting across the continent, requiring

the establishment of new and more artificial lines of intercommunication, similar circumstances, resulting also from the operations of nature herself, and therefore immutable, are rapidly making Pottawattamie county one of the most important, as it is in superficial area one of the largest counties in the State. The great Missouri river which flows along its western border will never cease to bear the burthens of its commerce, but the commercial importance of the river to this county is much diminished by the fact that the latter lies directly in the course of one of the great lines of railway which are soon to connect the Atlantic with the Pacific ocean; and the further fact that natural causes will tend to converge some of the proposed Iowa lines of railway to a point within it, and near the Missouri river. The principal of these natural causes — and none other will be discussed — consists in the peculiar and deep erosion of the valleys of the larger tributaries of the Missouri river which have their confluence with it to the northward, which render it nearly impracticable to build the proposed east and west lines directly across them. Upon reaching these from the eastward, they must bend their course southward along the valleys of these streams in order to reach the Missouri river with facility, or to connect with the great Pacific railway opposite Council Bluffs. These circumstances will probably require them all, either to pass into this county, or to approach it so nearly as to render a connection with those within it desirable.

These advantages, although remote in their origin and indirect in their characters, are of immense importance, and would in time cause an unfruitful land to be desirable, but in addition to these, Pottawattamie county has fully an average of inherent natural advantages, not the least of which is the possession of more than half a million acres of as fertile and tillable soil as can be found in the State.

That of the higher lands is composed almost entirely of the bluff deposit, which extends nearly or quite to the east line of the county. The greater part of its surface is prairie, the grasses of which are of the more nutritious varieties, rendering it one of the most desirable grazing regions to be found. The beautiful valley of the West Nishnabotany passes through its eastern portion from north to south,

which is also the general direction of all the other streams that drain the county. This is done so completely that hardly a pool of stagnant water can be found within its borders; yet the smallest of the streams, even in the present dry season, afford an abundance of water for stock. Excellent wells can be obtained almost everywhere, except in the immediate vicinity of the bluffs, and springs of pure cold water are often found along the banks of the streams, although often no stone or tree is near them to mark the spot.

Wood is more abundant in the western than in other parts of the county, where large bodies of young timber are rapidly growing up.

Limestone of good quality for lime, and also for building purposes is found in township 74, range 40, and large quarries of excellent limestone are found three miles eastward, and also six miles northward from Council Bluffs.

At various places along the base of the bluffs bordering the Missouri River bottom, large masses of coarse sandstone and conglomerate, as well as of light porous limestone are frequently seen, which appear in some cases to be parts of regular ledges of rock, but which are in reality of only limited extent, and have been formed by the deposition of lime from the spring water which issues, or has issued near them. The porous limestone has been formed wholly from the limy material deposited from the water upon reaching the atmosphere, and although impure, a similar substance has been used to make lime in some parts of the country, in the absence of better material. The sandstone and conglomerate have been formed by the percolation of the limy water through the beds of sand and pebbles belonging to the drift, cementing their particles together while they remained in the exact position in which they were deposited. Thus when these beds of loose material were deposited in horizontal layers, they retained that position when consolidated, and now present the appearance somewhat of rocky ledges. Some of these masses are quite hard, but the cementing material being merely a carbonate of lime, they are probably not so strong as the same mass would in time become if prepared with quicklime; for in that case, a part at least of the cement would be a silicate of lime, which is stronger and more indestructible.

The question is often asked by the people, "do stones grow?" or in other words, "are they now in process of formation by increase?" The reply is almost invariably in the negative, for the question is usually asked in relation to the stones as we usually see them, which not only do not grow, but like everything else without life have a constant tendency to disintegration and destruction. Some rocks, such as some of our boulders, are believed to have had their origin as such by fire when the foundations of the earth were laid, or by subsequent fusion, but all the strata of rock in our State at least, had their origin at the bottom of the sea, ages subsequent to the formation of most of the granite rocks, from which the majority of our boulders are derived. The sea of course then covered the ground where we find them, and similar strata are doubtless now being formed beneath the sea, but human eyes can never actually witness the operation. These masses are, however, an exception to the rule, and are now actually in process of formation beneath our eyes. None of these adventitious rocks are of any considerable value, but are yet very interesting to those who are fond of studying the operations of nature.

These springs, although containing so much lime, are nevertheless quite wholesome, and some of them, two or three miles above Council Bluffs, are among the largest in the State, the waters of which, if collected, might probably supply the city until the increasing population should render them inadequate for that purpose.

The peculiar bluffs mentioned as so striking a feature in Fremont and Mills counties also extend all the way through Pottawattamie county, bordering the broad river bottom. The extraordinary deposit of which these bluffs are formed reaches its typical development in Pottawattamie, and a point near Council Bluffs was selected by Dr. Owen from which to prepare an engraved view of the bluffs which embellishes his geological report to the General Government.

Faint traces of glacial action were observed upon the upper layers of limestone in the quarry now worked by Mr. Merritt, six miles north of Council Bluffs, but they are not so distinct as those seen in Mills county, and also a mile south of Omaha, all of which are described on other pages.

Very little can yet be said in reply to the great questions constantly asked by the people, "Have we any coal or other valuable material beneath our fertile soil?" The probability of finding any other valuable mineral substance besides coal in this county is so slight that little or no especial attention is given to that branch of investigation; and all that can now be said upon the subject of coal in addition to what has been said in the introductory pages, is that it is barely possible that the bed now worked along the Nodaway may be found in the western part of Pottawattomie county; but if found it will doubtless be thin and of little value.

MONTGOMERY COUNTY.

Montgomery partakes of the character of both Page and Mills counties, which it adjoins, which have been before described. A part of its soil is composed of the bluff deposit, and a part of it of the fine material of the drift. The division between these two varieties, seems to be along the valley of the Nishnabotany. Yet this is always difficult to determine from appearance alone, and in this county at least, the soil is equally fertile in most cases. All that has been said of the valley of the Nodaway in Page county, and that of the Nishnabotany in Mills and Fremont is, to a great extent, applicable to Montgomery; for both of these beautiful valleys extend entirely through the county from north to south. It is well drained throughout its entire extent, like all the region round about it. It is well watered also by its streams, and along the larger ones a considerable amount of timber is found, the young growth of which rapidly encroaches upon the prairies that are not annually burned. Pure, wholesome water is obtained without difficulty at a moderate depth almost anywhere upon the high lands and in the valleys.

Limestone is found in considerable quantity at various points along the Nishnabotany in townships seventy-two and seventy-three, from the quarries of which the country around is supplied with lime and building rock. It is also found in a number of places in the northeastern township of the county. A coal mine has also been worked in this part of the county, the bed being about one-and-one-half feet thick, and is doubtless the same one which is found near Quincy in Adams county, which is about ten miles distant from that point.

The same bed may probably be found at other points in the north-eastern part of Montgomery, particularly in the vicinity of the mine which has been worked. In an easterly and westerly direction from that point, it will probably be found not to vary much from a level with it, but to the southward the dip coincides pretty nearly with the fall of the Nodaway. Along the slopes to the valley of the Nishnabotany a heavy bed of sandstone appears at various points, which is, however, too soft to be used as stone, except in some instances where iron is the cementing material. In such cases, irregular layers of very hard, dark-colored stone are found in it, which will serve a very good purpose for walling wells, in the absence of better material.

Upon the first examination of this sandstone it was found to rest unconformably upon the upper coal-measure limestone, and was suspected to be of Cretaceous age, and the provisional name of "Nishnabotony sandstone" was applied to it. Subsequently it has been proved to belong to that age by the discovery of characteristic fossil leaves in the exposure within the village of Red Oak.

At the base of this sandstone, as seen on land of Mr. Johnson, section 2, township 72, range 38, a bed of clay is found which is a mixture of a dark red ochery clay with that of nearly a white color. The latter has been tested for the manufacture of common pottery and pronounced to be the best yet found in the southwestern part of the State, and judging from its appearance, this is probably correct. Clay of a reddish color, and doubtless the same bed, is also seen in the hillside near Stover's Mill on the Nishnabotany, a couple of miles below Red Oak. This clay, with the exception of its ochery ingredient, is similar to the beds of fire-clay which underlie the beds of coal in the eastern part of the State, and it is not improbable that a thin bed of coal may yet be found in connection with this, but there is little hope that it will prove, if found, of sufficient thickness to be profitably worked. Mr. J. B. Packard, of Red Oak, exhibited some material which he had used for paint, having the appearance of the clay above mentioned, but containing a much greater proportion of ochre than any before seen. It was obtained from his land near Frankford, in this county, where it is found in considerable quantity. It has been used for painting barns and out-houses for a number of

years, and seems to give a good body to the paint, and resembles, when applied, the material known as "Blake's fire-proof paint." It is of a dark-red color, suitable for bridges and barns, but is too sombre in appearance for that cheerfulness which should characterize our dwellings.

The soil of Montgomery county is of that excellent quality which prevails in this part of the State, and it needs only the extensive planting of forest trees, and railroad-communication, to make it as beautiful and prosperous as can be desired. Even now many neighborhoods give evidence of wealth and prosperity in their well-cultivated farms, large herds of cattle and comfortable homes.

CASS COUNTY.

Cass, although only the second county from the Missouri, is yet the most easterly one of the third tier which is wholly upon the watershed of that river.

The East Nishnabotany does not take its rise in this county, but it nearly loses its identity here by its subdivision into Indian, Camp, Buck, Turkey and Troublesome creeks, while Seven-Mile and Sixteen-Mile creeks form the head waters of the Nodaway, and complete the drainage of the county, which is accomplished in the same thorough manner as that of those which adjoin it.

The Nishnabotany retains its broad, beautiful valley as far up as the vicinity of Lewis, the county-seat, where it passes for the distance of a few miles through a narrow space between the gently-sloping hills, without the broad bottoms which characterize it below. Above this, the valley is found to widen again, and continues thus as far up as the sub-division of the river into the creeks before mentioned.

Interesting as the characteristic portion of the valley of this river is, the vicinity of Lewis is no less pleasant, with its wooded slopes and gentle declivities, which, together with the valleys of the creeks in the neighborhood, give a pleasing diversity to the scenery around.

The soil of Cass county is of that abundant and uniform fertility which characterizes this portion of the State, and some of it has the appearance of being a little warmer, from a slight admixture of sand, doubtless derived from the cretaceous sandstone before referred to as

existing in Montgomery county. This sandstone is found at a number of places along the Nishnabotany and its tributaries, in this county. Thus far it has been also seen in the southeastern part of Pottawattamie and the northeastern part of Mills counties. It seems to lie in detached masses, or outliers, rather than as a continuous formation, and the greatest thickness yet observed is thirty feet. Half a mile below Lewis, the county seat of Cass county, it is quarried to a considerable extent. The stone is soft when first taken from the quarry, but hardens upon exposure to the atmosphere. It is of a brown color, and in ordinary buildings presents a sombre appearance. There are certain styles of architecture, however, in which this color would not only be unobjectionable, but agreeable.

The upper coal-measure limestone is found along the creeks near the border of Montgomery county, and also along the Nishnabotany and its branches. The supply of limestone in the vicinity of Lewis is abundant, and the quality good both for building and the manufacture of lime. The western part of the county is quite well supplied with timber, but there is a deficiency of fuel in the eastern part.

No coal has yet been found in this county, but it is not improbable that the bed now worked near Quincy in Adams county, and also in the northeastern corner of Montgomery county, may be found to exist in this also. Should this be the case it will probably be found no thicker, if so thick as it is there.

ADAMS COUNTY.

Adams, like all other counties of the "Missouri slope," is a well-drained, yet a well-watered county; the drainage being effected principally by the West and Middle Nodaways and their tributaries, which also furnish excellent water for stock; and in addition to this the two rivers furnish a number of good mill privileges. Good wells are obtained at a moderate depth in all parts of the county; it has fully an average supply of timber, a considerable supply of stone, and more coal which is now accessible than any other county to the westward of or adjoining it. Its soil is also of the same excellent quality which prevails in this part of the State.

If the county be divided through its center from north to south the advantages of its resources are found to be singularly in favor of the

western half, for although the eastern half possesses an excellent soil, a little timber—which is principally along the Nodaway—and good water, yet the western half has, in addition to these, a very good supply of timber, and all the coal and stone yet found in the county, as well as all the valuable water power. The valleys of the Nodaways are narrower in this, than in the counties of Page, Taylor, and Montgomery, but they are yet beautiful and fertile. The timber is rapidly encroaching upon the prairies from the borders of the streams, because the inhabitants keep the fires out in protection of their farms. Stone, good enough for ordinary purposes, is found in every township of the western half, and coal is mined at intervals along the West Nodaway from Harader's Mill, three miles north of Quincy, to about the same distance below the town, on land owned by the Drs. Rawson of that place.

Near the middle at the crossing of the river, two miles westward from Quincy, several openings have been made and considerable coal taken out. Near this place Messrs. Barnett and Smith have sunk a shaft to a depth of about forty-five feet below the bed of coal they are now working with the hope of finding a still lower bed. They have for the present discontinued their work upon it with the intention of resuming it. Such an enterprise is not unreasonable, although undertaken without any previous experience in that direction in this part of the State, for the bed they are now working is the same one which is worked in Taylor, Page and Montgomery counties, and the only bed yet discovered upon the "Missouri slope," south of the north line of the third tier of counties. This bed of coal also, as well as all the other strata which appear in Adams county, belong higher in the series than the productive coal-beds along the Des Moines river. As yet, however, we have had too little experience in our own coal-field to give positive encouragement to these gentlemen to continue their work, although it would be perfectly in accordance with the principles of geology to do so, taking the hazard of those beds having thinned out before reaching so far westward. Should these lower beds exist there, it is not believed that they lie at an impracticable depth, but this is a question which must be decided after further investigation.

The people of this county give evidence of much thrift and public

spirit, and even the eastern half possesses many bright spots, made so by the strong hand of honest toil, the society of which would shed lustre and benefit on any part of the older States.

ADAIR COUNTY.

Adair County lies directly upon the dividing ridge between the watersheds of the Mississippi and Missouri rivers. It is in this county that Grand, and the East, and Middle Nodaway rivers have their rise; and North and Middle rivers are small prairie streams where they enter its borders. The surface of the county is almost entirely prairie, for its streams are all small, although called "rivers," and as is usually the case with small streams in this part of the State, very little timber is found along their borders. There is, however, a sufficient supply of fuel of this kind for the present inhabitants.

The drainage of the county is perfect, and yet there is no difficulty in getting water for stock from the numerous streams, and for domestic use, from wells and springs. The surface is more deeply cut by the streams and their tributary branches and ravines than one would expect to see in a regions lying upon a "divide," which gives an unevenness of surface, which near the streams is too great for convenient farming.

The soil however, is everywhere good, as in the neighboring counties, and this broken region will afford excellent pasturage for sheep, either with the wild, or cultivated grasses.

The only stone found in the country — except the drift boulders — appear along Middle River, at frequent intervals from about three miles south of the northern boundary, to where the river enters Madison county, about the middle of the east line of Adair. At various points near the river in township 76, range 30, almost any desired quantity of limestone can be obtained, which for making lime, and for the purposes of ordinary masonry, is very good. Near the heads of Grand River a number of large boulders, quite large for this latitude, are to be seen, the home of which, as almost every one knows, is far to the northward.

On section 22, township 25, range 32, a dark carbonaceous matter was found by the citizens exposed in a small branch of the Middle

Nodaway, and a shaft of a few feet in depth was sunk down to it from the bank.

This, at the time of my visit, was partly filled with water, the work having been discontinued. By bailing it out with a bucket, a view of the bed was obtained and some specimens secured for further examination. It has the appearance of impure coal, but lacks the characteristic angular fracture of bituminous coal. No specimens have yet been obtained beyond the action of the atmosphere and frost, and when worked farther beneath the hill it may prove to be a valuable article of fuel, particularly in a region where timber is so scarce.

It is possible that this is the northern extension of the bed now worked at Quincy and elsewhere. If so, it may prove more valuable than present appearances would indicate, beside which, it is thicker here than the Quincy bed has yet been found.

UNION COUNTY.

With the exception of half-a-dozen square miles of the extreme northeast corner of Union, which are drained into Clanton's fork of Middle river, the whole of Union county lies upon the Missouri watershed, and is drained principally by Thompson's fork of Grand river. Highland, near the center of the county, is the highest land between the Mississippi and Missouri rivers on the line of the Burlington and Missouri River Railroad, being twelve hundred and eighty-seven feet above the level of the Gulf of Mexico, and eight hundred and one feet above low water in the Mississippi river at Burlington. The county is of the same size and shape as Adams, which borders it on the west, and if divided through the center from north to south the west half would be found in all respects similar to the eastern half of that county in its prairie surface, being sparsely supplied with timber, and also in containing no quarry rock. The eastern half contains a considerable amount of timber along Grand river and its tributaries, and from the vicinity of Afton to the southeast corner of the county, good quarry rock may be readily obtained at frequent intervals. This rock is of good quality for building purposes, and the greater part of it will make excellent lime, of which necessary material the inhabitants of some portions

of the neighboring counties obtain their supplies from this. The soil of Union is excellent, and practically identical with that of all those which adjoin it upon the southward and westward, being covered like those counties with a heavy deposit of drift material.

All the stratified rocks found in this county belong to the upper series of coal-measure strata, so that there is little hope of finding a workable bed of coal above the level of its deepest valleys, unless the bed now being worked in Adams county shall be found to extend into this. Even then it would probably be found to be very thin. There is hope, however, that coal may yet be found at an available depth beneath the surface.

It was observed that fruit-trees grow thriftily in this county, wherever they have been planted, and Mr. John C. Wicks, who lives a few miles south-east from Afton, has succeeded admirably in cultivating the principal fine varieties of grapes, of which he has a flourishing little vineyard.

This, like the neighboring counties, beside being well watered by its streams furnishes wells of pure, cold water, wherever the necessities of the inhabitants require them to dig one.

The number of inhabitants is rapidly increasing by settlement, attracted hither by the natural advantages which the county affords, and also those in the immediate future to be derived from the early completion of the Burlington and Missouri River Railroad, which is to pass westward nearly through its centre, and will soon place its inhabitants in direct communication with both the Atlantic and Pacific sea-boards.

MADISON COUNTY.

The upper coal-measure series of strata are more fully developed in this, than in any other county yet examined, and in the deeper valleys. The general dip of all the strata is found in the southern part of the State, to be nearly or quite coincident with the fall of the streams. But in the "Three-river country," as that region has been called, which is drained by South, Middle and North rivers, the drainage is to the eastward. Consequently in that portion of the region toward the drainage of the Racoon fork of the Des Moines, one would expect to find the lower series of coal-measure strata

nearer the surface than they are farther to the southward. This is actually the case, and although along Middle river from the middle to the western part of the county, the upper series is in full force, before reaching the north-eastern part of it, they have nearly or quite disappeared, and the strata of the middle series only are seen. These well-developed features of the geology of Madison county are not only of great interest within its own borders, but the facility afforded here for observing so complete a series, necessarily makes the results of such observations the standard of comparison for similar investigations over the whole region occupied by corresponding strata

The subject of coal in this county has received as much attention as it was possible to bestow upon it, the results of which have thus far, been only partially satisfactory. From the mud-sill of Compton's mill on Middle river, one and a half miles southward from Winterset, to the level of the town plat, is about two hundred and thirty feet in perpendicular height. The upper fifty feet of this is composed of soil, sub-soil and drift material. The remainder, except the stratum upon which the mud-sill of the mill rests is at present all referred to the upper coal-measures, the lowest stratum probably belongs to the middle coal-measures, although at first supposed to belong to the lower.

The following is a section of the rocks exposed in the valley of a small creek a little southward from Winterset, numbered from the top downward, omitting the fifty feet of drift which covers the whole and which forms the surface deposit of the region around.

SECTION OF THE ROCKS NEAR WINTERSET.

No. 1.	Thin bedded yellowish limestone	1	foot.
No. 2.	Light-bluish marlite	4	"
No. 3.	Gray, massive limestone with dull fracture	6	"
No. 4.	Gray, regularly bedded limestone with concholdal fracture	12	"
No. 5.	Black, laminated, carbonaceous shale	2	"
No. 6.	Gray limestone with marly partings like No. 4	34	"
No. 7.	Black shale like No. 5	2½	"
No. 8.	Regularly bedded gray limestone with many cherty layers	15	"
No. 9.	Compact limestone with concretionary structure	2	"

No. 10.	Limestone of varying quality — in some parts siliceous and same of the interestitial material micaceous and finely arenaceous	16½ foot
No. 11.	Impure coal	½ "
No. 12.	Light blue marlite	2 "
No. 13.	Bluish, concretionary limestone, breaking readily into small fragments	5 "
No. 14.	Bluish and reddish clays	6 "
No. 15.	Sandy, micaceous shale, with fine grained micaceous sandstone in thin layers of bluish and greenish colors	71 "
No. 16.	Bluish, shaly, impure limestone seen in the bed of the river at Compton's mill	2 "
		181½ feet.

As one goes from the town to Compton's mill, on Middle river, two miles southward from Winterset, he passes down through each successive stratum, as it were, the small stream along which the road runs having, in former ages, worn its valley through them, leaving the edges of the firmer ones appearing at intervals in the sides of the hills, while those of softer material are obscured by disintegration.

By digging down beneath the stratum No. 16 at several places in the vicinity, a very thin seam of coal was found. Thus it will be seen that although two coal horizons exists in the series of rocks exposed here, besides the two beds of carbonaceous shale, there is little hope of finding a workable bed of coal near Winterset, above the level of Middle river.

Going twelve miles northward from Winterset, in which direction as before said the upper strata disappear, the bed numbered 16 is found exposed in the right bank of the north fork of North river, and thirteen feet of bluish shale underlaid by a bed of coal, all appearing beneath it.

Working of the coal was suspended at the time the locality was visited so that only one and a half feet of its thickness was seen. Mr. George Clarke, the owner of the property, reports the coal to be two and a half feet thick, which no reason was seen to doubt. Some twelve miles southward from Winterset, at and near Anderson's mill, on Clanton's fork of Middle river, the same bed is recognized, but it is there only eight or nine inches thick.

These, so far as known, are the only exposures of coal yet found in Madison county, but since the productive coal-measures lie beneath all the strata found in this county, there is a reasonable hope that an abundant supply may be obtained by sinking shafts. These should of course be commenced in the valleys because they are already cut out of the strata which must be bored through before reaching the level of the streams if commenced on the high lands. It is believed that coal would be reached within one or two hundred feet from the valley bottoms, but no exact estimates can yet be given.

The beds No. 5 and No. 7 being a black carbonaceous shale are often regarded by the people as an indication of coal, but although they are often found associated with coal-beds, yet their presence is of no value for such purposes.

At a number of places in the vicinity of Winterset, bed No. 3 of the preceding section furnishes unusually fine, massive blocks of grey limestone which are largely used in that region for building purposes, and dressed blocks of it have also been carried as far as the capital on common wagons.

The time will soon come when the counties which adjoin this upon the south and west at least, will require facilities for obtaining the stone which is so abundant along all the rivers of this county. The other beds of limestone beneath the massive one just mentioned also furnish immense quantities of stone for lime, and for ordinary masonry, while there is enough broken stone in the beds of its streams alone to McAdamize all its roads.

Timber of excellent growth and quality is also so abundant along the streams as to make it desirable to check rather than encourage its encroachment upon the prairies. These streams afford good water, and upon the larger ones are numerous valuable water privileges, many of which are improved by the erection of substantial woolen, flouring and saw mills.

The quality of the soil is not surpassed anywhere, and the general aspect of the county is one of unusual beauty. The monotony which often accompanies prairie views is here completely relieved by gentle undulations, and the wooded hillsides and valleys.

SALT.

The following article was written and published in the newspapers as a reply to numerous enquiries by letter from different parts of the State as to the prospect of finding salt in Iowa in paying quantities, particularly in Davis county, where "saline lands" have long been understood to exist:

By the word salt, we invariably mean in common language, what the chemist invariably means by "chloride of sodium," and no one misunderstands us. But he uses the same word in a far more extended sense than we, and makes it signify any substance which results from the chemical union of any acid with any base. Consequently he has almost an infinite number of different salts, some of which readily dissolve in water, but many others are as insoluble as the rocks themselves; and a part of these are indeed nothing more or less than chemical salts. Thus nature also produces, in her chemical laboratory, both soluble and insoluble salts; that is, soluble or insoluble in water. The most abundant of the latter is limestone; of the former, *salt*. Further on, water saturating the earth under certain circumstances will be mentioned. This, all will understand. We shall also speak of water being saturated with salt. This is the chemists' use of the word, and signifies in this instance, water having dissolved all the salt of which it is capable, when any more being added would fall to the bottom and remain there undissolved. When water is fully saturated, it contains about 36 per cent. of salt, whether hot or cold.

In writing upon subjects related to chemistry, one is often obliged to make use of some of its technicalities; hence these few words of explanation. The sea, as every one knows, is the great repository of common salt, but perhaps every one does not know, which is really the case, that sea water also holds in solution many other salts besides this, but in very much smaller proportion. These are almost the sole cause of the impurity of all salt artificially manufactured from sea water. When good salt is produced from sea water, as is now the case on Turk's Island and many other parts of the world, it is by a natural purifying process of crystalization, resulting from the slow evaporation of the water by the heat of

the sun, which affords time for the chemical separation of the other salts, which is only partially accomplished by the artificial process. All the salt obtained as such, from the mines of different parts of the world, are believed to have been originally produced from sea water by a natural process, similar to the one referred to, at a time when the place which the deposit now occupies, formed a broad shallow lagoon near the shore of a then existing sea, and with which it communicated at full tide. As the sea receded, by the ebb of the tide, evaporation of the shallow water of the lagoon continued without interruption, leaving behind a greater amount of salt than served to saturate it. This excess of salt constantly increased, because nothing but pure water passed off as a vapor, and because every returning flood of the tide brought more salt as well as more water, until the lagoon was filled with salt, and would receive no more water from the sea. This process may now be observed in several parts of the world, and should some geological change of the earth's surface take place, as they have taken place in past ages, to bury these salt deposits beneath the earth, the salt there would be in the same condition as that of the mines of England, Poland, and other parts of the world. Thus we see that the salt of mines, although deep within the bowels of the earth, has doubtless been derived from the sea, or from an inland salt lake where it has accumulated by a process presently to be described. But notwithstanding this fact, the original home of the salt is in the earth, and not in the sea, for it is believed that all the water upon the earth once existed in the form of vapor diffused in the atmosphere surrounding a red-hot world, and vapor can contain no common salt.

After the surface had cooled sufficiently to form a crust, the vapor began to condense; and these first rains were as fresh, so far as containing common salt is concerned, as those which fall upon our heads to-day. The first seas were formed by the rains, in the depressions which they found upon the surface, and their waters were comparatively fresh, for nearly all the soluble salts, (of which *salt* is the chief,) or their chemical constituents, were yet disseminated in the substance of the earth. A still further cooling of the earth's crust, and disintegration of its substance, admitted free

percolation of the water which fell upon its surface and which in its passage again to the sea, took up the soluble salts with which it came in contact in its terrestrial passage, in addition to those which may have existed in the bed upon which the sea was formed. Thus the sea has derived all its salt from the earth by a process of leaching similar to that by which the frugal housewife obtains potash-lye in the domestic manufacture of soap. Thus its waters have constantly increased in saltness from the earliest to the present time; for the rivers of the world are even now carrying down salt to the sea, although the amount of their water is proportionally so great that it is perceptible only by the most careful analysis. The immense amount of fresh water constantly poured into the sea does not diminish its saltness by dilution, but on the contrary, constantly increases it by addition of salt, while the same amount of water which the rivers bring, is returned to the earth again by evaporation.

Whenever the relative positions of sea and land have been changed, and such changes have been many in past geological ages, every lake which may have resulted from the elevation of land from the bottom of the sea, was as salt when it was first formed, as the sea from which it derived its waters; but when such a lake had an outlet, the accumulation of waters beyond and around its surface by drainage, soon rendered it as fresh as the streams which emptied into it. But where such a lake or inland sea has no outlet, the surface would rise or fall to a level at which the evaporation just equalled the supply of water, which level would have no necesary relation to that of the great sea, which is also determined by the same law. Such a lake would increase in saltness from the same cause that the sea has done, but more rapidly if the area drained into it contained more than the average amount of soluble salts. When the salt in the water of such a lake had increased to the degree of saturation, it would commence to be precipitated, and form upon the bottom, a bed of crystalline salt. This is actually the case in Great Salt Lake, as well as in others. But still other salt lakes and inland seas have not yet reached this point of saturation, and they consequently precipitate no more salt than the great sea does. Should Great Salt Lake is future geological times become buried under other strata of the earth, its bed would be a subterranean

deposit of salt, similar to some that are now known, which, doubtless, had a similar origin, if they did not originate in lagoons as before described. The salt of such a deposit might never have had, either directly or indirectly, any connection with the sea, any more than the salt of Great Salt Lake has had.

Although the earth, and not the sea is the original home of the salt, yet in the various elevations of the land above the sea, composed of strata which were formed there, or of the muddy sediment of marshes which existed upon its borders, it was impossible that they should not have retained within their substance some of the salt of the water with which they have been constantly saturated, and in this sense some of the salt disseminated throughout the substance of the earth, may be said to have been derived from the sea. Now when these strata, which are always more impervious to water vertically, than horizontally, were elevated, they were almost never left in the horizontal position in which they were deposited, but in the movement of elevation were more or less tilted, so that drainage by percolation could take place throughout the mass in the direction of the interstices between the layers, and the greater part of the salt they may have contained was thus really carried back to the sea again. But suppose a series of such strata, composed, as is usually the case, of material, alternating, more and less impervious to water, to have been elevated in such a manner that their dip around the whole area which they occupied should be toward the center, and they resting upon each other like a pile of saucers in the dish-pan of the housewife with the water between them. In such a case all the saline substances they may have contained at the time of their elevation would remain there just as the water would remain in the saucers if carefully lifted from the pan. Water would indeed penetrate the mass by percolation from the surface but find no channel out, would escape only by the ordinary process of evaporation from the same surface, leaving all the saline matter behind. Consequently upon boring down through the mass, water would be obtained in those strata which are most permeable by it, and this would be found to be salt water. Such a condition of strata actually exists, occupying nearly the whole southern peninsula of Michigan, as was first pointed out by Prof. Alexander Winchell, the State Geologist, to the

correctness of whose predictions in relation to the abundance of salt his State would soon produce, every market in the country now gives ample testimony.

The salt of the Michigan brine may never have existed in the crystalline form since it was first leached into the sea from the place of its original distribution, but brine is sometimes obtained from the earth which has probably derived its salt from such deposits as have just been referred to, in its passage through them beneath the earth. Such deposits are sometimes found containing so much earthy admixture that to obtain the salt in an available form, fresh water is artificially added to produce a brine, from which it is then manufactured in the usual manner. Thus we see that the present distribution of salt in the earth has originated from a variety of causes. It, or its component elements were originally disseminated throughout the substance of the earth, the greater part of which has been carried to the sea by a leaching process of nature; that the stratified rocks have salt also disseminated through them as a result of saturation by the sea water in which they were deposited; that it exists also in the earth as an accumulation of brine; as subterranean deposits of crystalline salt derived from ancient lakes, lagoons and marshes, and finally as brine formed from such deposits by the percolation of fresh water through them. It is only by the three latter methods that a sufficient accumulation has taken place in the earth to render its production possible in such quantities as our necessities require.

The question then very naturally arises: have we in Iowa any evidence of the existence of deposits of salt, or of a condition of the strata which would retain the brine of the sea in which they were deposited? As regards deposits of salt beneath the surface of our State, while we have yet no evidence that any such exist in the crystalline form, we certainly have none that they may not yet be discovered. There are springs in different parts of the State, the waters of which contain small quantities of salt, but so far as I am yet aware, these are all confined to those regions underlaid by coal-measure strata. It is possible that this salt is derived from crystalline deposits of that material, but we have yet no evidence of the existence of them. If the coal with some of its associated strata

were formed in broad marshes in close connection with the sea level, as is generally believed, then we may infer that the salt of the coal-measure strata of Davis county was derived from that which was then freely distributed throughout those marshes. Whatever may have been its origin, the reason that it remains in those strata may be due to the fact that while the general dip of all the strata of the State is to the southward; there is also a slight counter dip to the westward in the southeastern part, forming at least two sides of a very shallow depression in the strata (not in the surface), which may have served to collect the saline matters of the strata there into that region, of which the northeastern part of Davis county may probably be a centre. Some of these waters have been analyzed, and proving to contain less than one per cent of salt the prospect of obtaining it in paying quantities is not now encouraging. Yet, as before intimated, there are no positive reasons why it may not exist in such quantities in our State.

SECOND ANNUAL REPORT

OF

CHARLES A. WHITE, M. D., STATE GEOLOGIST.

To His Excellency, William M. Stone, Governor of Iowa:

SIR: I herewith transmit to you my second annual report of progress of the State Geological Survey, together with copies of reports of Mr. O. H. St. John, Assistant, and Prof. Gustavus Hinrich, Chemist.

I also herewith transmit, as a part of my report, copies of fourteen letters in relation to the geological work, which I have prepared and published from time to time in the newspapers of the State, in accordance with the provisions of law. Accompanying these are also copies of a number of letters prepared and similarly published by Professor Hinrichs and Mr. St. John.

Immediately after my first annual report of progress to you, I commenced the arrangement and study of the collections made during the previous season, and also the preparation of papers upon subjects connected with the State Geologica Survey, for publication in the scientific journals. These were duly credited to the survey in the imprint of their titles, so that the State should receive credit for the priority of investigation and discovery, which would otherwise be in danger of loss by delay of their publication in our final report.

On the 15th of March I was joined and assisted in these labors by Mr. St. John, whom I had previously appointed Assistant.

The opening of spring being later than usual, no field-work was done until the 16th of April. Intending to devote the greater part of the year's labor to the investigation of our resources for fuel, this work was commenced on that day in Mahaska county, and continued until the 6th of May, embracing the examination of the coal deposits of the greater part of the counties of Mahaska, Monroe, Jefferson and part of Wapello.

It being then necessary to commence field-work in the western part of the State where it was left at the close of the previous season, preparation was made to proceed thither with the appropriate outfit. At this time I received a proposition from the eminent naturalists, Mr. F. B. Meek and Dr. Theodore Gill, both of the Smithsonian Institution, and both also connected with the United States Geological Survey of Nebraska, to accompany me across our State to Nebraska, review on the way a part of my last season's field-work, and meet Dr. F. V. Hayden, Director of the Nebraska Survey, at Nebraska City, to compare notes,

and if possible, to arrive at some estimate of the depth at which the equivalents of the productive coal-measures lie beneath the unproductive strata exposed along the Missouri river. This proposition was very gladly accepted, especially since the first-named gentleman is probably better acquainted with the geology of the Missouri river region than any other person living.

Accordingly upon the arrival of Mr. Meek and Dr. Gill we all started in company from Iowa City on the 22d of May, and arrived in Nebraska City on the 6th of June, where we were joined by Dr. Hayden. We made some satisfactory estimates of the aggregate thickness of the strata exposed within the limits of Iowa, but judging from exposures found by those gentlemen in Nebraska and Missouri, it seems probable that there is a thickening of the strata to the westward, which the Iowa exposures do not reveal, so that the equivalents of the productive coal strata which are seen along the Des Moines river, lie deeper beneath the surface along the Missouri river than would have been inferred by an examination of Iowa rocks alone.

Circumstances obliged me to suspend the investigation of this important subject, but I still think it reasonable to expect to find coal there at less depth than that at which it is successfully mined in some other parts of the world.

Parting with our distinguished friends at Council Bluffs, I placed Mr. St. John in charge of the work in the western part of the State, assigning to him for examination that portion of the fourth, fifth and sixth tiers of counties which lies between the Missouri and Des Moines Rivers. He has prosecuted his labors with an earnestness and zeal which can only be inspired by a love of science; and I am much gratified with the careful and able manner in which he has performed the work assigned him. I respectfully refer you to his report of progress to me, a copy of which is herewith submitted.

Returing to Iowa City, I accompanied Prof. Hinrichs to the lead-mines of Dubuque, for the purpose of obtaining material and information in regard to the mode of occurrence of those ores, and the methods in use for smelting them. Although our stay there was brief, the results obtained were of much interest and value.

Resuming the fuel investigations, I visited all the operated mines in the counties of Marion, Wapello, and Van Buren, entering and examining them in person, and collecting authentic specimens for analysis.

The dryer part of the year having arrived, I made the necessary preparation, and in the latter part of August went to the northern part of the State to examine the country for peat, directing attention principally to the counties of Franklin, Wright, Cerro Gordo, Hancock, Worth, Winnebago and Kossuth. Very large quantities of this valuable fuel exist in those counties, as will be seen by reference to the accompanying letters.

Those examinations were continued until the commencing cold weather made it hazardous to health, when, returning by way of Ft. Dodge, I met Mr. St. John there with his camp, and together we spent the greater part of two weeks in the examination and mapping of the large gypsum deposits of that region.

Pleasant weather continuing later than usual in the autumn, both Mr. St. John

and myself made frequent excursions to such points as it seemed most desirable to examine. Among these excursions were visits to important peat marshes in the counties of Muscatine, Linn and Clinton.

The usual winter work is now in progress, the results of which promise to be of increasing interest and importance.

I beg to call your especial attention to that portion of the report of the chemist in which he describes his methods in the cheminal analysis of coals, which he claims to be new and eminently practical.

It will be seen that thus far the work of the survey has been one of general reconnoissance rather than of detailed field-investigation, and much of such general work yet remains to be done. It is necessary to ascertain the geological structure of the northwestern portion of the State, and to make further general examinations in the coal and peat regions. After this the details of our geology should be fully investigated; especially should we know with the greatest possible accuracy the minute geological structure of our coal-field, for upon this knowledge depends the intelligent prosecution of mining operations, and the consequent avoidance of useless expenditures of money and labor which will otherwise be sure to occur.

Application will be made to the Twelfth General Assembly for a sufficient appropriation to prosecute the work to a successful completion. The people everywhere evince a lively interest in the success of the survey, and their uniform kindness to its officers is a constant source of gratification.

Very respectfully, your obedient servant,

CHARLES A. WHITE,
State Geologist.

Iowa City, Iowa, January 3, 1868.

REPORT

OF

O. H. ST. JOHN, ASSISTANT STATE GEOLOGIST.

To Dr. C. A. White, *State Geologist:*

Dear Sir: In accordance with your instructions, I have prepared and herewith submit the following report of progress of the field-investigations under my charge during the past season.

In compliance with your instructions, on the 13th of June last I began the preliminary survey of that portion of the State comprising the fourth, fifth and, in part, the sixth tier of counties lying between the Des Moines and Missouri rivers. One of the principal objects of this reconnoissance was to ascertain with as much accuracy as possible in so short time, the extent and character of the coal-field in the region embraced in this geological district. With this view, I made a journey from Council Bluffs up the valley of the Missouri, through Harrison, Monona and Woodbury counties to Sioux City; thence we passed into Crawford, Shelby, Audubon, Carroll and the southern portion of Sac county. The above enumerated counties, with the exception of the eastern portion of Carroll and Sac counties, lie wholly upon the Missouri water-shed, and present a variety of physical features which one would hardly suspect from a casual glance.

Few rock exposures occur in the above-named counties; however, there are localities which supply a very fair quality of stone for all the ordinary porposes of construction. It is believed, further, that the manufacture of bricks for building may be successfully undertaken in almost all localities; so that, after all, the scarcity of good building-stone in most places will scarcely be noticed, much less can it ever have a detrimental influence in a region so highly favored in other respects.

In the region about Sioux City good quarry rock is obtained from the lower members of the cretaceous deposits there exposed; and a fair quality of quicklime is manufactured from the upper chalky beds known among geologists as the *Inoceramus beds*, from the prevalence of this shell in this horizon. In the immediate neighborhood of Sioux City, at Sargent's Bluffs, and at Bruguier's Bluffs, and above on the Big Sioux River, the lower members of the cretaceous are beautifully exposed, enabling us to construct a complete section of these rocks of above one hundred and thirty feet in vertical thickness, and which were studied in as much detail as the limited time at my disposal would permit. On the Boyer, in Harrison county, limited exposures of strata belonging to the upper

coal-measures also outcrop, and are quarried to some extent in the vicinity of Reel's mills, on the line of the Chicago & Northwestern Railway. At other points in Harrison and Monona counties, a tufaceous deposit occurring near the base of the "bluff formation," affords a durable material for underpinning, &c. Also in other parts of these counties the modified drift affords limited exposures of a more or less coarse ferruginous conglomerate, and considerable quantities of lower Silurian limestone boulders, gneissoid and quartzose boulders are met with, particularly upon the broad upland ridges in Ida, Crawford, Carroll and Sac counties.

What most strikes the observer, traveling over these prairies, is the unusual development of the post-tertiary deposits, affording him one of the most interesting fields of research. An extensive and intimate knowledge of these later geological deposits —comprising the glacial drift, the sands and coarser materials of the modified drift, the fine class of the bluff and finally the thick accumulation of soil at the surface— would have the most direct and practical bearing upon the development of the agricultural resources not only of this particular section, but of the State generally. Throughout this region the soil is unsurpassed in fertility, and the very numerous water-course affords a perfect system of drainage, thus furnishing a satisfactory explanation for the remarkable infrequency of wet, untillable land.

The heavy deposits of drift, &c., which so extensively prevail and to a great extent conceal from view the underlying rock formations in the counties mentioned in brief above, offered insurmountable obstacles to the successful examination of the carboniferous strata which are supposed to underlie a large portion of that section of the country. Therefore it became a matter of greatest importance to explore the country lying to the eastward, or between the grand divide and the Des Moines river, that the necessary data might be sought by means of which to enable us to arrive at some satisfactory conclusion regarding the nature of the strata in the region to the westward. Commencing these explorations in Green county, I first made a tolerably detailed examination of the valley of the North Coon, and subsequently its two principal tributaries, the South and Middle Coon rivers, and their numerous affluents in Guthrie, Dallas and Polk counties, The first exposure of unequivocal coal-measure strata is found in the southeastern part of Green county; and thence along the North Coon to the confluence of the South Coon, the bluffs which continuously border either margin of the valley, afford quite extensive and very satisfactory exposures of the coal-measures, consisting of sandstones, arenaceous and argillaceous shales, occasional layers of limestone, and two or three thin beds of coal, which latter are being worked at numerous points in the valley.

The South and Middle Coon valleys also contributed valuable data. In the region bordering upon the lower reaches of these streams, we recognized a set of beds which attain a thickness of about two hundred feet, and which hold a position intermediate between the coal-bearing strata, of the Des Moines river region and the upper coal-measures, which latter series you saw-admirably defined during your investigations the first year of the survey in Madison county and

the southeastern portion of the State. This middle series of strata is composed of thin beds of sandstone, sandy shales and variegated clays, impure limestones always in comparatively thin bands, and sometimes wanting wholly, carbonaceous shales and coal. There are three distinct and constant coal horizons, which separate or sub-divide the lines into as many lithologically well-marked groups. But the palæontological characters bind the whole together, as it was, and indicate a nearer alliance to the lower coal-measures — as we at present understand that series — than they do to the upper measures, from which latter it is quite distinct in its lithological features also. The three beds of coal above mentioned are mined with considerable success at the present time in both Guthrie and Dallas counties, and the quality of the coal is usually excellent, although the beds are very thin, possessing an aggregate thickness not above four feet. The productive or lower coal-measures lie beneath at variable depths, and can be reached, doubtless, by ordinary shafting at most any point in these counties at a depth of two hundred to three hundred feet, and in valleys at a much less distance below the surface. Indeed, at Redfield, in Dallas county, where a bed of coal nearly three feet thick, which outcrops in the banks of the Middle Coon, and is overlaid by a thickness of at least forty-five feet of sandstone, and which, it is believed, is equivalent to the coal seen at Des Moines. This bed has, therefore, been upraised so as to occupy about the same elevation above the level of the Middle Coon at Redfield as it does above the level of the Des Moines river at the Capital. And the intervening country forms a broad, shallow synclinal, the axis of which has apparently a northerly and southerly direction. Hence it is that at the South and North Coon rivers, there occur beds which belong pretty well up in the middle series, or to its middle groups of strata.

As we ascend all three of the Coon rivers, to the northward, we encounter sandstones and clays, and ferruginous grits, in Guthrie, Carroll and Greene counties, the equivalency of which have as yet not been satisfactorily determined. And in carrying on these examinations up the beautiful little valleys of the tributaries of the South Coon, in the southern portion of Guthrie county, the westward dip of the strata has brought down the lower members of the upper coal-measures almost on a level with the valley of Deer creek; but before we have gained the headwaters of Beaver creek, whose course is nearly parallel with, and only two or three miles north of the former stream, the strata have again been upraised, so that in the vicinity of Mr. Mann's and Mr. Cleman's, in Townships 78 and 79, Range 31, W., we are again brought in contact with familiar horizons, long since recognized at Vanmeter's, a few miles above the mouth of South Coon, and also near Adel, on the North Coon, &c. We need no more conclusive evidence to prove the irregularly and gently-undulating character of the strata in this section. The most easterly indication of one of these broadly swelling-anticinals, in connection with the middle series of coal-measures, is seen in the bluffs which border the north side of the Coon river, a few miles above Des Moines, and in the region to the southward, in Warren county. Beyond this line of outcrop — eastward — not a vestige of the middle series has thus far been detected.

The importance, I may say the necessity, of a thorough and well-sustained

exploration of the area occupied by this most important mineral product within our borders, must be apparent to every intelligent person; for, I believe, we shall be able, when once the details of the structure of our coal-measures shall have been fully worked out, as has been done in other states, to estimate the depth at which a certain bed of coal may be found at any given point, with almost as great accuracy as we measure up the bared face of a river bluff in order to ascertain the thickness of the strata therein exposed. However, much still remains to be accomplished in this section of the State, before the work shall have attained that degree of perfection which shall contribute largely to the economic interests of the State, and merit the commendation of the public.

During the summer my friend Mr. J. A. Allen, of the Museum of Comparative Zoology, Cambridge, joined my party, with the view of studying the Natural History, particularly the Ornithology and Botany of the State; and to this end he made valuable collections of objects of natural history, and I doubt not he will cheerfully, at the proper time, prepare his observations in a form which shall receive the highest approbation of our people.

It would be superfluous to extol the merits of a region so well and favorably known already, as that comprising the four or five eastern counties of the district herein mentioned. And it is with grateful acknowledgements I return my sincere thanks for the many courtesies my party received at the hands of gentlemen in all parts of the District.

On the 8th of October, in compliance with your request, I discontinued the work in the counties west of the Des Moines, and joined you on the 10th, at Fort Dodge.

Very sincerely and respectfully,
Your obedient servant,

ORESTES H. ST. JOHN.

IOWA CITY, 28th Dec., 1867.

POPULAR LETTERS

OF

THE STATE GEOLOGIST

FOR 1867.

SURVEY OF COUNTIES.

MAHASKA COUNTY.

The principal object aimed at in these partial examinations of Mahaska, Marion, Monroe, Wapello, Jefferson and Van Buren counties, was to place before the public reliable information in relation to the mineral resources of those regions, that those who were contemplating the investment of capital in public improvements, manufactories, or other enterprises, might know the advantages our State affords.

The largest part of the labor performed was in the examination of the mines and outcrops of coal. The mines were all entered and examined in person, specimens from different parts of the bed collected for analysis, and notes taken of its thickness and general character.

The St. Louis limestone (sub-carboniferous) is found cropping out near the bottoms of the valleys of the Des Moines and Skunk rivers, as well as some of their tributaries. Thus it is known that all the coal of the county, which is immense in quantity, will be found in the high lands above the level, at least of the Des Moines river, because it is useless to search for coal beneath the limestone of this region; so that no very deep mining will be necessary to reach all the coal that the county contains. That which is now mined is reached by drifting into the sides of the valleys of the rivers, creeks and ravines.

In the north part of the county, near the confluence of Buck creek with the north branch of Skunk river, several mines have been opened in a four-foot bed of coal, and many more may without doubt be opened there whenever the demand will warrant it. Along Spring creek, from near its confluence with South Skunk river to

within a mile or two of Oskaloosa, several mines have been opened, the coal of which ranges from four to upward of five feet in thickness. On this creek there is reason to believe that two good beds of coal exist, the one beneath the other. There is no doubt that large quantities of coal exist along this creek, which may be readily mined by drifting into the beds at their out-crop or approach to the surface on each side of the valley.

Around the outskirts of Oskaloosa several mines were visited the beds of which varied from three and a half to five and a half feet in thickness, and there is no doubt that the whole city is underlaid by a good bed of coal at a moderate depth. At Oskaloosa Station, on the D. V. Railroad, two and a half miles from the city, the thickest bed of coal is worked yet known in the State. It measures from five to nearly eight feet thick of solid and good coal. Messrs. Roberts & Co., and the Iowa Coal Company of Keokuk, both have mines in operation in this bed near the station, and the coal in their mines will probably average six feet in thickness, and in several places it reaches seven and a half feet thick. They are conveniently ocated in relation to the railroad, having car-tracks laid from the railroad platform all the way into the rooms where the mines are working. The coal cars are drawn all the way into the mines by mules of ordinary size without difficulty. Two thousand five hundred bushels daily are shipped from these two mines, beside a considerable quantity of coke, of good quality, which they have lately commenced preparing for shipment.

Several other openings have been made within a few miles of these, and the coal found to be as thick as in the two mines just mentioned. All along the line of the Des Moines Valley Railroad, and of the proposed Iowa Central Railroad, between Oskaloosa and Eddyville, there is an abundance of coal which may be readily made accessible for shipment upon those roads, both near their main tracks, and by running branch tracks up the branches of Muchekinock creek, and opening mines on each side of them by drifting into the hill-sides.

There is no reasonable doubt that the whole ridge between the creek before named and the Des Moines river is underlaid by at least one good bed of coal, and indeed it is quite as conclusive that the higher lands of the greater part of the county are so underlaid.

The St. Louis limestone furnishes a good supply of building-rock and lime, the brick-clays are of average quality and timber is more plentiful than is usual in Iowa.

MONROE COUNTY.

Along all the creeks and streams of Monroe county, coal is to be found, but the lower and better bed is reached only in the deeper creek valleys, because the county, lying upon the divide between the drainage of the Mississippi and Missouri rivers, is rather higher than those adjoining it, and the material above the coal is consequently thicker. It is probable that large quantities of coal may be obtained by sinking shafts down from the high lands to a depth not exceeding two hundred feet. Along Miller's creek on the line of the Iowa Central Railroad there have been a number of mines opened, and much coal may doubtless be obtained there by the usual process of mining. On Bluff creek, from four to six miles northward from Albia, several mines are opened, and many more may be. On Cedar creek, in the northwestern part of the county there is a bed of coal exposed in the bed of the creek which has been found to be nearly seven feet thick at that point.

On Coal creek, three miles westward from Albia, a bed of coal only thirty inches thick but of excellent quality is worked. At this mine, upon the clay floor of an abandoned opening a quantity of an efflorescent astringent substance was found which the chemist reports to be native alum. Standing in little pools around the mouth of the mine, and more particularly near a mine on Bluff Creek in the north part of the county, a deep-red colored water is found. This the chemist reports to be a solution of the per-sulphate of iron, with sulphuric acid in excess, as well as a little free phosphoric acid. On the line of the Burlington and Missouri River Railroad, near Chillicothe, along Avery's creek in the east part of the county, Miller's creek in the northeastern part, and along Cedar creek in the north western part, this lower and thicker bed of coal has been worked, affording an abundance of good coal. The upper and thinner bed, from two three feet in thickness is opened at numerous localities along the valleys of the smaller streams in varous parts of the county, particularly in the vicinity of Albia. The quality of

this upper bed of coal is equal to that of the lower bed, which is worked in the creek valleys before referred to. The sub-carboniferous limestone is found near the mouth of Miller's creek, at which point alone it has been seen within the county, the other streams, so far as known, not having cut their valleys down so deeply as to expose it.

Along many of the creeks of this county there are exposures of sandstone which furnish a very good material for common masonry, it being harder and firmer than the coal-measure sandstone usually is.

The limestone referred to, without doubt extends beneath the whole county, forming the floor of the coal-measures, and if this limestone is reached in boring or digging for coal, the work should be stopped, for there is no hope of finding coal beneath it.

Timber is sufficiently abundant in Monroe county to furnish fuel for its inhabitants, even if they had no coal, and the abundance of the latter fuel will always keep the former at a reasonable price for those who prefer to use it.

JEFFERSON COUNTY.

Jefferson county has been known longer perhaps than any other county in the State as a coal region, and many years before any railroad had reached Iowa, Fairfield coal was carried in wagons to the Mississippi river towns, and was in high repute among blacksmiths.

The Burlington & Missouri River Railroad has since been built near these mines, which are now worked by two parties, Mr. Heron and Mr. Richardson, who ship the greater part of their coal to Burlington.

At Coalport, ten miles eastward from Fairfield and on the line of the same railroad, a four-foot bed of coal is worked by Messrs. Brown & Co., from which large quantities of coal are also shipped to Burlington and intermediate points. These mines are nearly a mile to the north of the railroad, and the coal is brought to it on a wooden side-track. There is good reason to believe that the land between these mines and the railroad, as well as the land adjoining these tracts, is underlaid by as good a bed of coal as that which

Brown & Co. are now working; so that considerable supplies may be expected here in the future for shipment and local use. No statistics of the amount of coal shipped from the mines of this county on the Burlington & Missouri River Railroad have been obtained, but this trade is one of considerable importance.

From six to eight miles northward from Fairfield, on Walnut creek, there have been quite a number of mines opened in a four-foot bed of coal, and many more may be opened there whenever the demand will warrant it.

There is so little demand for coal from these Walnut creek mines, except in winter, that only one was found in operation. It is owned and worked by Mr. Shaw, who was conducting the work in a very creditable manner, and he will soon be able to supply a large amount of coal.

Along Cedar creek, a few miles southward and southwestward from Fairfield, several mines have been opened and many more may doubtless be opened along the creek for several miles. Messrs. Young & Stubbs have a good mine in operation four miles south of Fairfield, in a bed which measures from three and a half to nearly four feet thick. There is also another bed of coal overlying the main one almost twenty feet. This bed being a little less than two feet thick is thought to be unprofitable to work in view of the abundance of coal in the county. It may be that this bed will be found of profitable thickness elsewhere; indeed it is not improbable that the mine worked by Messrs. Heron & Richardson, may prove to be in the same. If so, it is probable that another bed exists beneath it. At Read's mill, three miles southwestward from Fairfield, a good mine is in operation, and the coal is taken out from the pit by the machinery of the mill. Along Walnut creek in the northern part of the county there have been a number of mines opened in a four-foot bed, and many more may be opened there when the demand will warrant it.

Our coal region needs long and careful study before any definite estimate can be made of its productiveness, but the following are some of the conclusions arrived at after the limited examinations thus far made. The larger streams have generally cut their valleys down

to the limestone which forms the floor of the coal-measures, beneath which no coal may be expected. Thus no very deep mining will be necessary in the region named. The larger streams have cut down their valleys to, and through the coal beds, and nearly all the mining is now done by drifting into their edges from the side of the valleys. There is no doubt that the coal-beds are continuous beneath the higher lands, and that they may be reached by the more expensive method of shaft-mining whenever the demand will warrant it.

The beds of coal lie so nearly horizontal beneath, and irrespective of the general surface, that very safe calculations may be made in the vicinity of those worked upon opening other mines at about the same level in the neighboring slopes.

A little below Read's mill, on land of Col. Thompson, there is a good quarry of limestone from which some large and excellent stone have been taken as may be seen in the basement wall of the new building for the High School in Fairfield. Similar stone are also found in the northeastern part of the county, but there are comparatively few exposures of it. This is the limestone before mentioned which forms the floor of the coal-measures, and consequently it is useless to seek for coal beneath it; and if in the future sinking of shafts for coal, this limestone should be reached, the work should be discontinued.

Overlying the coal at the mine of Messrs. Young & Stubbs, as well as elsewhere in the county, is a deposit of soft sandstone, some twenty feet in thickness. Most persons would pronounce it to be too soft for use, but the former gentleman has an out-house built of it which has stood unchanged for a number of years, and the hardness of the stone has much increased upon exposure. It will doubtless serve a good purpose in the more inexpensive buildings, for which the ease with which it is worked recommends it.

Fuel is so abundant in this county that there is good reason to believe that timber is now growing faster than it is being used. The excellence of the soil is too well known to need commendation from me, and there is hardly one of the natural resources which the county does not contain.

DUBUQUE LEAD MINES.

A short visit was made to these mines in July, for the purpose of collecting data and material to supply deficiencies in our means for investigating their mineralogy, and the methods of smelting the lead ores; and in some respects we were quite successful.

Some of these results have now a definite, practical value, but others are, at present, only interesting scientific facts, yet we do not know how soon they may assume practical importance. Among the interesting facts which we obtained there, are several that have long been known to the miners, but have never before been published to the world. We are apt to forget that scientific knowledge is only the knowledge of the few collected, arranged, systematized and published for the benefit of all; and that the knowledge of the miner differs from that of the mineralogist only in degree, not in kind.

Capt. Thomas Levin, an old and experienced miner of Dubuque, who furnished much valuable information for the former Geological Report, also first called our attention to the well-marked physical difference between the lead ore of the east-and-west and the north-and-south lodes. This difference is constant, easily recognized by any person after his attention has been called to it; and the fact is a very interesting one, yet it has never appeared in print before, so far as we are aware. Prof. Hinrichs is giving this matter its merited attention, and hopes to derive some hints from it concerning the relative difference in the age of the two systems of crevices or lodes.

Mr. R. Simpson, of Rock Dale Smelting Works, also called our attention to a grey substance in the ore obtained from a limited part of one of the mines near Dubuque, which he finds to greatly retard the process of smelting, and to diminish the product of lead. We subsequently obtained good specimens of this ore at the mine, and the Professor has already made analyses of the substance referred to, which he finds to be carbonate of lead — the same in composition as the grey substance often found coating the common ore. In this case, however, it is disseminated throughout the mass of the ore, the small cavities of which are often filled with crystals of the same substance. The carbonate of lead when obtained in sufficient

quantities, is an excellent ore if smelted in a suitable manner, but the process in use for the common ore (the sulphuret) is not suitable for the carbonate, and the presence of the latter with the common ore, seems to be worse than useless. This arises from the fact that the carbonate fuses at a much lower temperature then the sulphuret, flowing over the latter ore in the furnace, and prevents the compustion of the sulphur which it contains and the consequent liberation of the lead. The only modification of the common process which is now in use for the smelting of this mixed ore, which he would suggest, is to add small quantities of crushed charcoal at frequent intervals during the smelting; and even this he thinks of doubtful value.

It seems improbable that large quantities of these mixed ores will be obtained, and furthermore it is reasonable to expect that the "grey slag" obtained in smelting it will contain more than the usual quantity of "slag lead" which will be saved by the second smelting, and the aggregate product may thus not fall so far short as the diminished product of the first smelting would seem to indicate.

From the smelting works before mentioned, we obtained specimens illustrating every stage of the process of washing and smelting, including the sediment from the troughs, the different slags from the furnace, and both "soft" and "slag" lead.

We also obtained specimens of quite a number of other mineral substances which are usually associated with lead ore. From these, and from examinations of the cabinets of several citizens of Dubuque, Professor Hinrichs was able to make out the order of occurrence of nearly a dozen different minerals; or, to be more explicit, it is known for instance that a certain mineral is found in a crystalized form upon the surface of the rock, and that upon the former, crystals of another mineral will be found, and still others upon the last, &c. It is this order of occurrence of the different minerals which is in part engaging the Professor's attention.

It was also our intention to obtain statistical information in relation to the present and past product of the mines, but we found that *perfectly reliable* statistics of this kind were very difficult to obtain. Indeed the oldest and best informed mining and smelting proprietors

were slow to give a definite opinion upon this subject, although they were very willing to comply with our wishes in this respect as far as possible. From conversation with these gentlemen I obtained the following impressions, namely: that lead-mining is now in a tolerably prosperous condition, but there were times in its early history when more ore was raised per man than now. The increased price of lead makes mining as profitable now as it ever was, although it requires a greater proportion of labor and skill to obtain the ore than formerly.

Little or no change has taken place in the methods of either mining or smelting during the past twenty years, except the projected drainage of the mines by means of adit levels.

An enterprise of this kind has been a couple of years in progress by a New York company, and promises to be very successful. A large area will be drained by this level when completed, which experienced miners believe will yield large quantities of lead ore, now inaccessible on account of the water. Should this enterprise succeed, there are other regions near Dubuque which may be drained in the same manner with equally good prospects of success. A new era in the history of Iowa lead-mining evidently depends upon the success or failure of the company now operating.

Up to the present time there are no indications that deeper mining will be profitable, or indeed in any degree productive in this region. The thickness of the Galena limestone in the vicinity of Dubuque is about two hundred and fifty feet, and the principal portion of the lead ore is found above the middle of it, very little being found near its base or top. The only exception at present known, is shown in an opening recently made a short distance from the city by Messrs. McCraney & Hickok. Here these gentlemen have found a lead-bearing crevice in the extreme upper part of the Galena limestone, which has no cap-rock, the shales of the so-called Hudson river group lying immediately upon the top of the fissure. What the extent of this deposit of ore is, remains to be proven, as it had been opened only a few days at the time of our visit. Upon some specimens of lead and zinc ores thrown out from this mine, and also some presented to us by the proprietors, we found numerous small crystals of native sulphur. Sulphur in the water of springs is of course

well known, but we believe this is the first discovery of native crystalized sulphur yet found in America, and its occurrence here is also somewhat at variance with opinions which have been entertained concerning the occurrence of sulphur in nature. Science is progressive, and why should not Iowa contribute her share to its progress?

MARION COUNTY.

Every coal mine in this county which it was possible to enter, was visited in person, although to accomplish this it was not unfrequently necessary to wade in almost ice-cold water, which collects in the mines when they are not worked. This is the condition of the majority of them during the summer months, at which time there is little demand for coal, there being at present no railroad through that portion of this county which contains the largest amount. The first mines visited were those of Messrs. Roberts, Fisher and Barnes, near Otley station, on the Des Moines Valley Railroad, about seven miles westward from Pella. They are situated on the upper branches of a creek which empties into the Des Moines river, the two former on section twenty-eight, township seventy-seven, range nineteen, and the latter on section twenty-one, township seventy-seven, range nineteen. The thickness of the coal in the mines of Messrs. Roberts and Fisher, is from five to six feet. That of Mr. Barnes' mine is four feet thick; and being evidently in the same bed and nearer the depot than the others, it has been suggested that the coal probably thins out in that direction, and that it would not be reached by sinking a shaft at the depot; but since coal, and probably the same bed, has been discovered three feet thick several miles beyond the depot in the same direction, there appears to be no good reason why it should not be found of profitable thickness by sinking a shaft at that point. There is evidently a large amount of coal in that part of the county, a small portion only of which has been fortunately exposed by the erosion of the creek valley before mentioned. Mr. Nossaman, four miles southward from Pella, has opened a three-foot bed of coal near the left bank of the Des Moines river, which, with those before mentioned, are the only ones visited on the east side of the river in this county. At Coalport, some four or five miles from

Pella, Messrs. Bosquet & Thompson have opened a mine in the face of the bluff immediately upon the right bank of the Des Moines river, the coal of which measures from six to seven feet in thickness. There is a band of cannel coal of several inches in thickness associated with the bituminous coal of this mine, but which the water prevented me from seeing at the time it was visited. This bed of coal appears in the face of the bluff as a broad black band; and about ten feet beneath it is a similar band about two feet wide, which represents another bed of coal of that thickness. Making Knoxville a point from which to work up the west side of the river, the mine next visited was that of Mr. O'Neal, about two miles north of town, on section nineteen, township seventy-seven, range nineteen. This consists of two beds of coal, each about two feet thick, with a bed of shale between them of similar thickness. The evidence that these are two distinct beds of coal is increased by the fact that there is much difference in the quality of each; that of the upper being the best, and much esteemed by blacksmiths. Going northward from here about half a mile on the Red Rock road, we see in the face of the bluff, composed of sandstone and sandy shale, immediately upon the right bank of White Breast creek and near the mill, another bed of coal two and a half feet thick. This last named bed is nearly on a level with the mill-dam there, and probably represents the thick bed of other parts of the county. The depth at which this lies beneath those of O'Neal's mine could not be definitely ascertained, but it is probably not less than fifty feet. Going southward, immediately at the outskirts of town, Mr. Brobst has a mine in operation which measures four feet thick, and the same bed no doubt underlies the whole town of Knoxville.

The next mines seen in this direction are upon the banks of English creek, three or four miles from town. The coal in these mines measures from three to four feet in thickness. And the coal is exposed at frequent intervals along the hillsides bordering this creek, until they merge in those which border the bottom lands of Des Moines river. The bed of coal in which the last named mines are opened, evidently thickens in the direction of the course of the stream, that is, to the eastward, and probably also to the southward. This is clearly seen in the vicinity of Bussing's mill, four miles east

of town, where it has reached a thickness in some places of seven feet. The mines which have been opened in the vicinity of this mill, upon English creek and its branches, have from five to seven feet in thickness of coal. At the mines owned by Messrs. Sherman, Newman and Ferrin, about a mile southward from the mill, the coal is from five to six feet thick, and about fifteen feet beneath this, another bed of coal is seen cropping out in the bed of the small creek, which, however, is only about eighteen inches thick. Quite a number of mines have been opened in the hills in the vicinity of this mill, the coal of which is usually compact in most of them. While this character renders the mining of it a little more difficult, it will be more valuable for shipment because it will not crumble so easily; beside which, the more dense the coal is the more heating power it possesses if it is pure coal, which this seems to be. When an east and west railroad is built through this county it will probably pass up the valley of this creek, when the coal lands there will be very valuable, and the supply of coal for shipment will be immense. Numerous points along White Breast creek were visited where coal had been mined, which indicated that the supply that may be obtained along that stream is very great. A bank was visited some six miles southwestward from town, near this creek, from which considerable quantities of cannel coal are said to have been taken, but not now being worked it had unfortunately fallen in so that only a few fragments of the coal could be obtained. Although coal may doubtless be obtained in almost any part of the county, the southeastern quarter of it is pre-eminently its coal region. Perhaps, however, this is only apparently so, and that just as heavy beds of coal exist in other parts, the streams of which have not cut their valleys deep enough to expose them as they have in the southeastern quarter, which will be presently explained. Along the hillsides which skirt the North and South Cedar creeks from their entrance into the county to where they unite and enter the bottom land of the Des Moines river, a bed of coal is found naturally exposed at frequent intervals, which measures from five to seven feet in thickness and sometimes more. This region has now only a local country market for its coal, so that little more is yet done in the way of mining it, than to dig into the exposures to ascertain its thickness.

The thickest bed of coal found there, and so far as at present known, the thickest in the State, measures nearly ten feet in perpendicular thickness, the room in the mine being higher than many of the rooms of our dwellings. This mine belongs to Mr. Jacob Kline, and is located on section twenty-nine, township seventy-four, range eighteen. About three feet from the top of the bed of coal there is a band of shale a couple of inches thick, which suggests that there may in reality be two separate beds which at this point have come together.

Marysville, a cosy-valley village which has been built up by an intelligent and industrious community, composed principally of Pennsylvanians, since most of our maps were made, is situated upon the same section. Here two other mines are opened and worked with only sufficient force to supply the neighborhood and the mills of the village. The first is owned by Mr. John Yenser, and the other by Mr. D. F. Leiby. A couple of miles below the village Mr. G. H. Clemons has made an opening in the same bed. The coal at Marysville is seen in the face of the bluff on the right bank of the creek in much the same position as that at Coalport before mentioned; and a similar bluff exposure of the same bed is seen on the right bank of North Cedar creek, on land belonging to Mr. A. P. Chambers, section sixteen, township seventy-four, range eighteen. Farther down the creek, on land of A. B. Lyman, Esq., there are other exposures of coal, but the want of a market has prevented them from being worked. Beside these and numerous other exposures of coal along the two Cedar creeks there are many others along the hillsides which skirt the bottom land of the Des Moines river. Mr. Daniel Sherwood, a couple of miles southward from Attica, is working one upon a branch of North Cedar, evidently in the same bed as the others just mentioned.

Although that member of the sub-carboniferous limestone series, known among geologists as the "St. Louis limestone" is found in the bed of, and skirting the Des Moines river almost all the way from a few miles below the state capital to Keosauqua, and is often a very good building-rock, yet the same bed, when found in the vicinity of Pella is somewhat different in texture from that of almost all the exposures of it yet seen. At other localities, although often

in distinct and massive layers, it is usually very compact and brittle, breaking in such an irregular manner that it is dressed with great difficulty, yet in all cases furnishing a superior quality of lime. That of the Pella quarries is regularly bedded, and is not only wrought with great facility, being free from flinty material, but is evidently very durable as well as of a pleasing appearance when dressed. The quarries have a thickness of from eight to ten feet, the upper half of which is usually in rather thin layers, which are valuable for lime and all the purposes of common masonry; but the lower half is formed of the excellent material referred to, which may be quarried with comparative ease, in all the forms and sizes usually desired.

Although the stone varies a little in texture and appearance at each of these quarries, there is abundant evidence that they are portions of the same continuous beds, which also underlie the intervening region, although covered too deeply by soil and drift material to be accessible.

The texture of the massive layers in the quarries south-westward from the town is inclined to be oolitic — a term used to indicate a rock composed of small spherical particles resembling the roe of fishes — while the same beds two and a half miles north of town, four feet in thickness, are made up entirely of the fossilized, cast-off shells of a minute bivalve crustacean. (*Beyrichia petrifactor.*)

A mile and a half northward, the same beds, are seen in the quarries of Mr. Phillip Mather, and there present a dense, fine-grained texture of excellent quality for dressing, and of a lighter grey color than the others. From these quarries, beside specimens of each variety of the rock, a good collection also of the fossils which characterize this member of the sub-carboniferous limestone series, were obtained to add to the State Cabinet.

Mr. W. Nossaman has some excellent quarries, both for lime and dressed stone, almost four miles south of Pella. His coal mine, before mentioned, is only a few rods distant from his quarries, the bed of coal lying some twenty-five feet above the limestone, so that he runs the coal from his mines to his lime-kilns without any further transportation.

The limestone, although not the upper member of the full series of sub-carboniferous strata, is yet the upper member of that series

in our own State, and the coal-measure strata throughout the Des Moines Valley are found resting upon it. Consequently it is useless to look for coal beneath this rock, judging from all the experience which geology has yet furnished us. Throughout the greater part of Marion county however, this rock lies so deep beneath the surface as to give space between it and the surface for those important deposits of coal before described. The sandstone of this county belongs to the coal-measures, and of course overlies the limestone. Much of it is soft, at least when first taken from the quarry, yet it hardens considerably when exposed for a short time to the atmosphere.

There are, however, large quantities of this sandstone that is hard enough for any purpose as a building material. The principal of these firm exposures of sandstone are found at, and near the village of Red Rock, on the Des Moines river, although sandstone equally good, but of a different color, is found in various parts of the county. This stone at Red Rock assumes the character of a clean grit sandstone, most of which is of a bright brick-red color. The exposure here is a bold bluff, reaching a height of about seventy feet. In some few places the stone appears to be soft, but the greater part of it is quite uniform in hardness, and the layers so massive that blocks of almost any desired size can be quarried. Much of this stone has already been used in various places, and a part of that used in the construction of the State Arsenal was obtained from these quarries. On the opposite side of the river valley from Red Rock there are similar bluffs of the same sandstone, which presents nearly the same colors. The same exposure also is seen in a gradually diminishing bluff bordering the valley along several miles below Red Rock.

Some large and small concretionary masses of what geologists call quartzite were found at Red Rock and other places in this county, embedded in, and forming a part of the sandstone-deposit, the lines of stratification running without interruption through each, showing that the quartzite is a part of the same deposit. To produce this change of sandstone in nature it was once supposed that great heat

was necessary; but we have no evidence that any of the accessible strata of Iowa have been altered by heat.

The limestone before described doubtless underlies the whole of Marion county, but only appears where slight undulations have brought it up, or where the streams have cut their valleys down to it through the coal-measure strata. The coal-measures, composed of sandstone, shale, clay and coal, lie comformably upon this limestone, and follow it in its dips and undulations. Upon the coal-measure strata rests the drift material, a part of which forms the soil and sub-soil.

The original horizontal position of the limestone and coal-measure rocks has been but slightly changed in this county, and are quite independent of any inequalities of the present surface of the earth, because those inequalities are due to the erosion of the valleys by the streams which run through them, thereby cutting down through each successive stratum, the edge of every one of which would be seen in the sides of the valleys if it were not that they are covered by the soft material derived from their disintegration. Thus we find exposures of coal only where they have been cut through in this manner by the streams, and thus the conclusion is perfectly legitimate that the same beds of coal extend continuously beneath the high lands, whose edges we see upon each side in the valleys. The question often arises as to how many different beds of coal there are in this county. This question can-not be answered in a perfectly satisfactory manner until the whole region has been carefully and minutely examined, which will be a work requiring far longer time to accomplish than can now be given to it.

The conclusion arrived at from the partial examination thus far made is that there are in Marion county at least three separate beds of coal, the middle one of which is much the most important and extensive. The others seem to thin entirely out in some places, so that it is doubtful whether they would all be pierced by a boring made at any one point; yet there is probably no point upon the high lands of this county which is not underlaid by more or less coal. To be a little more explicit, it may be stated that the double bed—counted as one—of Mr. O'Neal's, is regarded as the highest, and

that the thick one in which the mines of Coalport, English, Cedar and other creeks are opened, is believed to be the second, and the thin one beneath the last-named bed, as seen at Coalport and also a mile south of Bussing's mill, would consequently be the third. The first occurs apparently above the principal sandstone horizon, and the second, a main bed, just beneath it. This horizon does not always present firm exposures of sandstone, as at Red Rock, Eagle Rock, Bussing's mill, a mile above Marysville, &c., but may be seen in the form of yellow comminuted sandy shale, upon the sides of the hills in many places—more, perhaps, than where it appears as firm rock. Thus, if one should sink a shaft with a view of reaching the main bed, after passing through the upper bed, as Mr. John Gamble has done in digging a well at his residence just north of Knoxville, where he found it four feet thick at a depth of thirty feet, he would then pass through a considerable thickness of either sandstone or sandy shale. If he were seeking the position of that bed upon the hillside, he might expect to find it near the base of that sandy horizon, whether of sandstone or sandy shale. The sub-carboniferous limestone before mentioned can not lie very deep beneath any part of the county; consequently no very deep mining will be necessary in any part of it. It is thought that a shaft of two hundred feet at any point in the county will reach all the coal to be found. The time will come when it will pay to sink such shafts from the highlands to obtain the coal from the extensive beds which are thus far only very slightly penetrated from their edges.

The quality of the coal of this county is fully equal to the average of Western coal, and that of many of the mines is in excellent repute among blacksmiths for working iron.

Marion is one of the best supplied counties in the State for timber. Much of the original forest yet remain along the streams, and the young timber is growing vigorously wherever it is allowed to stand. The prairies are comparatively small, and beautiful groves of native trees are scattered almost everywhere, giving a very pleasing effect to the landscape. The streams being numerous, the county is well watered, besides which, wells of good water are easily obtained at moderate depth almost anywhere, some of which have penetrated beds of coal. It would be superfluous to add

anything in praise of the fertility of the soil to those who see the bountiful harvest which is now everywhere burthening the fields.

WAPELLO COUNTY.

The examination of this county was commenced in the western part, on the south side of the Des Moines river, and the first mine visited was that of C. Dudley & Company, on section four, seventy-two, fifteen. Judging from what is now to be seen of this mine its coal will prove to be unsurpassed by any other now offered in the market, and these gentlemen will soon be able to furnish very large quantities. The bed is four feet thick, and very uniform in quality. They are now constructing a tram road from their mine to the track of the Burlington and Missouri Railroad, a little less than a mile distant. About half a mile southward, from this mine an opening has been made in what appears to be the same bed, but the quality of the coal now obtained is poor, and I fear the prospect is not flattering that it will improve much within a short distance. A quarter of a mile westward of Dudley & Company's mine an opening in the same bed is being made with good prospect of finding excellent coal. The bed in which the last named opening has been made, as well as that of Dudley & Company, is the second in the series, as may be seen by going down the creek a few rods, where the limestone — which, as said in previous letters, forms the floor of the coal-measures, and beneath which no coal need be sought for — is found in the bed of the creek. About three feet above this limestone is seen a bed of coal which is here only about one and a half feet thick, and which is of course the lowest in the series. Above this bed of coal is a space of about forty-five feet, the material composing which is partly hidden by the slope of the hill; and upon this rests the four-foot coal bed of Dudley & Company's mine. On the north side of the creek (North Avery) a little more than a mile from the last named mine, Mr. J. G. Heacock has opened one in a four-foot bed of coal, but since the before mentioned limestone is seen exposed in the slope only about five feet beneath the coal there, no doubt is felt that this is the lower bed of coal, and therefore not identical with that of the mine of Dudley & Company, but with the thin one which lies forty-five feet beneath it. Mr.

Heacock has only just opened his mine, and the quality does not seem to be as good as some others, yet it will no doubt make good fuel for steam purposes. It is reasonable to suppose, however, that the quality will somewhat improve as the mining proceeds beneath the hill, but there is also reason to believe that the coal of the second bed will be found to be better than that of the first, at least in this part of the county. Going down the river valley three miles below the village of Chillicothe, to the mines of Henry Shock & Company, on section eight, township seventy-two, range fourteen, the coal was found to be of good quality, and the bed five feet thick. These gentlemen furnish a large amount of coal for shipment on the B. & M. Railroad. About a quarter of a mile further up the small creek which comes into the Des Moines river there, and upon the same section, Mr. David C. Evans has just got a mine into good working order in the same bed of coal, which here also measures five feet in thickness, and the quality fully equal to that of Shock & Company. There is no doubt that the high lands bordering this creek and the adjacent high lands bordering the Des Moines river bottom are underlaid by as good coal as is seen in the mines just mentioned.

In the immediate vicinity of Ottumwa several mines have been opened, but the beds are rather thin and the quality poorer than the coal of the county will average, although they furnish a considerable amount of good coal. The first and second beds of coal are represented in the hills at Ottumwa, but yet it seems probable that the principal supplies for the city must be brought from mines four or five miles distant. About that distance to the northwestward from the city, on section thirty-three, township seventy-three, range fourteen, Messrs. Brown & Godfrey have some mines in operation from which they are preparing to ship large quantities of coal. Both the D. V. and B. & M. Railroads run near each other within a mile of their mines which will give them unusual advantages in shipping coal to various markets on both roads. The quality of their coal is good, and the bed measures from four to four and a half feet thick. Northwestward from these mines, and about a mile southward from Kirkville, several other mines have been opened, all apparently in

the same bed. Those latterly known as Smith's mines have been on fire for several months, probably the work of an incendiary, but are now nearly extinguished. The coal of these mines has long been in good repute, and Mr. Smith will soon have them in working order again. Mr. Joshua Marshall has a good five-foot mine in good condition on section seventeen, township seventy-three, range fourteen, and has a good local market for his coal. In the immediate vicinity of Eddyville several mines are worked in a bed which ranges from three to four and a half feet in thickness. From these mines some specimens of coal were obtained as fine as any I have seen in the West. An exposure of cannel coal was reported to exist in the immediate bank of the Des Moines river, about half a mile above the town, but the river was too high at the time of my visit to see it. From indications observed in the northwestern quarter of the county there is reason to believe that this region will furnish very large quantities of excellent coal for export, which may be readily run down to the railroads by branch tracks laid along the numerous small streams which empty into the Des Moines river. This will make Wapello one of the principal exporting coal counties of the State; indeed, more coal is now shipped upon the Burlington & Missouri Railroad from this county than from any other through which it passes.

Thus far very little coal has been found in the southwestern and northwestern quarters of the county, but in the former, if not also in the latter, it is probable that coal may be found at a moderate depth beneath the surface, but down to which the valleys of the creeks, being small ones, have not been cut, as has been the case along the river and the larger creeks. A large amount of coal, however, is found in the southeastern part of the county, the principal mine of which is worked at Alpine Station, on the D. V. Railroad by the Alpine Coal Company, under the direction of Mr. C. J. Love.

This mine furnishes large quantities of coal for the Keokuk market, where it is in good repute, being shipped there upon the D. V. Railroad. The bed is from four to five feet thick, and since the mine was opened it has furnished about one million bushels of

coal, which is probably more than the product up to this time of any other mine in the State.

The St. Louis limestone without doubt underlies the whole of this county in the same manner that it underlies those described in the preceding pages. It is exposed at numerous points along the Des Moines and its tributaries at and above Ottumwa. It furnishes excellent material for lime, and also good building rock, much of which is suitable for dressing.

Below Ottumwa the limestone rapidly dips beneath, so that the coal-measure sandstone is seen near the water's edge, a mile below town, and just below Alpine station, eight or nine miles from Ottumwa, a bed of coal is found in the bed of the river. The sandstone referred to, is of the same general character as the coal-measure sandstone before spoken of, but it is not quite so firm, nor so uniform in quality as that obtained at Red Rock. It will hardly be used where good limestone can be easily obtained, but yet much of it will answer well the purposes of common masonry.

Usually the strata of the Iowa coal-field, as well as the underlying sub-carboniferous limestone, are very regular and undisturbed, but commencing a little above Ottumwa and going down the valley there is seen to be considerable evidence of disturbance of the strata.

This disturbance has not been violent, but yet sufficient to pass the limestone beneath the level of the river just below Ottumwa, so that it does not appear again below that point in this county. At the Alpine mines below referred to, the coal and its associated beds also partake of the disturbance so that the bed of coal is entirely cut off at one place within the mine, by what seems to have been a settling of the superincumbent mass in longitudinal folds, the folds having a general direction from northeast to southwest. A number of these folds have been met with in the mine, depressing the roof, but only one of them has been found to cut the coal entirely off. Judging from the character of the others, the miners may expect to find the coal again after passing a short distance through the material which now occupies its place. The cause of these disturbances is not at present clearly seen, from the fact that the effects have not been traced in a longitudinal direction over a considerable extent of country as they usually may be in such cases.

Thus far no similar evidences of disturbances of coal-measure strata have been observed in Iowa, although the older rocks in the adjoining States are often found disturbed.

No minerals of value except coal, have been discovered in this county, and it is hardly probable that any such will be found. Small quantities of iron ore have been found in this, as well as in many other of the coal counties. It is usually in the form of small, irregular, lenticular masses, called clay-iron stone, or in still mere irregular masses of per-oxide of iron, usually called red hæmatite. The latter is an excellent ore of iron, but to be profitable it must exist in large quantities and easy of access. One can not fail to see that these small quantities of iron ore, however excellent, are valueless when he learns the fact that iron ore is now being shipped from the famous Lake Superior mines to the furnaces in north-eastern Ohio and north-western Pennsylvania, which were built for smelting the ores of their own regions. Upon the completion of our north and south railroads the iron region of Missouri will supply us much more cheaply than we could produce that metal, even if our supply of ore were many times greater than it is. In the fissures of the clay-iron nodules found in the dark shale just north of Ottumwa, small quantities of the sulphuret of zinc were found. This discovery is valuable, however, only as an interesting fact in mineralogy.

Wapello county is well supplied with timber, which will always keep wood at a reasonable price for those who prefer it to coal as a fuel. It is well watered by the Des Moines river and its numerous tributaries, as well as by numerous excellent springs. Good wells are easily obtained almost anywhere. It is superfluous to say that the soil is excellent, for no poor soil exists along the great valley of the Des Moines.

VAN BUREN COUNTY.

Van Buren was one among the first counties in the State known to contain coal, consequently some of the oldest mines in the State are found here. It was quite fully reported upon by Prof. Worthen in the reports of the former geological survey; and the principal object of my visit there was only to obtain some more definite ideas in relation to its coal.

Commencing in the north-western part of the county, all the mines were visited in succession which were in a condition to enter. The first was McHugh's mine, on section seventeen, township seventy, range eleven, a little below the town of Independent. The bed is about three feet thick, but is not now much worked.

Two and a half miles eastward from the last named town, on section ten, township seventy, range eleven, Mr. Rodefer has a good mine in operation, the coal of which is of good quality and the bed four feet thick. On the same section, and about half a mile further up the small creek upon which the Rodefer mine is situated, there is another exposure of a four-foot bed of coal, the identity of which with that of Rodefer's mine seems impossible, as it is evidently many feet above it.

Upon a branch of the same creek, near the last-named exposure, another is seen about one foot in thickness, which seems to be separate from both the others, probably lying between them. Should this supposition prove correct, there are three separate beds of coal in this county, all of which are to be seen upon section 10, township 70, range 11. The thin bed just mentioned is overlaid by shales of the same character and containing the same species of fossil fish remains as the upper bed does in Wapello and Monroe counties. Half a mile south of Business Corners, Mr. Alexander Findley is working a mine in a three-and-a-half-foot bed, which has supplied a large district around for many years. About a mile from the latter mine, on lands of Hon. Eliab Doud, at Doud's Station, several openings were formerly made, and a considerable quantity of coal taken out. They are now abandoned, although much good coal may doubtless yet be obtained here.

At and in the vicinity of Keosauqua several openings have been worked for a long time, but to the extent only of supplying the local demand. The bed ranges from two to three feet in thickness. These openings are all upon the right bank of the river, but there seems to be no good reason why the same bed should not be found beneath the higher lands of the great bend in which Keosauqua is situated, where they are above the level occupied by the limestone.

Coal has formerly been mined at several points along Chequest creek, but operations are now suspended there.

A couple of miles northward from Bentonsport, Mr. Carter is working a three-foot bed of coal, and several other openings have also been made in that township.

At Farmington very large quantities of coal were formerly mined for shipment on the Des Moines Valley Railroad to the Keokuk and other markets. On the south side of the river there the principal mines are owned by Messrs. Dibble, Wright & Tuttle, and no doubt they can yet be made to furnish large quantities of coal whenever the demand will warrant it.

On the north side of the river, a mile above Farmington, a New York Company own and formerly worked extensive mines, having a branch track from the railroad. In the northeastern corner of the county, near Hillsboro, several mines have been worked for several years to supply a local and northward market. Mr. Martin has a mine on section fourteen, township seventy, range eight, said to be seven feet thick, but learning that it was not in a condition to enter, it was not visited. There is evidently much coal in Van Buren county, but at present it is only worked to supply local demand.

Both the magnesian and calcareous members of the St. Louis limestone (sub-carboniferous) are freely exposed along the valleys of the Des Moines and its larger tributaries. This is particularly the case from Independent nearly to Bentonsport. At the latter place the Keokuk limestone appears beneath the St. Louis limestone, the latter there appearing near the tops of the hills. The same limestones are also seen in similar positions at Bonaparte, but upon reaching Farmington the Keokuk limestone has dipped down beneath the river again, and the St. Louis limestone is seen occupying a position near the water level.

It is always found that when these sub-carboniferous rocks are elevated, the coal-measure strata which rest upon them are also elevated with them. This proves that the elevation took place since the coal-measure strata were deposited, and since these have often suffered denudation, it is believed that this was accomplished by glacial action, and consequently the elevation of the strata took place before the glacial epoch.

In this county the limestones also show considerable evidence not only of unevenness of surface at the time of the deposition of the

coal-measure strata but also of some disturbance during the time of its own deposition. This is shown by the brecciated character of the rock in many places, and also by the evidences of the fracture and slipping of some portions past the other, producing something approaching to what are called faults. These fractures are always local, and can not be traced to any considerable distance, as faults usually can. During the deposition of the rock the disturbance was often so great as to break up the continuity of the beds and mix masses of limestone with the sandstone of the same formation, as may be seen above Thatcher's mill near Keosauqua.

These disturbances, together with the erosion which the formation seems to have suffered before the deposition of the coal-measures, left the general surface so uneven then that it has had the effect of causing a want of uniformity in the thickness of the beds of coal and also of their associated strata. Thus in this county, even where the continuity of the coal-beds can be made out, they are found to be in good workable condition in some places, and so thin in others as to be worthless. Thus the best mines of this county may be expected to occupy limited but not necessarily entirely isolated basins.

The St. Louis limestone presents at least three distinct subdivisions in Van Buren county, which are more distinctly seen in Keosauqua than elsewhere. The first presents the usual characters of that limestone; is about twenty-five feet thick, and immediately underlies the coal-measure strata there, as usual in other parts of the coal-field. The second is a sandstone about twenty feet in thickness, and is seen well exposed just above Thatcher's Mill, where it underlies the first. This sandstone is sometimes soft and shaly, but near the residence of Hon. J. Thatcher it presents quite a firm texture, and has the general appearance of the coal-measure sandstone before mentioned, but is lighter colored. Most of it will doubtless serve a good purpose for ordinary buildings, and being quarried with much less labor than the ordinary limestone, it will probably be found desirable for many purposes. The third division is magnesian limestone, and is to be seen at the water's edge below the dam at Kimmersly's Mill.

On Lick creek, near Kilbourne station, on the D. V. Railroad, Messrs. Knapp and Wright, of Keosauqua, own extensive quarries

of light-brown stone, which belong to th emagnesian portion of the sub-carboniferous limestone. These rocks were extensively quarried many years ago for the Des Moines River Improvement. Bridge abutments built then of these stone are standing now entirely unchanged, showing that the material is excellent for such purposes.

The layers are massive, yet they are easily worked and may be obtained of almost any desired size. They are of two distinct varieties, although both possess nearly the same color; the lower layers being properly magnesian limestone, and the upper layers being more properly an arenaceous limestone with a little carbonate of magnesia. Both derive their brown color from iron. Both varieties will make good building material, but I think the arenaceous variety a very superior stone for heavy masonry.

The upper limestone also furnishes much good building-rock, and also excellent lime. Messrs. Castor & Tuttle have a lime-kiln just opposite Keosauqua, and upon the same ground a coal-mine, from which they obtain the fuel for burning the lime.

On the farm of Mr. A. W. Mangum, two and a half miles from Keosauqua, a good bed of fire-clay is found, from which the principal supplies are obtained for the pottery of Mr. R. M. Dickson, at Vernon. Mr. Dickson employs twenty hands and uses two kilns, manufacturing all kinds of common pottery, and also drain-tiles.

No minerals of practical value, except coal, have been found in Van Buren county, nor does it seem probable that any such will be found. Samples of good iron ore — red haematite — were obtained from lands of Hon. J. Thatcher and Mr. Trebblecock, near Keosauqua, but there is no prospect that it will be found in sufficient quantities for profitable manufacture. Indeed, the Missouri and Lake Superior iron regions seem destined to supply the whole West with iron; for their ores are now carried long distances to be smelted with profit in furnaces which were built for the purpose of smelting ores from the grounds they stand upon.

Some citizens of Farmington within the last two years have bored an artesian well to the depth of seven hundred and five feet. It is now discharging water very freely, although the boring is not tubed. It has been conducted in a tube to a hight of forty feet above the

top of the well, still discharging freely. Thus far no use has been made of it. The temperature of the water is much above that of common well-water, and appears to taste slightly of sulphuretted hydrogen.

Hon. C. G. Dibble kindly forwarded a quantity of it to the laboratory for analysis, but the vessel containing it was unfortunately broken in its passage, and no opportunity has since presented itself for obtaining more.

Mr. J. J. Kinersly, in digging a well on his farm a mile northward from Keosauqua, came down upon coal-measure shale within fifteen or twenty feet of the surface. Water, presenting no unusual color, came in somewhat freely, having a very acid and acrid taste, so that he abandoned the well for ordinary purposes. An analysis of this water shows it to be very strongly impregnated with proto-sulphate of iron — common copperas — with some free sulphuric acid. The substances contained in this water are so cheap in the market that they may in this case be considered entirely worthless. The deep-red liquid seen standing in puddles about the mouths of coal-mines is of the same general character as that of Mr. Kinersly's well, except that the per-oxidation of the iron gives it the dark color.

MARSHALL COUNTY.

The reason why this county is so briefly reported upon, or rather why it is not reported upon at all at the present time, is because it lies directly in the path which it was necessary to travel to reach that portion of the State which it was proposed to examine for peat The immediate surface of the greater part of Marshall county is underlaid by sub-carboniferous rock, beneat hwhich no coal need be sought for but upon which the coal-measure sandstone is seen to rest at some points in the vicinity of Linn creek.

This sandstone and its associated shales has no doubt a considerable development just beneath the surface drift and soil of the western and southwestern part, although they may not be exposed to view. The general dip of all the strata being to the southward, these coal-measure strata would be expected to increase in those directions, while the sub-carboniferous rocks before mentioned, pass

beneath them and are seen no more. In defining the borders of a coal-field, geologists designate a line upon the map within which those rocks are found exposed that are known to be associated with, and of the same geological nature as the coal, although no coal may be discovered by them, or even if none actually exists there. Thus we know that the border of the Iowa coal-field so determined runs through Marshall county in a southeasterly and northwesterly direction.

Although there are some instances of a considerable development of coal within a short distance of the well defined-border of the coal field as above described, as for example near Eldora in Hardin county, yet such favorable exceptions are not often to be expected. While it is not at all impossible that coal may be discovered in the western and southwestern portions of the county, yet in view of the facts just mentioned, justice requires that I should not encourage a large expenditure of money or labor in the search for it.

The rocks of the eastern and central parts of the county have been spoken of as sub-carbaniferous. There are several distinct formations which constitute the rocks of sub-carboniferous period, most of which are found in our State. These are first — and lowest in the series — these rocks and their geological equivalents which are seen at the base of the exposures at Burlington, and called by the Illinois geologists the "Kinderhook group;" next the "Burlington limestone;" next the "Keokuk limestone;" next and highest in the series in our State, the "St. Louis limestone." It is the latter that the coal-measure rocks of Iowa are usually found resting upon; but the sub-carboniferous rocks of this county are geologically equivalent to the upper part of the Kinderhook group, and perhaps also to the lower part of the Burlington limestone.

Consequently the coal-measure sandstone which rests upon the limestone in this county is in geological language unconformable to it, because the upper Burlington limestone, Keokuk, and St. Louis limestones are all wanting from their places between the two.

The county is well supplied with stone for building purposes and for lime, from the limestone before mentioned, and the coal-measure sandstone is also used for rough masonry to a limited extent. The general surface is of a pleasing and gently undulating outline, and

delightful landscape views are numerous. The soil is everywhere fertile, but perhaps more especially so along the beautiful valley of the Iowa river, which runs obliquely through the county in the same general direction as the borders of the geological formations before mentioned. The whole region is well watered by springs and streams of constant and remarkably pure water.

Timber enough for the use of the present and prospective inhabitants is found in the groves, and in large bodies skirting the streams. Thus there is no real element of prosperity wanting to make Marshall county one of the most prosperous in the State.

FRANKLIN COUNTY.

Although it was expected from the first that this county would be found to contain peat, yet it was thought best not to devote time enough at present to the full examination of it, but to go to the more northern counties and return to this if time should permit.— From some knowledge of the general character of the surface, and from information since received, it is believed that large quantities of peat exist in the north-western and south-western parts of the county.

The first peat observed in the county was in the northern part of township ninety, range nineteen, a little north of the farms of Messrs. Smith and Hedge. It is found in a grassy slough, is from two to four feet deep, and probably covers two or three acres. The peat here is not of the best quality, but will make a desirable fuel when thoroughly dried. About half a mile north of this locality, in another slough, a real mossy peat bog of limited extent is to be seen. It occupies about an acre, and is somewhat peculiar in its accumulation, for it is raised in a slightly mound-like form above the surface of the surrounding parts of the slough in which it is located, so that it can all be easily drained. A spring evidently comes out here which affords constant moisture for the growth of the moss that forms the peat. This is a good clear article of peat, free from earthy matter, and is known to be more than seven feet deep in the center, but thins out toward the edges.

A small marsh, containing two or three acres, was seen in the southeastern part of township ninety-one, range twenty. It is

covered with grass, but the usual moss is seen to thickly cover over the surface at the roots of the grass. The peat reaches about three feet in depth, and will make a very fair fuel.

Another marsh was found on section twenty-five, township ninety-two, range twenty, two miles east of Hampton, the county-seat of Franklin county. It is estimated to contain twenty acres of peat which will average two and a half feet in depth. Although these, and other marshes of this county will doubtless furnish large quantities of valuable fuel, it can not be too strongly urged upon the inhabitants to plant largely of our forest trees, for there is no danger that any of them will not grow to be excellent timber, nor any danger that the supply will ever be too great.

Aside from the comparatively insignificant portion of the surface occupied by the marshes, there is hardly an acre in the whole county which will not produce a good crop of all kinds, for the farm; and a crop of trees, although slower in bringing a return, will eventually be found to be as profitable and certain as any other. Beside the certainty of pecuniary reward for the labor and money thus expended, there is the consideration of a duty which those owe, who are able to perform it, to provide this indispensable material for their children's use, and also for their own, in the chilling winters of their old age.

Let those theorize who will, concerning the origin of the prairies, but every day's observation in the whole State from south to north, and from east to west convinces me that there is nothing more certain than the growth of all kinds of our native trees upon prairie soil, and their rapid encroachment upon the prairies without further aid from man than keeping out the annual fires.

Extended observation has also convinced me of the fact that there is now more timber growing in Iowa than there was twenty-five years ago.

The immediate surface of this county is underlaid in the southern parts by rocks of sub-carboniferous age, and in the central and northwestern parts, by rocks of Devonian age, consequently the whole county is beyond the limits of the coal-field. It is well watered, and the streams and springs are beautifully clear. There is a sufficient supply of stone for all ordinary purposes of building, and the manufacture of excellent lime. The surface is nearly all beautiful

and fertile rolling prairie; the groves, and strips of timber along the streams afford sufficient fuel and fencing for the use of the present inhabitants, the only deficiency being the want of a full supply of this material to meet the demands of the prospective population of a region otherwise so inviting.

PEAT.

It was intended that extensive examinations of the northern part of the State should be made in the search for peat in the autumn of 1866, and in September of that year a brief article was published by me in several of the newspapers of the State, calling attention to the fact, and stating at the same time the reasons which induced the belief that peat would be found there. The substance of that article is repeated in the following, because there are so many of our citizens who are unacquainted with that fuel. It may be that the following description of the conditions under which peat is found, will not fully answer for all the deposits that may be discovered in the State, for these descriptions were drawn from observations made principally in the counties of Franklin, Wright, Cerro Gordo, Hancock, Winnebago, Worth and Kossuth.

Peat had its origin in the partial decomposition of vegetable matter under water, or in a condition of great moisture on, or near the site of its growth. In some parts of the world, having a moist atmosphere, it is found occupying elevated positions; but in our State it may usually be looked for in low marshes, most of which have doubtless once been ponds. Wherever a pond has existed, rank grasses, rushes and other plants, have grown upon its borders, and the frosts of each returning November laid them beneath its surface, their comminuted fragments narrowing the area and lessening the depth of its waters until the surface become the proper habita of a peculiar moss which continues to flourish upon the rapidly-decomposing bodies of the parent stems without a proper root, and which, with the remains of the grasses and other plants that grew with it, has filled some of them with the carbonaceous matter thus produced. A few of these ponds we find only partially so filled, a large margin of peat marsh surrounding the open water in the middle.

Again, upon the gentle slopes of some valleys, a belt of springy land often exists, where the water constantly oozes out along a considerable distance, and is not gathered into a definite spring stream. Under such conditions the necessary constant supply of water will be furnished for the growth of the moss and other plants, the remains of which form the peat. In such cases the accumulation of peat is not in the bottom of the valley, but upon its slope, commencing just where the water begins to issue. But in a country so dry as ours, we can seldom expect to find peat where there have been no ponds, and consequently it is not to be expected in the well-drained regions of our State in large quantities.

At the close of that period in our earth's history known among geologists as the glacial epoch, when the continents which now exist had already assumed their present dimensions and shapes, that portion of the surface in which our State is situated was much more uniform than it now is. Shallow depressions only existed then, and these gave initial direction to the courses of the streams into which the surface waters were gathered.

The rains, floods and frosts of the unnumbered years that have passed since then, together with the steady flow of the streams, have worn their channels deeper and deeper, causing the deepening also of their tributaries as well as the small ravines which lead into them. Thus wherever the streams are numerous, and their valleys deep, the country is perfectly drained; and consequently few or no ponds are found. But in a region where streams have their rise the depressions will, for a part of the year at least, be filled with water, because there is no accumulation of water beyond to send a current across them to cut a channel for their outlet. In the northern portion of Iowa the streams are numerous, and the region consequently well drained; but many of those streams having their rise in the northern part of the State, the physical conditions exist there which are necessary to the formation of peat. It must not however be understood that peat does not exist elsewhere, for it is well known that many excellent deposits are found, even as far south as the center of the State; yet the northern portions may be regarded as pre-eminently its peat regions.

The general surface occupied by the counties before named is of a more or less undulatory character, and although not possessing very strongly marked features, its prairies seldom present that well defined ocean-like horizon which one frequently observes upon the prairies further to the southward. A very large proportion of the surface is prairie; that is, it is covered with the usual prairie grasses and plants; and being largely destitute of trees, it presents to the eye a great many slight, irregular, rounded elevations associated with corresponding depressions. Some of these depressions are occupied by ponds and lakes because they do not communicate with each other so freely as the depressions do in well-drained regions; and a part of these ponds and lakes have become changed into peat marshes. Why they have not all become so changed is not known, but there are a few ponds and small lakes in this region which show little or no tendency to the formation of peat, even along their shallower borders. A range of these peatless lakelets, comprising a quite a number, exists along the "divide" between the Iowa and Boone rivers in the counties of Hancock and Wright.

They vary from half a mile to a mile and a half across, to some of which the settlers have applied appropriate names and some have none. Indian names are sometimes beautiful and perhaps appropriate, if we new their real signification, but Indian names are not popular among those who have so lively a recollection of the atrocities of Inkpadutah and his murderous band, and who have lived so near the scenes of their carnage. It is, therefore, thought not inappropriate to apply the personal names of Iowa's fair daughters to these beautiful lakelets. Thus Lake Cornelia will be found to lie principally in section sixteen, township ninety-two, range twenty four. Lake Flora is near the southeast corner of township ninety-four, range twenty-five, and Lake Mary is within a quarter of a mile to the eastward of it. The two last named, have been called Twin lakes, but this is an appellation given in a number of instances, in the northern part of the State, to lakes which happen to lie near each other. Lake Gertrude is about three miles west of Belmond, lying principally in section twenty-eight, township ninety-three, range twenty-four. Close to the border of the latter lake is a small pond which lies five or six feet below its level, and well

illustrates the relation which the peat marshes are sometimes found holding to each other.

The streams of this region have not those well-defined bottom lands which are so characteristic of the majority of the streams of Iowa, but there is generally a gentle and almost imperceptable descent from the higher lands between them, so that one can not say where the highland begins and the bottom ends. The whole surface, from near the streams to the low dividing ridges, is undulatory, so that the appearance of the descent is sometimes obscured. Thus the peat marshes are as numerous among the low knobs of the "divides" as they are nearer to the streams.

As before said the common prairie grasses and plants cover the general surface, but usually as spon as the border of the peat marsh is reached, there is a sudden and almost entire change of vegetation. The peat vegetation may be said to consist of a single species of moss and another of a peculiar grass. While other plants may, and do often grow upon, and enter into the composition of peat; mineral impurities, such as common soil and sand, which form the natural habitat of those plants, may, from this circumstance, be expected to have been diffused in the peat through the agency of floods, high winds, etc.; because these mineral constituents of soil seem to be indispensable to the growth of these plants, while they do not seem to be necessary to the growth of the moss and wire-grass. The peat of marshes near the banks of streams is subject to such impurities, while that of those marshes which are so situated that they can receive no washings from the surrounding surface, is found comparatively pure. Such marshes are covered almost exclusively, with the two species of vegetation just mentioned. Thus a very correct judgment may often be formed of the character of a marsh, by seeing its vegetation, without going upon it. It has been noticed that where the scouring rush grows profusely among the real peat vegetation, we do not usually find the peat very thick, nor very pure; yet none of the marshes are entirely free from this rush.

As we stand upon the higher land and look over one of these marshes, almost the only vegetation growing upon it which meets the eye is the peculiar grass before referred to, known among the inhabitants as *wire-grass*.

No specimen of this grass was found in flower or seed, but it is seen that it increases and renews its growth by lateral budding near the roots. These roots form a somewhat loose but very tough sod upon the surface. The leaves are long, slender, somewhat rounded and cellular. Being of nearly uniform length — two or three feet — the level marsh, stretching sometimes more than a mile away, presents much the appearance of a lake, as the wind blows over the waving grass. This is the general appearance of the peat marshes, but there are some marshes presenting this general appearance which contain little or no peat, although its formation there is probably in progress. These are generally small and consequently shallow. Considering the undulatory character of the surface before mentioned, it would be expected that the smaller marshes would be shallow, but this would of course depend in a great degree upon the abruptness of the undulations. Again, there are very broad marshes in a comparatively flat region, the peat of which, for obvious reasons, is quite shallow.

Those marshes which lie upon the more undulating surfaces are frequently arranged in series, each successively occupying a little lower level than the other, and not far apart, like the pond before mentioned near Lake Gertrude. In such cases the marshes may be easily drained from one to another, and finally into the brooklets to which they give rise.

Approaching the marsh, we find in most cases, as soon as we reach the moist ground in the vicinity of its border, the presence of growing moss among the ordinary prairie grass and plants. The moss increases in quantity as the surface becomes more moist, and upon reaching the peat surface we usually find it covered with a thick, soft carpet of moss at the roots of the wire-grass. As we walk upon the surface, if the peat is of any considerable depth, we perceive it quaking beneath us, producing the feeling of danger that we may slip through the loose but tough sod into the soft material below. Cutting through this sod with a sharp spade, and lifting out a piece as deep as the spade-blade, we find it a thickly interwoven mass of moss and grass roots in different stages of decomposition, which increases with the depth, so that the lower portion of it may be easily pulled to pieces with the fingers. This, and all between it

and the earthy muck at the bottom, is peat, yet the sod itself, when dry, will make a good light fuel.

Peat, in various parts of the world, differs much in quality — from a fibrous mass, almost as light as sponge, to a smooth, homogeneous substance, almost as dense, when dried, as coal. Our Iowa peat partakes of the fibrous character, but is not of the lightest varieties. It varies considerably in quality, or perhaps more properly speaking, in ripeness, by which is meant the more or less complete destruction of the vegetable texture in which it had its origin as a top sod, and which has been left beneath to perfect its peculiar decomposition, by the accumulating growth above. Thus when we bring up specimens from various depths we find that the deeper ones will usually dry into a more compact mass than the others. This is consequently a better fuel; not that it will burn any more perfectly, but being more compact it is more durable and capable of producing a more intense heat. Peat in the marsh holds within its substance almost an incredible amount of water, and where it is of considerable depth it quickly absorbs the rain which falls upon it, the surface rising and falling to a limited degree as the moisture dries out by evaporation, or is supplied by the rains; consequently the surfaces of the deeper marshes have no water standing upon them during the greater part of the year, even when communicating with the open water of an adjoining pond.

The citizens of Iowa are so universally acquainted with the numbers used in the government land surveys that no explanation is deemed necessary to a list of localities presented in that form. Indeed it is the only method by which localities in such a region could be definitely indicated. The marshes indicated in the list were all visited and tested by myself in person, but for the numbers indicating them I am indebted chiefly to the principal inhabitants, who are well acquainted with the land surveys, and many of whom accompanied me in the examinations. They indicate that the marsh lies wholly or principally upon the sections whose numbers are given, and are doubtless in the main correct. The number of acres given in the table was estimated, not measured, but an effort was always made to be quite within the limits of truth. The depth mentioned, is the greatest depth ascertained. Most of those indicated as six feet are doubtless deeper, for that was the length of the probe handle used, and when a greater depth was reached, a hole was dug with a spade in which to work the probe. Towards the borders of the marshes the depth was of course

always less than that indicated in the list, but the borders having less than two feet of peat were always excluded from the estimates.

NAME OF COUNTY.	Marsh.	Section.	Township	Range.	No. Acres	Feet deep.
CERRO GORDO	1	2	97	21	200	6
		11	97	21		
		12	97	21		
	2	13	97	22	100	7
		14	97	22		
	3	14	97	22	200	6
		15	97	22		
	4	25	96	22	125	6
	5	36	97	20	150	6
	6	2	96	19	100	7
	7	5	97	20	50	4
	8	23	100	20	250	8
		25	100	20		
		26	100	20		
	9	33	100	20	50	5
	10	8	99	20	150	5
	11	27	99	20	40	4
	12	1	99	21	75	5
		12	99	21		
	13	24	99	21	20	4
WORTH	14	13	99	23	40	6
	15	2	99	23	40	7
	16	24	99	23	450	6
		19	99	22		
	17	7	100	22	40	7
	18	14	100	22	100	7
		15	100	22		
	19	27	100	22	300	7
	20	27	98	22	300	7
		28	98	23		
	21	5	97	24	40	7
	22	5	97	24	50	6
	23	35	98	25	100	7
WINNEBAGO	24	20	100	24	1000	7
		21	100	24		
		28	100	24		
		29	100	24		
	25	19	98	23	1000	7
		30	98	23		
	26	1	97	25	500	7
	27	10	97	24	60	4
	28	3	97	23	50	4
	29	1	95	24	80	4
HANCOCK	30	9	95	24	500	5
		4	95	24		
		16	95	24		
	31	36	96	25	150	6
	32	11	94	24	100	9
	33	4	94	24	100	6
	34	35	93	24	150	4
WRIGHT	35	16	90	24	250	5
		21	90	24		
	36	21	90	23	50	4
KOSSUTH	37	1	95	29	40	4
	38	28	97	28	200	7
	39	16	96	29	100	4

The foregoing list of marshes is intended by no means to be a complete one for the region named, the principal object being to call public attention to the fact of the existence of large quantities of valuable fuel which have thus far been overlooked. All the marshes known to exist in this region were not visited, and many were seen that are larger than some of those here enumerated. Besides these, small marshes containing from ten to thirty acres each, with from two to four feet of peat, are very numerous. These are not included at all, although they will be capable of supplying the persons who own them with all necessary fuel within their own means. Other beds, again, it will be seen, are so large that they will supply material for the most extensive machinery, as soon as the demand will warrant it. Residents of this region have estimated, and perhaps correctly, that the counties of Cerro Gordo, Hancock, Worth and Winnebago, contain four thousand acres each of good peat lands. Certain it is that the supply is so abundant, and so generally distributed, that it will be very difficult for capitalists to obtain a monopoly of it. Kossuth county has been only partially examined, but it is known to contain some very fine marshes, and it is expected that its northern part will be found to contain many more.

In other parts of the world we learn that peat is found having a depth of thirty or forty feet; but we have as yet no reason to expect the discovery of any such beds in Iowa. In the region under discussion, the character of the surface, as before described, forbids it; the inequalities are too gentle to leave depressions of that depth which might become filled with peat. The majority of the marshes have probably less than six feet of peat at their greatest depth; yet some are already known to be more than eight feet deep.

So little is known by those who live in the West concerning the use of peat, that many questions which naturally arise, can not at present be answered. From the fact that much is said about the manufacture of peat, and that many machines are offered in the market, those who find themselves the owners of peat marshes earnestly ask the question: "Is it indispensable that peat must pass through a process of manufacture before it can be burned? If so, it is necessary that a capitalist with $5,000 or $10,000 should

stand between us and a supply of fuel from our own lands; or may we not prepare a good article within our limited means?"

These are important questions and will be answered as clearly as possible. It is *not* indispensable that peat should be manufactured before it is burned, for it has been used in the crude state for hundreds of years. Drain the marsh by cutting one or more ditches clear through it, communicating with the outlet, and put a gate at the outlet that you may protect it from the annual prairie fires by flooding it. When well drained, strip off the sod with a very sharp spade. Then with the same spade, or better still, with an Irish *slane*, cut the peat into convenient blocks, dry them on the ground, and store them in a dry place for use. The slane is an instrument something like a spade with the blade, which is of thin steel, about sixteen inches long and ten inches wide, bent at right angles like a carpenter's corner-chisel, so that the two sides will cut the width and thickness of the peat block at the same thrust.

This is the simplest method of its preparation, but the same peat which thus prepared will answer in a satisfactory manner all the purposes of ordinary fuel, can be rendered a very superior article, both for domestic and manufacturing purposes, by a condensing process of manufacture. The advantages gained by manufacture are the reduction of bulk, so as to require less storage room, and the increase of density enables us to produce a hotter fire within a small space.

Machines have been constructed for compressing peat into blocks when partially dried, and, although the fuel is much improved thereby, it has been found that the compressed blocks quickly disintegrate by absorption of moisture from the atmosphere, and by handling, so as to render it inconvenient and troublesome. It is now generally conceded that a *condensing*, and not a compressing process, is the proper one to be adopted in the manufacture of peat; and this view is without doubt the correct one. The condensing process consists in grinding the peat while wet, in a properly constructed mill, into a smooth pulp, which is then moulded into convenient blocks, without great pressure, and dried for use. While these blocks are drying, the cellular spaces which existed between the fibres of the crude peat, being broken up by the grinding process,

they shrink into a compact mass, quite unlike the light, crude peat from which it was manufactured. When thoroughly ground and prepared in this manner, it shrinks by the natural process of drying alone, into denser masses than blocks of the same peat would be when dry, after having been compressed by the most powerful machinery, without previous grinding, when, of course, the violent compression would be useless.

No data have been obtained by which to estimate the difference in value between the well-manufactured and crude peat, but, judging from specimens in my possession, it is certainly as great as that between bass-wood and good hickory.

Well-dried hickory is probably the best fire-wood in use, but, from the fact that it will float upon water, while pure, dry, well-manufactured peat will sink in it, it is evident that the latter contains the greatest amount of combustible matter, bulk for bulk.

There is no doubt of the value of the large condensing machines, such as Leavitt's and others, for those who wish to establish a business for the manufacture and sale of peat, but a great desideratum is a small machine which will come within the means of every family in the peat regions, so that they may prepare their own fuel by their own labor. Peat being much improved in quality, even by an imperfect grinding, it is not improbable that small machines may soon be introduced that will produce an excellent article of domestic fuel, in a more convenient form than it usually is when taken from the marsh without preparation.

Upon comparing samples of Iowa peat with my specimens from Ireland, and from various parts of our own country, no doubt is entertained that ours is all of excellent quality, nor that it will soon become invaluable in the settlement of the region where it is found. Estimates have been made as to the value of peat compared with wood and coal. According to some of these estimates a ton of well dried, compact peat is equal in heating power to a cord of hickory wood, but as far as the greater part of the Iowa peat region is concerned, it is perhaps, sufficient to say that the results have not been disparaging to peat, but such estimates are not at all necessary in this case, for the real peat region lies wholly beyond the limits of

the coal-field, and the timber although enough for the present inhabitants, can not supply a tithe of the fuel which the prospective population of a region so fertile and inviting, will soon demand. Peat has there a local value which can never be questioned.

Peat may be burned in ordinary fire-places, grates and stoves, but appliances, peculiarly constructed for its use, will doubtless be found in the market as soon it is generally known that there is a demand for them, and experience as to the best methods of its use will be gradually acquired. Messrs. Mumford & Emsley of Mason City, are making great efforts to introduce the use of peat among the inhabitants of their neighborhood and have just started a small mill for its manufacture at that place. These gentleman have resolutely overcome many difficulties, and the supervisors of Cerro Gordo county have very commendably encouraged them by giving them a favorable contract for furnishing the county offices with fuel.

The amount of fuel which the marshes of this region may be made to produce is immense; and yet they are not sufficiently numerous to be a reproach, as they are in some parts of Ireland; nor of such a character as to be an unsightly blemish upon its fair and fruitful surface.

The following data are believed to be reliable as to the amount of peat to be obtained from a given number of acres, and of its value as fuel;

Two hundred and fifty tons of dry fuel per acre of well-drained marsh for every foot in depth; the marsh being estimated to settle from one quarter to one third of its original depth by draining.

Thus we may estimate upon the annual allowance of thirty tons of peat to each family, that one hundred and sixty acres of peat, four feet deep will supply two hundred and thirteen families with fuel upward of twenty-five years.

Knowing the rapidity with which our forest trees will grow upon our soil, this would give ample time to grow a supply of fuel to be used when the peat should become exhausted.

Having necessarily been familiar with the few diseases prevalent in Iowa, I took particular care while in the region of peat marshes to make inquiries and observations concerning the health of the

people who live there. The time occupied by my examinations was, that portion of the year, when malarial diseases prevail (if they ever do); but I did not see or hear of a single case of those diseases, *nor of any other*. The presence of the peat marshes is evidently in no way prejudicial to health, from the fact that the profuse vegetation does not reach a complete state of decomposition, the resulting peat being itself antiseptic in its properties.

After the examinations referred to in the foregoing pages were made, three important marshes in the central parts of the State were visited, beside one in Whiteside county, Illinois. It has been observed in the northern part of the State that those marshes whose vegetation is almost exclusively wire-grass and moss contained the purest peat, and that those which contained a greater proportion of foreign matter had a mixed vegetation growing upon them. These marshes in the central parts of the State all have a somewhat mixed vegetation, yet the peat is usually very pure. Whatever may be the character of the more conspicuous vegetation, the moss is always present upon all marshes, and always enters largely into the composition of the peat.

Peat has been manufactured from all but one of these during the past season, and from these sources some very encouraging data were obtained concerning its manufacture and the great favor with which it is received as a fuel by those who have tried it.

The first marsh visited is situated in Muscatine county, principally upon section fifteen, township seventy-seven, range four, eight miles south of West Liberty, and about twelve miles from Muscatine. It contains about one hundred and fifty acres of peat, and the depth is reported to reach thirteen feet in some places. This marsh is on the line of the Burlington & Cedar Rapids Railroad, three-quarters of a mile from the right bank of Cedar River, and occupies an ancient bed of that river which was deserted as it cut its channel deeper, so as to leave a pond there which is now beyond its highest floods. This pond, supplied with a large part of the necessary moisture by springs which ooze out from the base of a sandy bluff about twenty feet high which partly encircles the marsh, has become filled with peat.

The reason why other similar depressions left by the receding river have not become so filled, may perhaps be found in the fact that they do not possess the surroundings that this one does, namely: stretching away from the low bluff which borders the marsh is a level tract of land which is itself bordered on the west by another low ridge having the general direction of the course of the river. Along the base of this ridge is marshy ground, but it is not a peat marsh, although it doubtless occupies a still more ancient bed of the same river. Between these two marshes the soil and subsoil is sandy, so that the water which falls upon the level tract quickly percolates through to the peat marsh or to the river. The peat of this marsh is good, and it will be of great value to the region where it is located.

The next marsh visited contains about thirty acres, and is situated on section eleven, township eighty-three, range six, about four miles west of Marion, Linn County. It is reported to reach ten feet in thickness, but where it is now worked, it is about five feet deep of drained peat. Mr. Hoffman and Mr. Cougill are the owners of the land, but Messrs. Traer and Bundy have leased it, and have commenced manufacturing the peat for market, using a machine which is an invention of the last-named gentleman. It was not in operation at the time of my visit, but some very good specimens of the peat prepared by it were obtained for the State collections. This is one of the best examples of a "spring marsh" yet seen. It lies wholly upon the gentle slope bordering one of the upper branches of a tributary of Cedar River, hardly reaching the branch itself. It is fed with moisture by springs which issue along this slope, while upon the opposite one there is little or no peat, doubtless because few or no springs exist there. The deposit is so rounded in its central portions that in general aspect it has very much the appearance of one of the ordinary elevations of the undulating surface of that vicinity. The marsh has been easily drained by cutting a ditch from its upper to its lower border, in which pure water flows, a perpetual spring. The above-named firm are producing a good article of fuel, and will no doubt be able to supply the demand next year.

Another marsh, containing about two hundred and fifty acres, two hundred acres of which contains peat of good workable depth, is

found in Clinton County, upon section twenty-nine, township eighty-one, range two, about two and a half miles south of Calamus station on the Northwestern Railway. A dense fog prevailed during the whole day this marsh was visited, so that the surrounding features of the country could not be seen, but there are some indications that it was formerly a pond. The subsoil of the region around it, however, being sandy, it is quite probable that it has derived its moisture largely from springs.

A firm have established machinery here for the manufacture of peat, but the season closed before they were fairly able to introduce the fuel to the market. Mr. Isaac Heald, of West Liberty, one of the proprietors, informs me that they expect to prosecute the business energetically as soon as the spring opens.

In Illinois, about seven miles eastward from Clinton, there is a very large peat-marsh where two or three machines have been in effective operation during the past season. At this marsh an opportunity was had to see some very satisfactory results of the manufacture, although none of the machines were in operation. The blocks of peat manufactured here are almost as dense as coal, and Mr. Dodge, one of the proprietors, informs me that he has not been able to supply the demand which already exists for it at seven dollars per ton. He also tells me that the cost of manufacture does not exceed two dollars per ton. Here is a profit, then, which ought to satisfy any one.

A ton of prepared peat being equal in value to a cord of hickory wood, and the latter averaging throughout the State, after being prepared for the stove, at least six dollars per cord, it is easy to see that peat will be valuable anywhere. But this is not the only way to estimate the value of peat to the northern part of the State. For instance, if by some possible disaster all the forest trees of a region dependent upon that source alone for fuel, should be swept out of existence. The loss would not be the market value alone of the fuel destroyed, but that loss would greatly lessen the value of all the other property of the region thus affected. The converse of this is also true; a region possessing all other elements of wealth, but heretofore supposed to lack one essential element, receives additional

value by the discovery of that element. The assurance that a sufficient amount of fuel exists in those almost treeless but fertile regions of Northern Iowa, will cause its settlement nearly a generation before it otherwise would be.

GYPSUM.

Although gypsum has been known to exist in the vicinity of Ft. Dodge, in Webster county, for more than twenty years, the public have had very little information concerning it. Information of this kind being desirable to the people of the State, about two weeks of last October were given to the examination of the region by myself and Mr. St. John, upon my return from the peat region further north. Although all the exposures of gypsum are found within an area of six miles in extent, northward and southward, and three miles eastward and westward, the amount of material is so great that it is practically inexhaustible, and, withal, it is one of the most remarkable deposits of this substance yet known.

The region round about has the general prairie surface so characteristic of a large portion of Iowa, but along the Des Moines River and its tributaries there is a good supply of timber covering the valleys and slopes which, with the bold features of the river valleys, give many interesting landscape views, and make Ft. Dodge one of the most pleasantly located towns in the State. The river has eroded its valley here to a depth of more than one hundred and twenty feet from the general prairie level, and it is along its steep bluffs and upon the sides of the creek valleys and ravines which lead into it that the gypsum is found. It is exposed in bold quarry-fronts, having in the distance almost the exact appearance of limestone, and one at first finds it difficult to believe that it is any thing else. At one exposure on the southwest quarter of section thirty-three, township eighty-nine, range twenty-eight, we measured twenty-eight feet in perpendicular thickness of solid gypsum. There is no doubt that it reaches thirty feet in thickness at that place, further into the bluff, and it is believed to be equally thick in other places. The gypsum rests upon shale, which, when exposed to atmospheric influence, softens into clay. Upon this, large masses have slidden down in some

places from their natural position, increasing the *apparent* thickness of the gypsum deposit, but we saw nothing to convince us that it is anywhere much more than thirty feet thick. The lines of stratification are horizontal and well marked, and no doubt is entertained that the formation is continuous horizontally over a great portion of the area, and perhaps further, just as limestone formations are.

Gypsum in other parts of the world is often found in irregular masses associated with shales and limestone, but here the deposit is one of solid gypsum, not intermixed with layers of shale or any other substance. It is proper to say, however, that all we yet know of this, or other deposits, leads to the belief that ours may not actually extend much beyond the region in which it has been discovered. The clearly defined base of the gypsum was several times found, but the top of it is always indefinite in consequence of erosion by water which reaches it from the surface.

The base of the gypsum deposit being so well defined we were able to clearly ascertain that it rests *unconformably* upon the strata beneath it. In consequence of this unconformability and the fact also that it contains no fossils, we do not know with certainty its geological age; but it is probably much later than the carboniferous age, since the strata of that age are now well understood in the west, and no true unconformability has been found to occur among them in Iowa, above the sub-carboniferous. Any one may recognize this unconformability by going down Two-mile creek from the exposure just mentioned where the base of the gypsum is seen resting upon the coal-measure shales. Following down the creek he sees the shales, clays and sandstone, as well as a little coal, exposed at intervals along the creek, and the gypsum above it all in the sides of the hills. Reaching the mouth of the creek and going three-quarters of a mile down the river shore he will find a small exposure of the same limestone formation that is seen in Lizzard and Soldier creeks above town. He will thus have passed down through a vertical thickness amounting to about one hundred feet. Now let him go to Mr. Mitchell's gypsum quarry on Soldier creek, which is about five miles to the northward from the last named locality, and he will find the base of it in such position that it must rest almost,

if not directly upon the limestone which Mr. Cummins is quarrying for his kilns a few rods distant; showing that although some coal measure shales are exposed on Soldier creek they are wanting at this particular point. This is what is meant by unconformability, and it gives in this case, satisfactory evidence of the want of other formations between the coal-measures and the gypsum. The limestone just mentioned is known by its fossils to be the same as that on Lizzard creek, and also that just mentioned on section five, township eighty-eight, range twenty-eight. It is sub-carboniferous limestone, and although not seen in all places along the river and creeks, doubtless underlies the whole region at no great depth.

The principal exposures of gypsum are three or four miles below Fort Dodge, but some important ones are almost within the city limits. Upon sections six and seven, township eighty-eight, range twenty-eight; sections one, two and twelve, township eighty-eight, range twenty-nine, and section thirty-three, township eighty-nine, range twenty-eight, they are very extensive and easily accessible. Very important exposures are also found on other sections, all of which have been mapped by us for publication in the final report, and we estimate that following down all the creeks and ravines in the region, limited as it is, one will find not less than seven miles of continuous exposure of gypsum, upon which quarries may be opened anywhere by a day's labor.

Masses of a few hundred pounds weight of white gypsum, almost chemically pure, have been found associated with that of the main deposit, but so far as observed they seemed to be somewhat concretionary in form, and partially detatched from it. The main deposit is of a rather uniform grey color, somewhat in shade like that of a printed page, yet plaster-of-paris prepared from it is nearly white. It has been fully tested at the Geological Rooms, and found inferior to none in quality.

It may be necessary to state for the benefit of some readers that gypsum is a chemical compound of sulphuric acid, lime and water. It is much softer than ordinary stone, and when crushed and ground to a fine powder in an ordinary grist-mill, it goes by the common name of "plaster," in which form it is largely and beneficially used as a fertilizer. If this dry powder is placed over the fire in an iron

cauldron it boils as if water had been artificially added to it. This is caused by the escape of the water before mentioned, which, when thus chemically combined, although nothing but common water, is just as much a solid as the lime is with which it combines. When the boiling has ceased the powder consists of sulphuric acid and lime alone, in which form it is called "plaster-of-paris," and is used in the arts for stucco work, models, ornaments, statuary, &c.

When plaster-of-paris has been long kept it absorbs water from the atmosphere, and thus approaches its original condition again. It can be fully restored to its former quality by re-boiling, of course adding no water.

The reason why objects formed in plaster-of-paris do not shrink in the process of drying, as other substances do when mixed with water, is because a large part of the water used to mix the powder with, enters again into chemical union with it, and is not again evaporated at ordinary temperatures.

The principal uses to which gypsum is applied are those just mentioned, but the people of Fort Dodge have been using it in the place of common stone. Some years ago, Hon. John F. Duncombe built a large, fine residence of it in the city, and he informs me that he is perfectly satisfied with it as a building material. Several other smaller buildings have been built of it, and large slabs which some of the quarries afford make excellent sidewalks, because they do not become slippery as stone walks do. We have no information that gypsum has ever been used as a building stone anywhere else than at Fort Dodge, consequently its citizens are as competent to decide that question as any one, but the following facts are worthy of consideration in estimating its value for such purposes. About three parts, by weight, of gypsum are soluble in one thousand parts, by weight, of water. If water which already holds gypsum in solution, rests upon it, it will not be affected thereby, but if it be exposed to the action of running or falling water, it will be rapidly destroyed. This effect is often seen where little rills of water caused by the rains, run over the face of an unused quarry, and cut deep grooves into it, sometimes giving it the appearance of melting ice around a waterfall.

When built into the walls of a house only a small portion of its

surface is exposed to occasional rains, the effect of which must be very slow, indeed, upon it. This effect can be almost entirely prevented by an occasional coat of linseed oil, which also improves its beauty, as can be seen in Mr. Duncombe's house. Wooden buildings require such protection, and even with it are probably no more durable than those built of gypsum, for those thus far built of the latter material show no signs of failure or decay. With the immediate prospect that Fort Dodge now has for railroad communication, her gypsum quarries must become very valuable.

By rough estimate it is calculated that there is now annually used in our State about seven thousand dollars worth of plaster-of-paris, for mechanical and artistic purposes alone, all of which is brought from other States, and from the province of Nova Scotia; the nearest of which localities is more distant from our State than Fort Dodge is from the most remote town within it. Should the manufacture of plaster be commenced at Fort Dodge, the State of Iowa would not furnish the only market for it, but Minnesota, Nebraska, and parts of Missouri, Illinois and Wisconsin would also find it more convenient to obtain their supplies of this material from Fort Dodge than from any other source.

This estimate does not include fertilizing plaster, which it is believed will largely benefit even the rich soils of Iowa, for it is doubtful whether the action of plaster upon soil is so much a fertilizer, in the common meaning of the term, as an agent effecting the retention of moisture. In either case, its effects are beneficial.

Allowing that the gypsum does not extend beneath the greater part of the area before mentioned, as it is believed to do, but that it is no more than fifty feet wide from the face of the exposures, and only twenty instead of thirty feet deep, the following figures show the supply of material that can be obtained from the estimated seven miles of exposure; 86,960,000 cubic feet of material as quarry rock, or 2,648,800 tons of plaster for fertilizing purposes, or 2,092,860 tons of plaster-of-paris for use in the arts. These estimates are based upon the following data: Quarry gypsum weighs 143½ pounds per cubic foot. When this is separated from its water of crystalization by heat, it leaves 113½ pounds of plaster-of-paris. These estimates are believed to embrace only a fraction of the

amount of material which actually exists there, and are only given to call attention to the great importance of that deposit.

Gypsum is much more easily quarried than stone. Instead of being drilled for blasting, it is bored with an augur as readily as wood, and blocks are dressed into any desired shape with common axes and saws, instead of being done with stone-masons' tools. Thus the labor of preparing it for building purposes is much less than that required for the preparation of stone for the same uses.

Salt is so often found in connection with gypsum deposits, that the suggestion often arises whether we may not expect to find it in connection with that deposit at Ft. Dodge. All that can be said upon this point is that no indication of the presence of salt in that region has yet been observed, and that since we are quite well acquainted with the condition and character of the strata which underlie the gypsum, the probabilities that a salt deposit exists there are not encouraging.

COAL, STONE, &c., AT FT. DODGE.

The season being so near its close, very little time could be given to the examination of the coal-measure strata in this vicinity; but enough was seen to convince us that the Ft. Dodge region, as a coal-producing district, has been much underrated. There is good reason to believe that the coal-field does not extend much to the northward of the city, but there is evidence that up to a point four or five miles below the city there is a very important development of the productive coal-measures.

A short time was spent in that vicinity, in company with Mr. Duncombe, visiting the mines and exposures of coal. These are principally along Holladay's creek, and the branches which lead into it, and also into the river.

We saw evidence of the existence of four different beds of coal here, all lying above the level of the Des Moines River, two of which are very important. One of these beds is known to reach a thickness at one point of nearly five feet. This is now thought to be the highest bed in the series in this vicinity, but we are not fully satisfied upon this point. It is believed to be one of the lower beds that is operated by Hon. Samuel Rees, near the bank of the river, just below town.

This is evidently not very far above the limestone, and is probably the lowest bed of bituminous coal in the region. Thomas Sargent, Esq., has an exposure of coal at his farm on Lizzard creek, some four miles west of town, which is believed to be identical with the bed of Mr. Rees' mine, and if so there is probably no other coal beneath it, unless it be the bed of impure cannel coal which is seen in the river bank, on section seventeen, township eighty-eight, range twenty-eight, which bed also probably underlies Mr. Rees' mine.

The sub-carboniferous limestone, before mentioned as occurring at the base of the coal-measures at Ft. Dodge, is known by its fossils and general characters also to belong to the St. Louis division, and is identical with that so often mentioned before as forming the floor (so to speak) of the coal-measures in Marion, Mahaska, Wapello, Van Buren, Jefferson and other counties to the southward, as well as in Hamilton, the next county eastward from Webster. This limestone seems to rise and disappear with considerable rapidity to the northward, after its appearance from beneath the river in the vicinity of Ft. Dodge. Mr. Cummins manufactures large quantities of excellent lime from it on Soldier creek, just north of town, and both upon this and Lizzard creek much building stone may be obtained. Along the Des Moines river for a distance of a few miles there are also large exposures which thus far have remained almost untouched, because the gypsum is obtained with less labor for the same uses that common stone is usually applied to.

In some places in the vicinity considerable quantities of the ordinary coal-measure sandstone are to be obtained, some of which would make good coarse building material, but much of it is poor.

In the spring of 1866, a very small deposit, containing a few hundred pounds of fine columnar sulphate of strontia was found in the coal-measure strata near Mr. Rees's mine just below town, and at the top of the gypsum on Soldier creek, a small quantity of the same mineral was also found. This is believed to be the first instance of the discovery of that mineral in Iowa. It is true it has very little economic value, except that it is used to produce the red light in fire-works, but it is very interesting to the mineralogist.

BOONSBORO COAL MINES.

While on the way home at the close of the season a very brief visit was made to the coal mines at Boonsboro.

These mines are opened at intervals along each side of the valley of Honey creek, which empties into the Des Moines river near Boonsboro and also along the hill sides bordering the river; all of them opening almost directly upon the Northwestern Railway. Two beds are now being worked here, one of which is a little over three feet, and the other two feet in thickness. These it will be seen, although they furnish large quantities of good coal are not by any means so heavy beds as some others in Iowa; and yet there are no mines in the State which have a greater present, and perhaps I may add, a greater prospective value, than those of Boonsboro. This arises from their unusually favorable location, affording them a good market at high prices, and also, from the further fact that they are intelligently and extensively worked. A number of the mines are in the hands of private individuals, but far the greater part of the coal land is held, and the coal taken out by two companies, the Northwestern Coal Company and the Moingona Coal Company. The former company, beside the products of its own extensive mining, purchase a great part of the coal taken out by private parties for shipment with their own. Much the greater part of the coal which this company ships, goes to the great Pacific Railway, the Northwestern Railway being supplied principally by the Moingona Company. From the fact that these two great lines of railway consume nearly all the coal of this region as fast as it is mined, very little has hitherto been known, by the general public, of the importance of the Boonsboro mines.

The Northwestern Coal Company are shipping about one hundred tons of coal per day, and this is probably not much more than half of the aggregate amount mined per day in that neighborhood. All the coal is sold as fast as it is raised, and the demand is constantly increasing. The energy with which these mines are worked gives some faint indication of the immense quantities of coal which our mines in other parts of the State will furnish when railroad facilities and other improvements shall have opened a market for it.

MISCELLANEOUS.

OBSERVATIONS UPON THE DRIFT PHENOMENA OF SOUTHWESTERN IOWA.

The following article was first published in the *American Journal of Science and Arts* (Silliman's Journal), for May, 1867:

In the year 1858, I discovered distinct glacial scratches upon an exposed layer of the Upper Burlington limestone (sub-carboniferous), and made full notes and drawings of the same, which having been unfortunately destroyed by fire within a year afterward, no account of the observations was ever published. No opportunity has since presented itself to verify those observations, but I think I am not mistaken in the recollection that there was but one set of scratches, which were straight, distinct, and rather numerous; having a direction south, about twenty-two degrees east. This, so far as I am aware, was the first observation of glacial scratches upon rocks *in situ* in the State of Iowa, although boulders with similar scratches upon them are often seen in various parts of the State.

During my official labors last season, although considerable attention was given to the drift deposit, no similar traces of glacial phenomena were ever discovered, until I reached the Missouri River in Mills county, where, on section sixteen, township seventy-one, range forty-three, west of the fifth principal meridian, very distinct glacial scratches were found upon limestone of the upper coal-measures not far from the middle of the series.

The locality is upon the western abrupt slope of the bluffs which border the bottom land of the Missouri River. The river being distant nearly three miles to the westward, the exact hight of the scratches above it was not definitely ascertained, but it is probably not much less than one hundred feet above the ordinary stage of water. About four feet in thickness of ordinary drift material rested

upon the straited surface. This had been partially removed by the quarrymen, exposing the scratches to view. Resting upon this light deposit of drift, and sloping upward to the high lands, are about one hundred and fifty feet of that peculiar lacustrine deposit called by Dr. Owen "siliceous marl," and by Prof. Swallow the "bluff formation," which deeply covers the drift and underlying rocks of this region, except where they have been exposed by fluviatile denudation.

The boulders and pebbles contained in the drift material of this locality are both granitic and metamorphic. They are well-rounded and worn, and straited faces were observed upon quite a number of them, thus as nearly as possible detecting them in the very act of scoring the rocks *in situ*.

The scratches here are in two sets, a coarser and a finer; those of the latter more numerous than the former, but those of both sets being perfectly parallel with their fellows, distinct and straight. The surface of the rock had been ground level and smooth, removing all unevenness of the natural bedding surface. The directions of the striæ were determined by a very good pocket-compass. That of the coarser set (No. 1) was found to be S. 20° E., and that of the finer set (No. 2) S. 51° E. No allowance was made in either case for the variation of the magnetic needle, which the local surveyers calculate at about eleven degrees east of north.

At an exposure of the same limestone one mile below Omaha, the capital of Nebraska, immediately upon the right bank of the Missouri river, and only some six or eight feet above the ordinary stage of water, other scratches of a similar character were observed. They were found upon the upper surface of a firm layer, which the workmen had exposed and were removing for building purposes. Here, however, there is but one set of scratches, their direction being S. 41° W. (set No. 3), not allowing for variation of the magnetic needle. The surface of the rock is nearly or quite level, but the roughness of the natural bedding surface has not been entirely removed, yet the striæ were so distinct that no difficulty was found in ascertaining their true direction.

The drift at this locality is principally composed of a dark colored, stiff, clayey material, intermixed with sand, gravel and boulders, and

varies from one foot to eight feet in thickness. Upon this rests the bluff formation as before described. The face of the bluff at the locality where the latter observations were made is nearly at right angles with the direction of the striæ.

Considering that the whole region surrounding these localities, and for a long distance to the northward of them, is an entirely open country; that the present prominently uneven features of the region had their origin at a period subsequent to the drift; and the extreme simplicity and uniformity of the strata over which the glaciers must have moved, the direction of their currents which these scratches apparently indicate seems very remarkable. We not only see at the Mills county locality that the scratches upon one and the same surface prove that two separate currents existed there during some portions of the glacial epoch, having a divergence of thirty-one degrees with each other, but also, only about twenty miles to the northward, we find the evidence that another current moved in a direction which formed an angle of ninety-three degrees with one of those in Mills county.

Since we see no evidence of the cotemporaneous existence of obstructions which might have deflected the current of a regular southerly-moving glacier, and thus have produced the scratches in the various directions shown, it seems necessary that we should seek for some other explanation of them. Observations thus far made certainly afford very inadequate data upon which to base a definite theory concerning the real direction of glacial currents over this part of the continent, but the coincidence of the direction of those scratches which have been observed with the general course of the drainage of the region in which they occur, is worthy of careful consideration. By reference to the mention of the locality, near Burlington, at the commencement of this article, and to a map of Iowa, it will be seen that the direction of the scratches observed there, coincides pretty nearly with the general direction of the drainage of the eastern watershed of the State.

Set No. 3 represents a current coinciding quite as nearly with the general direction of the drainage upon the western watershed; and sets No. 1 and No. 2 respectively represent currents approximately coinciding with the general courses of the Missouri and Platte

Rivers. That the close of the drift epoch left the surface of our State unmarked by strong features, and with shallow, longitudinal depressions which gave initial direction to the courses of the streams, and that these subsequently cut out their own valleys by erosion, there seems to be no reason to doubt. It seems not improbable, also, that these initial depressions in the surface, whether primarily caused by flexures of the earth's crust, as Whitney has suggested, or not, may be regarded to some extent as indices of the general direction of ancient glacial currents.

There is another interesting matter in connection with these observations of drift phenomena along the Missouri River, and the existence of the important lacustrine deposit there. The close of the drift epoch evidently left a large depression of the general surface in the region, a portion of which is now occupied in part by the counties of Fremont, Mills, Pottawattamie, Harrison and Monona. This depression became a large fresh-water lake, the borders of which have not yet been definitely ascertained, but no satisfactory evidence of its existence eastward of the East Nishnabotany River has been observed in Iowa. The Missouri River evidently emptied into this lake, and flowed from it, until it became filled with the peculiar deposit of fine, siliceous, marly material, known as the bluff formation, the character of which is very much the same as that of the muddy material which would now be deposited from the waters of the river if it were possible to throw a permanent obstruction across it. As the valley of the river was gradually deepened during the Terrace epoch, its waters found no difficulty in sweeping out the fine homogeneous material which they had before deposited, leaving those high peculiar bluffs upon each side of its broad bottom. Fresh-water and land shells of existing species, principally Gasteropods, are often found in this deposit, from base to top, and its thickness sometimes reaches more than two hundred feet above the drift material upon which it rests.

Seventy or eighty miles to the eastward of the Missouri River, in the southern tier of counties, there are evidences that the drift deposit reaches a thickness of more than a hundred and fifty feet. Westward from that region a sensible diminution of its thickness is seen, and, reaching the region of the bluff formation along the

Missouri river, the drift material is found in all cases comparatively thin, being thinnest where the bluff material is thickest.

At the localities where the scratches were observed, the drift material showed evidences of unusual violence of glacial action, being, as before remarked, only a few feet in thickness; and in some places in the same neighborhood it was entirely wanting, the bluff material resting directly upon the coal-measure limestone.

An explanation of these facts is naturally sought for. The most plausible seems to be, that glacial action extended more deeply beneath the general surface here than elsewhere, and that the direction and character of the currents were such that the greater part of the drift material was swept away to other places, leaving the lake basin to be filled with water at the close of the glacial epoch. Further investigations, however, are needed to decide such questions as these.

It is understood that the most reliable information we can obtain in relation to the general direction of ancient glacial currents will be the identification of the transported materials with those at the places of their origin. Very few observations of this kind have yet been attempted in Iowa, and it is but fair to state that those few are not now seen to harmonize clearly with the directions of the glacial scratches just described. I refer to the reputed discoveries of galena and native copper in several of the counties upon the eastern watershed of the State. The only *known* localities from which such materials might have been derived lie to the northeastward, in a direction nearly at right angles with the eastern drainage lines. Again, profusely scattered over the region between the Missouri river and the middle of the State, so far northward as the fourth tier of counties and probably much farther, are boulders and fragments of reddish-colored quartzite, closely answering the description given by Dr. Hayden of the rock which encloses the pipestone of southwestern Minnesota, and suspected to be of the same origin.* Should this be the case, it is not easy to see how they could have reached their present locations with glacial currents in the direction of the drainage of the western watershed, particu-

* See F. V. Hayden on the Geology of Northeastern Dakota; this Journal, January, 1867.

larly if they are of the age to which Dr. Hayden has referred the rocks of that famous locality; for in that case they can not be presumed to have ever existed much farther to the eastward.

The quartzite boulders in the region referred to are promiscously intermixed with those of other metamorphic and of granite origin, but those of the red quartzite are everywhere a little less waterworn and more angular than the others, suggesting a less distance of transportation, which would really be the case if derived from the pipestone region.

INDIAN MOUNDS*.

The whole history of the American continent, previous to its discovery by Columbus, is so wrapped in impenetrable mystery, that the least memento of its ancient inhabitants is regarded with unusual interest. Of the race which existed when Europeans first visited America, and which now occupies a large portion of it, we have comparatively full information; yet of their origin or advent upon the continent, we know nothing with certainty.

Notwithstanding this want of knowledge of their early history, the evidence seems to be satisfactory, that an aboriginal race more ancient than they, and having entirely different customs, once inhabited the country now occupied by the northern and north-western States, as well as parts of Canada.

The principal features of this evidence within the area named, consists in the remains of ancient copper-mining in the Lake Superior region, and the presence of what are commonly known as Indian Mounds. It is believed that the present race of Indians, at the time of the first visit of the whites, knew nothing of the working of any metal, not even of lead, and they also seem to be in as utter ignorance as ourselves concerning the origin of the mounds.

These mounds are rounded elevations of earth evidently scraped up from the surrounding surface; usually small, often scarcely distinguishable, but occasionally of considerable size. They are usually circular, sometimes oval, and even in some cases bear a fancied resemblance in outline to some animal. They are almost

* From the Annals of Iowa for January, 1868.

invariably in groups, numbering from two or three, to fifty or more. Sometimes they seem to be arranged on a definite ground-plan, but are often distributed without order.

Concerning the purposes for which they were constructed we are much in doubt, but they are usually regarded as memorials of the dead. Human remains have often been found in connection with them, but this is by no means invariable. When such remains are found they are usually placed around the base of the mound, where they are sometimes marked by the presence of flat stones, but they seldom if ever occupy the centre, with the earth heaped upon them. Rude pottery and other relics are frequently found with these remains, to which the present race of Indians seem to be entire strangers.

The mounds commonly occupy prominent, or otherwise interesting locations, in the majority of cases being found upon the brow of the bold characteristic bluffs which border the valleys of our Western rivers, but are not unfrequently located upon an elevated plateau which is skirted around by a low range of bluffs or hills. Standing among any of these mounds, one finds the surrounding scenery invariably interesting, and often very impressive, showing that a certain sentiment guided the builders in their selection of the ground, but what this sentiment was, whether of religion, veneration of the dead, or an appreciation of the beautiful and sublime in nature, we are left to conjecture. They are quite numerous along the bluffs of the Mississippi river, and the lover of that romantic scenery, having sought out some point from which to obtain a view more beautiful and impressive than the rest, will almost always find himself in the immediate presence of a group of mounds.

During the progress of the State Geological Survey, many of these interesting objects have been observed, but the press of other matters has prevented that careful examination of them which the interest of the subject requires. Along the bluffs of the Iowa River between Iowa City and Columbus City, a large number of them have been observed, a very numerous group of which occur just below the mouth of English River, about twelve miles from Iowa City. An interesting group is found on the land of Hon. Eliab Doud, near the Des Moines River in Van Buren County.

Visiting Sac City, Sac County, last autumn, I observed several mounds within the village, and having no time to devote to a careful examination of these, Mr. D. Carr Early, an attorney of that place has kindly furnished me with data for the following account of them, accompanied by a carefully drawn plat, which I regret can not be published with this article.

Sac City is pleasantly located in an abrupt bend of Raccoon river, which sweeps around it upon the north, east and south, and rests upon one of those level, or gently inclined spaces called by the settlers "second bottom." They were doubtless true bottom lands ages ago, long before the river had cut its valley so deep as it now is, and long before the mound-builders occupied the ground, but they are now, and were when the mounds were built, some of the most interesting and fertile spots, and far above the reach of floods. On the west the town is bordered by a moderately elevated bluff, and thus the whole space is surrounded by strongly-marked topographical features rendering it one of the most interesting spots in the whole region. It is about the centre of this space that we find the mounds, and doubtless an appreciation of the surrounding features guided the mound-builders in the one case, and the town-builders in the other, in the selection of grounds. The mounds are eight in number, arranged in a general direction from northeast to southwest, but without regular order, the distance between the two extremes in that direction being a little less than six hundred feet, and in the transverse direction, less than one hundred feet.

Two of these mounds are oval in outline, and all the others are circular. The oval ones are located further to the northeast, and commencing with the first of these, which is near his residence, Mr. Early gives their dimensions, as follows, progressing in the order of their occurrence to the southwest.

No. 1, 96 feet in diameter, east and west, and 36 feet north and south, and two feet high.

No. 2, 60 feet in diameter, east and west, and 30 feet north and south, and two feet high.

No. 3, circular, 66 feet in diameter and 5 feet high.
No. 4, " 80 " " " 6 "
No. 5, " 60 " " " 3 "

No. 6, circular, 60 feet in diameter and 3 feet high.
No. 7, " 50 " " " 2½ "
No. 8, " 60 " " " 3 "

It will be observed that three of these mounds are of exactly the same dimensions, and that the long axes of two oval ones are in an east and west direction, and not in the line of their distribution.

Nos. four, five and six have been dug through the centre to the undisturbed earth, the public well having been dug through number five, and the flag-staff set in number six; and nothing of human remains or works of art have been discovered.

It is to be hoped that during the progress of the State work sufficient time may be devoted to the careful examination of these works of the former owners of our soil.

LAKES OF IOWA—PAST AND PRESENT.

After returning from the northern peat regions, I published in several of the Iowa newspapers an article upon "Walled Lakes." Subsequently the following article was communicated to the *American Naturalist*, (Salem, Mass.,) and is inserted here, in place of the other, because it contains some additional matter, and because it is fuller upon the subject of those lakes:

Within the last ten or fifteen years a number of articles have appeared in the newspapers and periodicals of the country in relation, more particularly, to two small lakes of Northern Iowa. Some of the writers have contented themselves with merely a description of what they saw, while others have told strange stories in which they described the "remains of the wonderful handiwork of a departed race of men." While in that part of the State during the past season, excellent opportunities were had of examining both of the lakes just named, as well as others of the same character, fourteen in number, of which the following is a list:

1. Clear Lake, Cerro Gordo county.
2. Rice Lake, Worth county.
3. Silver Lake, Worth county.
4. Bright's Lake, Worth county.
5. Crystal Lake, Hancock county.
6. Eagle Lake, Hancock county.

7. Lake Edward, Hancock county.
8. Lake Mary, Hancock county.
9. Lake Flora, Hancock county.
10. Owl Lake, Humboldt county.
11. Lake Gertrude, Wright county.
12. Lake Cornelia, Wright county.
13. Elm Lake, Wright county.
14. Wall Lake, Wright county.
15. Twin Lakes, Calhoun county.
16. "Wall Lake," Sac county.

According to those stories the remains consisted of walls of huge stones encircling the lakes like that of an artificial fish-pond, so raised as to prevent an overflow of water upon the adjacent low ground, sloping to the water's edge with a pavement like a Mississippi levee, rounded and graded with earth upon the top, forming a good road upon which the Jehus of that departed race doubtless drove their elk or buffalo chariots in pursuit of pleasure or of their daily vocations, and the whole finished with a garniture of sage reflections upon the mutability of human affairs. Such fantastic stories have rendered those modest little lakelets so famous that many pilgrimages have been made to their borders with the hope of finding something to aid in penetrating the mystery that shrouds the early human history of our continent.

It is such lakelets as these, and their origin, that will now, in part, engage our attention; and while showing the groundlessness of the stories referred to, we hope to present still more interesting and wonderful facts, because, in the realm of nature, truth *is* stranger than fiction.

First, let us go back to their origin, for they originated from causes so definite that we are often able to comprehend them as clearly as if we saw them in operation; and the time of their formation in relation to other geological changes is as accurately determined as that of any other. Not only have the lakes had a definite origin, but, as we shall presently see, some of them have also had an end, and we know they once existed only by means of the records they have left in the earth they once covered. Hence the addendum to the above title — past and present.

Lakes have doubtless existed upon the earth's surface in every geological age, but those of which we are speaking had their origin at a period really very remote, when considered in relation to the historic era, but *very* recent when compared with the geological ages which preceded it.

All geologists are agreed that at the close of the Tertiary age, after the stratified rocks had been formed, and before the present condition of things existed upon the face of the earth, a long period of time elapsed, during which the whole northern hemisphere, as far south at least as the thirty-ninth degree of north latitude, was covered thickly and constantly with ice; which time they call the Glacial epoch. All are not entirely agreed as to what condition the ice was in, whether floating in a shallow sea in the form of floes and icebergs, or in the more completely frozen condition of a widespread, continuous and southerly moving glacier; yet the latterhy pothesis is generally accepted as according with the greatest number and most important of known facts. All are, however, agreed that the boulders and pebbles which we see every where scattered over the face of the country are of northern origin, and that they have received their rounded forms by attrition in water or moving ice during the time of their journeyings from their northern homes. We see those boulders and the gravel upon the surface only, because we can look no deeper, but we have abundant proof that they are intermixed with all that incoherent mass of material which geologists call drift — that material which meets our eyes every where, forms our soil and subsoil, and covers all the stratified rocks like a mantle, except where they have been bared by erosion. Some of the finer material of the drift was doubtless brought from the north with the boulders, but, with the exception of the latter, it has been largely derived by attrition from the rocks over which the glaciers passed, or from those which now underlie the drift. Thus the soil is nothing more than pulverized rock, and the whole drift formation, composed as it is of boulders, gravel, sand, clay and soil, had its origin as such through the agency of ice.

At the close of the glacial epoch the ice disappeared from the temperate zone, the present condition of the seasons was established, and the continent assumed very nearly its present dimensions

and form. The northern part of the Great Valley — it is to this region which more especial reference is made — was then unmarked by strong topographical features, for it was traversed by no ranges of mountains, nor by any rivers or streams. Shallow depressions only, marked the surface, which were filled with water from the rains and the melting ice. These were the primitive lakelets and existed before any definite streams were formed. Where the depressions were longitudinal, or connected in chains, they gave initial direction to the courses of the streams into which the surface waters were gathered, and carried away to the sea. These are the streams of to-day, and their ceaseless flow, aided by the rains and frosts of the unnumbered years that have passed since then, have worn their own channels down, not only through the incoherent drift, but often also through solid stratified rocks, the edges of which we see protruding from their valley-slopes. Thus all the valleys of this region are valleys of erosion, and it is meterological erosion alone that has given it its most prominent physical features.

As one stands upon the broad, level prairies of Southern Iowa, 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. Approaching this, the surface becomes 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 surfaces of which are often more than one hundred and fifty feet below the prairie level from which he started; and the surfaces of the larger streams are sometime a hundred feet deeper still. The higher prairie surface of to-day is the same surface which was left by the retiring waters at the close of the glacial epoch, and the time which has passed since then — that during which the valleys were formed — is called by geologists the Terrace epoch, because the oscillations of the streams from side to side of their valleys in the process of their erosion have left frequent terraces of material which successively constituted "flats" or "bottoms" bordering the streams, but which are now far above the reach of their highest floods. The Terrace epoch verges upon the present time, because the same streams still flow,

and earthy matter is still carried by them to the sea, as rapidly perhaps as it ever was, although only occasionally sufficient in amount to muddy the water. Thus it will be seen how slowly the mightiest operations of nature are performed; for this most recent of the geological changes has doubtless required a length of time so great that the human mind is incapable of comprehending it.

In Northern Iowa the prairie horizons are not so clearly defined, as they are further to the southward, and it was doubtless so at the beginning. The drift also contains more gravel and boulders there, from the fact that nearly all of those materials originating still farther to the northward, their abundance diminished with the diminishing force of the glaciers to the southward. Numerous irregular rounded elevations or knobs mark the surface, between which are corresponding depressions; not produced, however, by erosion since the drift was deposited, as the river valleys were, but are, like the knobs, inequalities left by the glaciers.

Some of these depressions have become drained; some of them are still occupied by the lakelets, and some by peat marshes. Streams are numerous in Southern Iowa and their valleys deep; consequently the country is so well drained that all trace of the primitive lakelets is usually obliterated. But many of those streams have their rise in Northern Iowa, and many of those lakelets still exist there, because no accumulation of water beyond has sent a current across them to cut a channel for their outlet. Lake-basins are sometimes hollowed very deeply into the earth, showing bold exposures of stratified or unstratified rocks upon their shores. But the lakelets of which we we are speaking had their origin in shallow depressions left in the surface of the drift alone at the close of the glacial epoch. By the action of subsequent causes they, in certain regions, became "walled lakes," for a majority of them are as worthy of that designation as those are of which the fanciful stories have been told. Nor are lakes of that character confined to Iowa alone, but are known also in Minnesota, Wisconsin, Michigan, and even in Connecticut, yet all except two, one in Wright county and the other in Sac county, Iowa, seem never to have been favored with the visits of an imaginative writer to tell fanciful stories of their associated remains of human handiwork.

It seemed necessary to make the foregoing statement of facts and the geological principles which they involve, before attempting a description of the lakelets themselves, that such a description might thus be rendered more intelligible, and which is here given as the result of long-continued observation of sixteen such lakelets in Northern Iowa, including the two which have become noted as walled lakes. They usually occupy an open prairie region. Sometimes small groves are near them, but trees are often entirely wanting, especially since the settlers mercilessly destroy them for fuel. They are from one to five miles across, but always very shallow, because the undulations within which they rest are very gentle. None of them are more than fifteen feet deep, and the majority are so shallow that they permit a luxuriant growth of wild rice and other aquatic plants from their bottoms over the whole, or a large part of their areas, among which water-fowl find shelter and abundant food, but which renders them rather uninteresting features of the landscape.

A true description of the so-called walls, but which we shall term embankments, will be best understood if given in connection with a description of their origin.

When a pile of sand, obtained from the river-shore, has been left by the workman for a long time exposed to the washings of the rains, the gravel which it contains, and which at first is hardly visible, becomes in some cases even more conspicuous than the sand itself, because a part of the latter has been wasted, while the gravel remains. Thus, it has been upon an extended scale with the drift, which, as before stated, is composed of boulders, gravel, sand, clay and soil, although little except the latter is usually seen upon the prairie and surfaces. Sometimes the drift is more than a hundred feet thick, and all the boulders contained in the whole mass which has been swept out to form the valleys, have gradually rolled down upon their slopes, and many of them into the streams. For this reason we usually find them more numerous upon surfaces that have suffered erosion than anywhere else. Again, the ceaseless dashing of a lakelet's waves stir up the finer material beneath its waters to be carried away in the form of muddy water at the times of its overflow, leaving the boulders and gravel strewn upon its bed; while they may not be seen at all upon the prairie-surfaces around them. This

latter fact, being misunderstood, has led to the supposition that being absent upon those surfaces they had been gathered up by human hands and carried to the shores to build the "walls," while the truth is, the embankments, as well as the presence of the materials of which they are composed, are due to natural causes alone, and their origin is wholly referable to the periodic action of ice, aided in some degree by the force of the waves.

The water in the lakelets is usually very low in late autumn, and when winter comes it is sometimes frozen nearly to the bottom in their deepest parts, so that occasionally all the fish are killed by this means. The ice of course freezing fast to the boulders as well as to whatever else may be within its reach, and the expansive power of from one to five miles of freezing water is exerted upon them in a direction from the centre toward the shores — a power much more than sufficient to move the largest boulders upon those gentle slopes.

The embankments are from two, to six feet high, and from two, to twenty feet across the top; and always separate a low piece of ground from the lake, because where the original shore is a little abrupt, and higher than the high-water level, no embankment is formed, but the boulders are merely thrust against the shore with such force as to render it steep, and often thickly studded with them. Meeting no such obstruction on a marshy side, the material thrust out, accumulates just where the expansive force of the ice is spent. This process repeated year after year, from age to age, has cleared the bottom of the lakelets of the boulders and other materials, and piled them up in circular ridges upon their shores; and these are the "walls" which have excited so much wonder. It has been observed that the embankments are heaviest 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 material to which it had frozen fast would thus be floated against those shores when the spring floods had raised the water of the lakes; and in part also by the further fact that the dashing of the waters would be most constant against those shores.

Thus it will be seen that whatever was originally upon the bottom, whether boulders, gravel, sand or mud, has been carried to the shore,

and we find the embankment composed of all these materials arranged in perfectly natural disorder. If boulders were numerous the embankment is largely composed of them. If sand prevailed, a broadly rounded embankment is formed, just such as we should expect from such material; and where a peat marsh extends out into the land an embankment of turf is thrown up at the water's edge which being supported by living rootlets, is frequently high and very narrow. The latter are somewhat numerous and are often called beaver-dams; but this is also a misconception, because beavers never attempt to dam still waters. They dam running streams to obtain ponds of still water.

Thus we see that the same natural force placed the boulders in the embankments that brought them down from their northern homes, namely, the expansive power of ice. The embankments are really very interesting natural objects, and it is not strange that they have attracted attention; but with a correct knowledge of the action of natural forces, it is difficult to understand how any one could suppose that human hands had any thing 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 intelligence in their location and plan.

If its crust should remain perfectly stable long enough, the earth would become nearly a perfect sphere by the disintegration of its exposed substance, and the levelling force of gravitation. It is true that its inequalities of surface are now very insignificant compared with the vastness of its bulk; but in such a case there would be no mountains, no islands, no continents. All would be an endless and shoreless sea. The erosion of the river valleys, and the consequent drainage of a majority of the primitive lakelets may be regarded as the first steps in this levelling process, after the glaciers had ceased from the Great Valley; for its post-glacial geology seems to warrant no subdivision into epochs such as are made for other regions; therefore the whole is here referred to the Terrace epoch. Long before this levelling process can approach completion other elevations and depressions will be formed upon the changing surface, just as the

present seas and continents occupy the places of other seas and other lands that existed long before them; because perfect stability of the earth's surface never has existed, and probably never will exist. See then how small a part of such a result has been accomplished even by the erosion of the valleys of the great Mississippi and its branches. A part of the primitive lakelets, and a part of the original surface of the drift still remain almost unchanged since their formation. The prairies have still their ocean-like surfaces, and the greatest change the lakelets have undergone in that immense lapse of time is the formation of their insignificant embankments, if aught in nature may be called insignificant.

Let us look a little to what has been accomplished by erosion in the Great Valley* during the Terrace epoch, as before defined, and we will find enough to excite our wonder and admiration.

Along the courses of what are now the Mississippi and Missouri Rivers, large depressions formerly existed, which formed lake-like expansions of those rivers. Thus, after the Mississippi had made for itself a definite valley, but before it had cut its channel nown to its present level through the rocky obstruction at the Keokuk rapids, that portion of it which borders a large part of the eastern side of Iowa was little else than a lake which averaged about five miles wide and filled the space between what are now the bluffs that border each side of its broad, flat valley.

This is proven by the existence there of the terraces, composed of very fine sedimentary material, such as could have been deposited only in comparatively still waters, and also by the existence in that sediment of shells which inhabit still waters only — the same species which now inhabit fresh-water lakes. River shells, such as now exist in the river, are found on the sides of the bluffs near the rapids at a hight of seventy feet above the present high-water mark; and since such beds of shells exist only at low-water mark when alive, upward of eighty feet must be estimated as the hight of the river above its present level at the time they lived.

It will be observed that river, and not lacustrine shells, are found

* It will be observed that the word *valley* is used with two separate significations — one applied to the hydrographic basin drained by a certain principal stream and its tributaries, and the other to the depression occupied by any particular stream, and which its own waters have cut out of the general surface.

near the rapids. This is accounted for by the fact that the obstruction which caused them, being a flinty formation, and not so easily disintegrated as the other rocks over which the river runs, has existed as such from it its earliest history. Consequently the water there always had a considerable current, while further to the northward there was too little current to produce a congenial habitat for those shells. The estimated eighty feet is doubtless only a part of the actual hight from which the erosion of the Mississippi Valley has reached, because it now averages about two hundred feet deep from the general prairie surface. Thus we see that when that lake-like expansion existed in the Mississippi river, its valley had already been eroded to considerable depth, and the Terrace epoch was well advanced. But on the other side of the State we have proof of the existence in the early part of that epoch of a lake which was larger and deeper than Lake Erie. This proof consists principally in the presence there of a peculiar lacustrine deposit, extending at least from the Big Sioux to the mouth of the Kansas river, and from twenty to thirty miles on each side of the Missouri river, through which the latter has cut its present valley, in some places to a depth of more than two hundred feet, before it reached the drift which was deposited there during the Glacial epoch. That material is known to have been deposited in fresh water, because only fresh-water shells are found in it, and they are found in it from top to bottom. It is known to have been deposited in still water, because the same kinds of shells are now living in still water only, and because the whole deposit is a fine, homogeneous material, without sand, gravel, boulders, or any thing else, except what would have been deposited in a lake of *muddy* water.

It has been claimed by a few geologists, that at the close of the Glacial epoch a shallow fresh-water lake occupied the whole hydrographic basin of the Mississippi, and that the fine soil and subsoil of the prairies and other lands of the whole region, as well as the peculiar deposit just referred to, are identical in their formation, and had their origin in one and the same broad lake. Upon this hypothesis some have accounted for the origin of the prairies and for the absence of trees upon them, but the fact is, prairies exist upon both these deposits; and it would require direct effort

to keep all kinds of indigenous trees from encroaching upon kinds of indigenous trees from encroaching upon the prairies if there were no annual fires.

It is not improbable that such a wide-spread sheet of fresh water did exist at that time, and that a large part of the sedimentary material that composes our soil and subsoil had such an origin. But that is widely different in physical characters from the deposit under discussion, which evidently had a different, as well as a subsequent origin. These circumstances seem to leave no room to doubt that a well-defined lake existed there after the continent was in great part dessicated, but before the great rivers had cut their valleys down to any considerable depth.

The lake, although so large and deep, was doubtless filled with sediment to the general prairie level within a comparatively short time after the glaciers ceased, just as the sediment of the same river which then flowed into and from it, now speedily fills the reservoirs of the St. Louis water-works, so that they must often be re-excavated. Just as the same river would now fill with the same kind of sediment, any depression, however large, if such existed in its course.

The great Northern lakes are not thus filled, because their tributary streams are pure; and their streams are pure because they flow over geological formations that are not easily disintegrated; while the main tributary of that ancient lake — the Missouri river — is even now one of the muddiest streams on the globe. In the earlier portion of the Terrace epoch, it was, if possible, more so; for then, as now, it gathered up its sediment from that broad region occupied by the friable rocks of the Tertiary and Mesozoic ages, stretching far away towards the Rocky Mountains, at that time strewn with the grindings fresh from those "mills of the gods" — the glaciers.

The formation of the basin in which the lake rested is known to have taken place during the glacial period, because the drift with its striated boulders now covers its bottom beneath the lacustrine deposit, and because the cutting out of the river valley has exposed, in a number of places, the stratified rocks which the drift rests upon, the surfaces of which are scored and striated by the moving glaciers of that period. It is known that the filling of the lake with sediment

occurred in the early part of the Terrace epoch, because it was filled up even with the prairie surfaces, which would not have been done if the Missouri river had first eroded its valley to any considerable depth below the lake. We know that the lake was so far filled with sediment before it was drained, that it was little else than a marsh, because the top of that deposit of sediment is now nearly even with the higher prairie surfaces, and because the river bluffs which it forms are as high as those formed of the usual materials, — the drift and stratified rocks.

The physical characters of this lacustrine deposit are so peculiar that they attract the attention of every person who becomes acquainted with it, although a stranger might pass over the formation without observing more than its peculiar outline of bluffs. It is perfectly uniform in character and color from top to bottom, and a hundred miles of distance show no more difference than a hundred feet. It is of a slightly yellowish ash color, except where rendered darker by decaying vegetation, very fine, not sandy and yet not adhesive. At the surface it makes excellent soil, and is just as fertile if obtained at a depth of two hundred feet. It is easily excavated by the spade alone, and yet 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 that the spade-marks remain upon it for many years. Road-embankments, upon the sides of excavations, stand like a wall, showing the names of ambitious carvers long after an ordinary bank of earth would have disappeared. As that part of the valley of the Missouri river below the lake was deepened during the Terrace epoch by the natural process of erosion, the peculiar material which its own waters had previously deposited, offered little obstruction to that process, but was readily swept out again as muddy water, and sent on its way to the sea. Thus no more of it was cut out than served to form the valley, which is from four to six miles wide, while the larger part remained, forming the bluffs and extending far inland from the river. The tributary streams which at first emptied into the lake, now traversed its ancient bed of sediment to the river, and cut down their own valleys to meet it. The sides of these valleys, where they traverse that sedimentary deposit

are steep like the river bluffs, and the streams being smaller, their valleys are narrow and very deep. This is particularly true of all those Iowa streams that empty into the Missouri river above Council Bluffs, and they thus present great obstacles to the construction of lines of railway directly east and west through that State. For this reason, and for the purpose of connecting with the great Pacific Railway at Omaha, the more northern of those lines are diverging to the southward down the valleys of the streams, instead of crossing them, so that passengers will pass dry-shod through the bed of that ancient lake, although many fathoms beneath the level at which its waters used to rest.

The peculiar outline of the bluffs along the Missouri river valley is one of the most interesting features of this remarkable deposit. As one views them in the distance, and in their nakedness, for they are often entirely destitute of trees, towering up from the level bottom land, sometimes more than two hundred feet in hight; so steep in some places that a man can not climb them, he can hardly rid himself of the idea that they are supported by a framework of rocks as other bluffs are. Yet not a rock or pebble of any kind or size exists above their base of drift, except a few calcareous concretions which were formed from the limy water that now percolates through the whole mass. The form and arrangement of their numerous rounded prominences sometimes present views of impressive beauty as they stretch away in the distance, or form bold curves in the line of hills. A few miles below the city of Council Bluffs they present a full crescentic view to the westward, with the broad Missouri bottom stretching miles away from their base to the river. Their only vegetation here is a covering of wild grasses, and as the mound-like peaks and rounded ridges jut above each other, or diverge in various directions while they recede backward and upward to the higher lands, 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 IOWA COAL-FIELD.

The character of the field-work of the survey has thus far been that of a general reconnoisance, so that the boundaries of the

coal-field has not been determined with precision. So far as the eastern and northern borders are concerned, they were at least approximately determined by the former geological survey. As that report may not be possessed by all into whose hands this shall fall, a description of it, somewhat modified, is here given.

Draw a line on the map of Iowa from the southeast corner of Van Buren county directly northward until it touches the south line of Washington county; thence northwestward, keeping six or eight miles to the northward of North Skunk river, to the south line of Marshall county, a little west of its centre; thence to a point three or four miles northeastward from Eldora, Hardin county; thence to Webster City, Hamilton county; thence to Fort Dodge, Webster county,—and you have approximately the eastern and northern borders of the *productive* coal-field of Iowa. It is not claimed that all the coal of the State exists southward and westward of this line, for it is already known to exist in Lee, Henry and Washington on the other side of it as well as in Muscatine and Scott counties, but it is believed that very little coal will be found outside of the line thus designated.

Indications of coal are often found to the northward and eastward of this line, but although the strata discovered are really coal-measure strata, yet they are small isolated deposits, called outliers by geologists, too small and too thin to afford a workable bed of coal. An exception to this rule is the large outlier extending from Muscatine almost to Davenport, where a small bed of coal has been worked several years. A number of other small outliers have been discovered in Johnson, Louisa, Benton, and doubtless may be also found in other counties. The dip of the strata (the general dip, not the local dip; the general dip is too slight to be perceptible to the eye), being to the southward and westward, it follows that at the northern and eastern borders of the coal-field it would have a thinner development than further within the field. Thus it will be seen that one encounters greater hazard in exploring for coal along its thinning-out border than he would within the main portion; yet some instances are known of the existence of good mines very near the well-defined border.

To the westward, and southward of the Des Moines river, it is not known how far the productive coal formation actually extends, for it passes beneath the unproductive series of coal-measure strata, and beneath the heavy deposits of drift which are not deeply cut along the dividing ridge of the State as they are in other parts.

Some coal has been found in Webster, Boone, Dallas, Madison, Lucas and Wayne counties, west of the Des Moines river, beside the thin bed in the upper coal-measures, along the Nodaway river; while Polk, Warren, Marion, Monroe, Mahaska, Wapello, Appanoose, Davis and Van Buren, lying wholly or partly upon the west side, are among the most important coal counties. Thus far, however, the greater part of our coal is obtained northward and eastward of the Des Moines river. For further remarks upon the probabilities of finding coal, by deep mining in the western part of the State, see introductory chapter.

In that part of the productive coal-field thus far explored, there is satisfactory evidence that no very deep mining will be necessary in any part of it. This is inferred from the fact that the larger streams are found to have cut their valleys down through all the coal-measure strata to the sub-carboniferous limestone.

The distance down to this limestone from some of the higher surfaces in this portion of the coal-field may sometimes be as great as three hundred feet, but it probably will not exceed this depth anywhere to the northward and eastward of the Des Moines river, and may usually be expected at a much less depth.

Although the known area of the productive coal-field of Iowa, as thus defined, is smaller than some have supposed, yet it will be seen that its area is equal to that of the whole State of Massachusetts beside which, it is expected that this area will be extended to the westward by the discovery of coal at an increasing depth beneath the surface.

SOIL, VEGETATION, &c.

There is probably not an equal area upon the earth that contains proportionally less untillable land than does the State of Iowa.

By far the greater part of it is of drift origin, all of which is scarcely less fertile than the rich alluvial and lacustrine soils found bordering the rivers.

The drift deposit is very deep in all parts of the State, and

consists of so much fine material that the boulders, gravel and sand it usually contains are almost nowhere the least obstruction to farming operations. It has been estimated by some that seven-eighths of the surface of the State are occupied by the prairies. These prairies are always fertile and exist upon all varieties of soil, and their origin can not therefore be due to any one of them. The greater part of the forest trees are found in the vicinity of, and skirting the borders of the streams; and there is little variation in the kinds of trees which compose the forests throughout the whole State that can be ascribed to a difference of climate. Its principal forest trees are several kinds of oaks, black and white walnut, hickories and pecan, white and sugar maple, cottonwood and aspen, linden, red birch, horse chesnut, box elder, ash, honey locust, red and slippery elm, &c. *It is a notable fact that all these trees will grow thriftily upon all varieties of our prairie soil; even those whose chosen habitat is in the neighborhood of the streams.*

Thus far no chestnut nor beech have been found in the State, but a few of the former have been introduced. Of introduced trees, the black-locust succeeded well for many years and until it was attacked by the borers in 1863, since which time almost all the trees have been killed by this means. The osage-orange succeeds well in at least the southern half of the State, where some as perfect and effective hedges of it as one could desire have been in use a number years, and its use is rapidly increasing. It has not yet been fully tested in the northern part of the State. The prairies are always covered with rank, and usually nutritious grasses, beside a great variety of other plants which differ little in species throughout the State. Of shrubbery there is almost as little difference; hazel, wild-plum and crab-apple being the principal kinds everywhere. Of edible berries, the blackberry, raspberry and strawberry are the chief. The common cranberry has not thus far been observed in the State, although the so-called high-bush cranberry is occasionally found in the northern part. It is not properly a cranberry, for it has only a single seed like the black haw, to which it is closely related, and which, except in the color of its fruit, it much resembles.

The adaptability of our soil to grapes, all kinds of orchard fruits, grasses and staple cereals, is too well and widely known to need mention at this time.

COAL AT DES MOINES.

No connected observations have yet been made in Polk county, but while making visits to Des Moines on business, several of the coal-mines in the vicinity of the city have been examined. These are those of Messrs. Redhead & Vincent, just above the city on the west side of the Des Moines River, and two or three on land of Mr. C. C. Van, almost within the city, on the south side of Raccoon River.

The most that can now be said of these mines is that the coal of all is of good quality, much of it excellent. There is no doubt that the high lands surrounding the city are all underlaid by a bed of coal, but it is doubtless better and more workable at some points than others. It is at present believed that the coal-beds now worked at Des Moines belong to the upper part of the lower coal-measure series, in which opinion Mr. St. John concurs, who has also visited them, and has also traced out the geology of the Raccoon river region with much care. If this opinion is correct, it is not improbable that other beds of coal exist beneath the one now worked; and if our present estimate of the thickness of the lower coal-measure series of strata is correct, a shaft commenced in the valley would pierce all those strata by reaching a depth of from one hundred and fifty to two hundred feet. It will of course be seen that we infer that some of the mines worked in Marion and other counties are in beds which belong in the series below the Des Moines coal, yet these beds may or may not exist beneath those at Des Moines.

COLLECTIONS.

During the progress of the work, important collections of fossils, minerals, rocks, coals, &c., have been made, the greater part of which yet remain at the rooms in Iowa City for want of time to distribute them as the law provides; yet some excellent selections have already been sent to the following-named Institutions, and their receipts taken therefor, viz: State Agricultural College, four boxes; Cornell College, one box; Iowa College, one box; Tabor College, one box.

These specimens have all been carefully ticketed and plainly - written catalogues sent with each collection, so that by observing the number written upon the small ticket which is pasted upon each specimen, and the corresponding number in the accompanying catalogue, its name, locality, and geological position will all be known. A complete record of all is kept in the office, so that in case of the loss of the catalogue, it can be restored by writing to the office and sending a list of the numbers upon the specimens.

Every specimen, great and small, receives this small ticket, about a quarter of an inch in diameter, as soon as they are unpacked at the office and washed, and the locality and geological position at least are immediately recorded, so that whatever disarrangement they may afterward suffer, so long as the tickets remain pasted upon them, their history and character can always be known.

Thus far the collections have been made principally from the upper, middle and lower coal - measures, the sub - carboniferous, and part of the lower Silurian rocks. Beside this, the specimens consist chiefly of coal from different parts of the coal - field; grey, white and fibrous gypsum from Fort Dodge; sulphate of strontia from Fort Dodge; geodes from Bentonsport, &c., &c.

While examining the collections during the winter of 1866–7, we found among them fourteen or fifteen species and three new genera which were new to science. These have been described under the authorship of White and St. John, and published gratuitously by the Chicago Academy of Science, the survey receiving credit for priority of labor. The new genera referred to are Meekella, Cryptacanthia, and Tomoceras, the following being the full list:

Amplexus fragilis.....Keokuk limestone.
Aulosteges spondyliformis.....Upper coal - measures.
Axophyllum rudis.....Upper coal - measures.
Beyrichia petrifactor.....St. Louis limestone.
Beyrichia foetoida.....Upper coal - measures.
Crania modesta.....Upper coal - measures.
Cryptacanthia compacta.....Upper coal - measures.
Cryptoceras Springeri.....Upper coal - measures.
Cythere simplex.....St. Louis limestone.

Hydreionocrinus verrucosus.....Upper coal - measures.
Meekella striatocostata (*Cox sp.*).....Upper coal - measures.
Nautilus divisus.....Upper coal - measures.
Pinna Hinrichsiana.....St. Louis limestone.
Tomoceras Gillianum.....Upper coal - measures.

Besides the above, numerous specimens of a small object was found in the upper coal - measure marlites, which is supposed to belong to the Protozoan genus Amphistegina, specimens of which have been sent to Dr. William B. Carpenter of England for examination, since no one in our country is known to be giving especial study to those unusual objects.

LETTERS

OF

MR. O. H. ST. JOHN

ASSISTANT STATE GEOLOGIST.

SURFACE GEOLOGY OF THE RACCOON RIVER REGION.

During the past season, through the kindness of the Director of the Geological Survey, the writer was permitted to spend a considerable portion of the autumn in the country traversed by the Raccoon rivers, with the view of studying the stratigraphical geology of that section of the State. The counties of Polk, Dallas, Guthrie, Greene and Carroll held out important inducements to that end, and the result of the season's work was satisfactory in a high degree. The counties lying to the southward and bordering upon those above mentioned, had been already examined, and their geological structure made known through the labors of Dr. White during the previous season. But heretofore little, I may say nothing, was known of the character of the strata in the country drained by the Raccoon rivers, save that they were coal-bearing. Their relations to the well-developed upper coal-measures found along the North, Middle and South rivers, in Madison and adjoining counties, and to the lower coal-measures which are exposed on the Des Moines, remained to be determined. Nor was the nature of the coal-beds themselves any better known beyond the localities where they made their appearance; and their relations to one another were unexplained. Indeed, the field was new, and gave promise of valuable results in behalf of the economic interests of the State.

To facilitate our review of the ground, I will at once introduce a vertical section of the strata with which we have to deal, presenting only such details as shall be essential to our purpose.

COAL-MEASURES.

U. C. M.			Sandy shales and sandstones.
MIDDLE COAL MEASURES.	UPPER GROUP.		Black fossiliferous shales and sandy shales, 5 to 10 ft.
			COAL C.
		50 FEET.	Clays, with layers of compact, impure, fossiliferous limestone, 40 feet and upwards.
			Lower black shales of upper group.
	MIDDLE GROUP.		Clays, arenaceous shales and sandstone.
			COAL B.
		70 TO 90 FEET.	Clays, arenaceous shales and bands of micaceous sandstone; towards upper part, layers of impure fossiliferous limestone, and locally developed black shales—70 to 90 feet.
	LOWER GROUP.	5 FEET.	Layers of argillaceous, fossiliferous limestone.
		5 TO 10 FEET.	Black shale, clays, impure limestone band.
			COAL A.
		30 TO 50 FEET.	Variegated clays, with nodular bands and arenaceous layers—30 to 50 feet.
LOWER COAL MEASURES.		20 TO 45 FEET.	Sandstone, 20 to 45 feet.
		10 TO 15 FEET.	Argillaceous and arenaceous shales, 10 to 15 feet.
			Des Moines Coal, 3 to 5 feet.
			Concretionary sandy shales.

It will be observed from the section that we have all three of the coal-measure series represented in this region, but of the lower and upper measures only their upper and lowermost members are accessible. The middle coal-measures, however, here attains its full development, and it is with this division our attention shall be mainly occupied.

MIDDLE COAL-MEASURES.

The *middle series* of coal-measures, as developed in this part of the State, may be sub-divided into three groups, each of which possesses its own peculiar lithological characters in distinction from the other groups. The lower group has a thickness of from forty to seventy feet, the middle one eighty to one hundred feet, and the and the upper groups, probably, upward of fifty feet; making the average thickness of the middle series about two hundred feet. Towards the top of each of the groups the deposition of carbonaceous matter took place, forming as many distinct coal-horizons. The upper bed, coal C, is the most valuable one of the *middle series*. Its thickness varies between fifteen and thirty inches, and is a workable bed. It is overlaid by two to four feet of dark shales, abundantly charged with fossil remains which serve to distinguish this coal horizon from any of its associates. At the base of the upper group a well-marked carbonaceous bed is found, but it seldom presents any coal, though the highly carbonaceous black shale, capped by a single layer of compact argillaceous rock, is always met with wherever it has not been denuded. A bed of sandstone five to ten feet thick, forms the upper bed of the middle group, immediately beneath which the second carbonaceous horizon, coal B, occurs. This bed is very variable in thickness, ranging from one inch to two feet, and presenting even in short distances all the gradations from a black shale to coal of an excellent quality. It constitutes, however, a constant horizon, notwithstanding at certain localities it becomes so attenuated as scarcely to retain its identity. In the middle and lower portions of this group local developments of dark shales, sometimes more or less carbonaceous, are not unfrequent, beside there are bands of impure fossiliferous limestone, and the lower half is made up of clays and arenaceous beds. The lower

group is limited above by several layers of argillaceous lime rock, five to ten feet below which coal A, occurs, varying from three to fifteen inches in thickness, overlaid by black shale and a band of compact argillaceous rock. This latter horizon is subject to the most remarkable variations of any of the beds previously described. Sometimes the black shales have a most exagerated development, and then, again, the layer of earthy rock is reduced to a lenticular nodular band, or lost entirely. The base of this group rests immediately upon the sandstone overlying the Des Moines coal, which is regarded as the upper bed of the lower coal-measures.

The coal which is being so extensively mined in the vicinity of the city of Des Moines, presents the interesting feature of three distinct layers of coal separated by thin seams of clay, so that the whole are wrought as one bed, the maximum thickness of which is about five feet. But, independently, the layers are very variable in thickness — sometimes the upper ones are the most important, then again the lower ones become the best developed, as may be seen by examining the out-crops upon either side of the Des Moines, in the upper part of the city. The middle stratum, however, is more constant in this respect, averaging about eighteen inches in thickness, while the upper and lower ones range from six to thirty inches. Overlying the Des Moines coal, which is practically but one bed, we find about ten feet of clay, capped by eight to twelve feet, or more of soft sandstone, which in turn is overlaid by variegated clays, exhibiting a vertical section of the strata associated with this coal horizon of about forty feet. The line of outcrop of the coal is probably fifteen to twenty feet above the level of the river, and could not be more accessible for advantagous mining. Its product has received the local name of "Diamond coal," and in quality it is esteemed the best coal in this market. The importance of this coal to the manufacturing interests of Des Moines can not be overestimated.

Now, that we have made ourselves somewhat familiar with the characters associated with the Des Moines coal on the Des Moines river, let us at once transfer our examinations to the Raccoon river coal-field proper, immediately to the westward. Taking the road which passes along the north side of the valley of the Raccoon,

three miles above Des Moines, at Fagan's Mill, in the bluff on Walnut creek, at an elevation of about sixty feet above the stream, there are indications of a thin stratum of coal, overlaid by black shales and a layer of clayey limestone, and in the slope above, clays and fragments of impure, thin-bedded limestone, affording us our first section in the middle coal-measures. The exposure represents the upper portion of the lower group, including coal A. This bed has been prospected by drifting into the bank, but we presume it was found too thin for profitable working, as the entry is now in ruins, and appears to have been abandoned for some time.

The fact that the coal at Fagan's mill holds, apparently, a position forty feet above the Des Moines coal, very naturally would *seem* to offer conclusive evidence that this bed overlies the latter by as many feet as constitute the difference in their respective levels above the level of the Des Moines river. It is not thus, however, the geologist arrives at his conclusions regarding the order of superposition of strata; else discrepancies would constantly embarrass the observer, and errors without number would unavoidably accumulate in the end, compelling all mining enterprises to resort wholly to the expensive and uncertain expedient of practically demonstrating the existence of mineral wealth, which experience proves has oftener than otherwise resulted in the irrecoverable expenditure of millions. Therefore if we would master the details of structural geology, thereby rendering our science subservient to the interests of man, we must apply ourselves diligently to the study of all the various strata, both their lithological and external peculiarities, and the organisms they contain, which latter, though they may range through a greater or less thickness of strata, always give us reliable data in the manner of their association in the various horizons, which will render invaluable aid in our examinations, as I shall presently endeavor to show.

Four or five miles above Fagan's mill, in the bluff banks and ravines upon the north side of the Raccoon, in the vicinity of Fitzsimmon's mills, several layers of impure limestone are quarried for building stone, which give a tolerable exposure at an elevation of twenty feet above the stream. A quarter of a mile or less above, however, just below the mills, the same beds out-crop in the river bank ten to fifteen feet below their level at the quarries. By the

association of fossils found in these thin layers of argillaceous limestone, we at once recognize them as belonging to the horizon observed at Fagan's mill, though then shown only by a few fragments out-cropping here and there a few feet above the thin coal A. By making a liberal estimate of the fall of the river between the two above-named localities, the beds at Fitzsimmons' are found to occupy a much lower level by, probably, not less than thirty feet, showing that the beds gently incline as we ascend the valley to the westward from Des Moines, which has carried coal A below the river bed at Fitzsimmons'. The inclination of the strata is so gradual, and the beds are so subject to local inequalities and undulations, that it would be extremely difficult, to say the least, to make any trustworthy observations on the general dip of these beds at any one exposure. This is true, too, of nearly all the exposures in this region; so that the impracticability, the absurdity, of recognizing equivalent horizons at remote localities by comparing their positions in reference to a common base of level, will be apparent from the illustration afforded by the localities already mentioned.

The next considerable exposures ascending the river are found in the vicinity of the Boone estate, and a couple of miles above in the bluffs upon the right side of the valley (sections twenty-six and twenty-seven, township seventy-eight, range twenty-seven, Dallas county), near Mr. Benjamin Colton's, to whom I am indebted for my knowledge of this locality. The strata at this point outcrops in the sides of deep, narrow ravines, and though the exposures are limited and isolated, they exhibit when brought together nearly seventy feet thickness of strata, all of which pertain to horizons higher in the series than those heretofore mentioned, or to the middle groups of the middle coal. Sixty to seventy feet above the river, coal B is met with, resting upon clays, and overlaid by sandy clays and a five-foot bed of sandstone, embedding large trunks of ancient club-mosses; and above the sandstone the lower black shales of the upper group, capped by a foot layer of impure limerock charged with fossils, completes the top of the section. Thirty feet below coal B, layers of compact argillaceous rock, interbedded with dark shales and variegated clays, are seen; but in a thickness of seventy feet only the one little six-inch bed of coal occurs.

Four miles nearly due north from the above locality, on the headwaters of Sugar creek, near Mr. Huston's place, coal B outcrops in the margin of the stream, presenting the same association of beds as noted in the section near Colton's. Here, however, the black shales at the base of the upper group have a much greater development than at the former locality, and the bed is finely exposed all along the creek for half a mile or more above, when it disappears beneath the bed of the stream at the quarry on Mr. Frank Graham's farm (section six, township seventy-eight, range twenty-six, Dallas county). The same coal-bed also appears on a branch of Walnut creek near Mr. John Cutler's place, four or five miles north of Huston's.

Regaining the valley, three miles above the confluence of the North Raccoon at Vanmeter's Mills on the South Raccoon, the bluffs on the left bank give a very perfect exposure of the upper half of the middle group. Coal B, a thin band of rotten coal three to six inches thick, is seen in the face of the bluffs twenty-five feet above the river, and overlaid by the upper sandstone of this group. Below the coal, clays and layers of argillaceous rocks alternate to the water level. The lower black shale of the upper group does not appear in the section at Vanmeter's, but in the bed of a little branch on Mr. Miller's place, and at the crossing of the Winterset road on the Bulger, two miles south of the mills, the uppermost layers of the sandstone appear in the bed of the stream, supporting a few feet of clays, upon which rests the black shales and bands of clayey limestone, presenting a section identical with that at Colton's, five miles below. It will further be observed that the position of coal B, at this locality would still indicate a slight westerly inclination of the strata.

Again let us make a detour, and ascend the valley of the Bulger to the southwestward. This little valley has been selected for the route of the C., R. I. & P. Railroad, in its ascent from the Raccoon Valley to the "Quaker Divide," and consequently its importance as a great commercial thoroughfare far exceeds that of the larger streams of which it is but one of many diminutive affluents. Near the head waters of the Bulger, and just within the borders of Madison county, limestone ledges are met with, which doubtless belong

to the upper coal-measures, and are high above any rock exposures we shall see on the Raccoon rivers. These ledges afford a very excellent, durable building stone, and when the railroad shall have been completed to these quarries, their value will be greatly enhanced. There are also thin beds of carbonaceous shale in the upper coal-measures, as shown by Dr. White; and on the head-waters of Bear creek, on the southern line of Dallas county, in the vicinity of Mr. Price's, one of these black shale horizons of the upper coal-measures is found underlying limestones, very similar if not indentical with those on the upper course of the Bulger. The elevation of these quarries above the South Raccoon at Vanmeter's can not be far from two hundred feet; and when we take into consideration the inclination of the middle coal strata in the same direction, we may safely estimate their elevation above coal B at one hundred to one hundred and fifty feet.

From Bear creek we strike across the beautiful upland prairie, known as the "Quaker Divide," to the northward, and gain the hights overlooking the valleys of the South and Middle Raccoon rivers in the vicinity of their confluence. The south side of the valley is bounded by steep, wooded bluffs, and a low sandstone ridge crowned with forests rises between the two streams. The north side of the valley rises, terrace upon terrace, to the general upland level, and dotted in every direction with thrifty farms. Upon one of these high benches, on the east bank of the Middle Raccoon, the prosperous manufacturing village of Redfield is located.

Descending into the valley, the first exposures we meet with in the river bank, just below the Newport Woolen Mills, presents arenaceous beds crowded with lenticular concretions, which strongly recall the deposits underlying the coal at Des Moines. Ascending thence the Middle Raccoon, a short distance above its mouth, in the left bank (section nine, township seventy-eight, range twenty-nine, Dallas county) on lands belonging to J. Ward Redfield, Esq., a bed of coal outcrops, overlaid by clays and a heavy-bedded sandstone, thirty to fifty feet thick, presenting a section of strata essentially like that described at Des Moines. The Redfield coal, like the Des Moines bed, is not a single bed, but consists of two layers separated by a thin clay parting. It differs, however, from the Des Moines

bed, in being one layer less, although it still retains an aggregate thickness of three feet. With these facts alone we could hardly prove beyond a doubt the identity of these banks. It is well known that coal-beds are very variable in their physical characters, and not unfrequently the lithological characters of the associated strata become changed to such a degree as to be almost or quite unrecognizable at distant localities. However, in this instance, we are not left in doubt regarding the validity of the identification; and notwithstanding the exaggerated enlargement of sandstone above the coal at Redfield, we shall be able to show conclusively that the Des Moines and Redfield coals belong to one and the same horizon.

If we take the valley road leading from Redfield to Panora, we will meet with exposures of the sandstone, which overlies the Redfield coal, at frequent intervals in the bluffs between Redfield and the Musquito. A short distance above the Musquito creek bridge, in the bluffs on the east side of the creek, at Parker's bank, coal A of the *middle series* outcrops at an elevation of thirty feet above the level of the Middle Raccoon. The coal is six inches thick, and is overlaid by the black shales, band of argillaceous lime-rock and clays usually associated with this bed. At Piatt's bank, a few hundred yards above, the black shales have increased in thickness from eighteen inches to forty inches; the "cap-rock" only exists as thin pyritiferous modules, above which brown, yellowish and grey shales occur, which are in places charged with fossils. The coal is about the same thickness at both banks, but in other respects they could hardly be more dissimilar. About a quarter of a mile southwesterly from Parker's bank, a ledge of rocks juts into the Middle Raccoon, which upon examination proved to be the upper argillaceous layers of the lower group of the *middle series*, and present almost the same characters they possess at Fitzsimmons', eighteen miles east. Although these beds are not seen at Parker's and Piatt's banks, having been removed by denudation, they nevertheless overlie that coal-bed, and their occurrence in the river margin, thirty feet below the level of the coal at Parker's, indicates a southwesterly inclination of the beds equivalent to about one hundred feet to the mile at this locality. Presently, however, we shall see the sequence of these beds fully exemplified, and also their relation to the coal at Redfield.

Crossing the South Raccoon a short distance above the confluence of the Middle Raccoon we ascend by a steep acclivity to the uplands upon the south side of the valley. The road passes over a natural, though somewhat obscure, exposure composed of layers of impure limestone, identical with those last observed in the banks of the Middle Raccoon near Mr. Fee's. This band, clays and fragments of hard, earthy lime-rock are seen, and a faint trace of a carbonaceous band indicates the horizon of coal A, at a level of sixty-five to seventy-five feet above the coal at Redfield, a mile to the northeast. Continuing up the valley of the South Raccoon two miles above the last-named locality, on the borders of Dallas and Guthrie counties, one of the most interesting and important exposures in the valley was examined. The discovery of this locality I owe to Mr. Peter Marshall, who by intelligently-directed practical examinations had already made himself perfectly familiar with the local geology, and to the writer it is a particular pleasure here to acknowledge the valuable co-operation he gave me in my field-examinations, and the kindness he showed to the members of my party during our stay in this vicinity. At this locality, which we shall call the "Marshall section," the strata have a very decided westerly dip. At the lower end of the bluff, a six-inch bed of coal outcrops at the water-level, and which is overlaid by a bed of black shales and impure limestone, five to eight feet of clay, and four feet of earthy lime-rock with clayey partings, upon which thirty feet or more of clays, sandy shales and thin beds of sandstone are superimposed, affording a complete section of forty-five feet, the lower part of which presents a typical exposure of coal A and the beds forming the top of the lower group of the middle coal-series. No other locality, to my knowledge, exhibits so satisfactorily at a single exposure the direct order of superposition of the members which form the upper part of the lower group and the base of the middle group of this series. Five hundred yards below the "Marshall section," coal A outcrops in the hill-side forty feet above the level it occupies at the latter exposure. The easterly-rising of the strata at this locality corresponds precisely with what was observed in connection with the same horizons on Musquito creek, four miles northward. The forces which upraised the Des Moines coal above the level of the Middle Raccoon at

Redfield, also uplifted the superincumbent strata of the *middle series*, giving rise to a broadly-arched anticlinal ridge, upon whose flanks the strata sweep down in opposite directions, and gradually accumulate vertically, bed upon bed, as they approach the axis of the shallow synclinal depression which occupies the intervening country between the Des Moines and the mouth of the Middle Raccoon, a distance of thirty miles. Hence, we shall at once understand the occurrence of beds pertaining to the middle and upper groups of the middle coal, as at Vanmeter's, at the same levels occupied by much lower strata whose edges are exposed high upon the flanks of the two parallel anticlinal ridges which define the east and west margins of the intervening depression.

Nearly three miles west of the Marshall section, at Miller's coal-bank, a six to ten inch coal-bed has been opened, which is equivalent to the black shale horizon at the base of the upper group of the *middle series*. It is very seldom that coal is found with this bed, and its occurrence at this locality affords an interesting illustration of the local deposition of a thin layer of coal at the bottom of a well-characterized and constant horizon of carbonaceous shales. Coal B, and the overlying sandstone are not exposed at Miller's bank; but in the banks of the South Raccoon, south of Morrisburg, the sandstone and carbonaceous horizon above were observed, and in a boring half a mile above, a bed of coal is said to have been found, which may be equivalent to coal B.

Four miles south of Morrisburg, on Deer creek (section twenty, township seventy-eight, range thirty, Guthrie county) at Lonsdale's bank, a two-foot bed of coal outcrops, and is overlaid by three to four feet of dark, highly-fossiliferous shales. Ten feet above the coal a soft, yellow sandrock is imperfectly exposed, between which and the dark shales a second band of impure coal is said to occur. In the slope forty-five feet above the coal, layers of compact grey limestone are seen, which is the highest rock exposed at this locality. The coal at this locality is regarded as the uppermost coal-bed of the *middle-series*, or coal C. It is one of the conspicuous palæontological horizons in the coal-measures; containing an assemblage of minute fossil-forms, which readily distinguish this from all other carbonaceous horizons of the middle coal-measures. The present

workings at this locality are on lands belonging to Mr. John Lonsdale of Dale City. The coal varies in thickness from twenty to thirty inches. Its elevation above the creek greatly facilitates the working of the bank. The coal is excellent in quality, and with the rapid settlement of the beautiful country about, it will prove an important source of wealth to that section.

Four miles west of Dale City, on Spring Branch of Beaver creek, near Mr. Loring Mann's, horizons equivalent to coal B and the lower carbonaceous horizon of the upper group are found; but neither of the carbonaceous horizons are here coal-bearing. However, higher up the Beaver, two miles northwestward from Spring Branch (in lot 4, section 5, township 78, range 8, Guthrie county,) the same beds appear, presenting a marked contrast to their appearance on Spring Branch. Coal B here affords a twelve-inch bed of coal; and twelve to fifteen feet above, the lower black shales of the upper group are underlaid by a four-inch layer of coal, presenting precisely the same appearance possessed by this bed at Miller's bank. Mr. Thos. Coleman informed us of other localities in this neighborhood where the same bed has been seen, and it is not improbable that coal B may be found much thicker in this vicinity. Indeed, at Marshall's coal bank, on Long Branch in the southeast corner of Guthrie county, a very good bed of coal one to two feet thick is being mined, and which, I am inclined to believe, belongs to this horizon.

Thus far our examinations have been confined to the valleys of the Raccoon and South Raccoon rivers, along a nearly direct line extending west from Des Moines forty-five miles into the interior. We have had opportunity to study all the members of the middle coal-series, from the Des Moines coal of the lower coal-measures to the arenaceous deposits and limestones at the base of the upper coal-series. And it now remains only to describe the principal coal-exposures found along the Middle and North Raccoon rivers, both of which streams have afforded excellent facilities in the prosecution of the investigations of this division of our coal-measures.

At frequent intervals along the Middle Raccoon between Mr. Fee's and Huggin's branch two miles above, rock-exposures appear in the bluffs, and as we ascend the stream the westerly inclination of the

strata brings successively to view higher and higher beds, comprising the arenaceous and argillaceous bulk of the lower half of the middle group of the *middle series;* and, finally, in the high bluff opposite the mouth of Huggin's branch, the remainder of this group may be seen, crowned by the bed of sandstone. A few feet below the sandstone, coal B is represented by a six-inch band of impure coal at an elevation of about one hundred feet above the river. Ascending Huggin's branch in a westerly direction, the same beds are again observed, but at a much lower level, and the black shale at the base of the upper group here makes its appearance. Near the head of the branch, about a mile from its mouth, at Huggin's bank, a characteristic section of the Lonsdale coal, or coal C, is found, (Section 2, Township 78, Range 30, Guthrie county.) The coal is two feet thick, and is overlaid by the dark shale which presents its usual varied fauna.

About three miles above Fee's, at Duck's Mill, a fine section of strata appears in the bluffs upon either side of the Middle Raccoon, exhibiting in detail the upper portion of the middle group, and in the tops of the bluffs northwest of the mills, coal C is obscurely exposed. The lower black shale of the upper group is finely developed at this locality, but no coal is associated with it. Ten to fifteen feet below this shale coal B occurs, varying from four to ten inches in thickness, as may be seen in the bluff above the mills.

In the vicinity of Tam's mills, one or two miles above Duck's mills, numerous exposures are met with in the main identical with those just discovered. In the hillside near the mills, coal B outcrops at an elevation of forty-five feet above the river, and is represented by a six inch layer of rotten coal. The sandstone overlying the coal is well developed, being some ten feet thick. Three or four feet above the sandstone, the lower black shale of the upper group, capped by its argillaceous cap-rock, is also well shown. But no signs of the presence of coal C were detected at this locality. A mile north of of the mills, on Hook's branch coal B affords a handsome layer of coal eight inches thick. Descending this picturesque little dell, the argillaceous limestone layers of the upper part of the middle group are successively passed over, affording a plentiful harvest of fossils; and toward its entrance the arenaceous beds of the lower portion of the group are met with. At this point the Middle Raccoon

abruptly bends westward, and half a mile above the branch, on the north side of the river, a high bluff gives an imperfect section of the same beds above described. Ninety feet above the water the black shales of the upper group appear at the surface, and eight feet below this bed the sandstone which overlies coal B outcrops. The elevation of the above horizons at this exposure, compared with their level above the river at the mills, shows a westerly uprising of the strata at the rate of about thirty-five feet to the mile. A few hundred yards above the last mentioned exposure, coal A has been brought to view above the water level. This bed is six to ten inches thick, and capped by a massive sheet of dark calcareous, fossiliferous shales twenty inches thick, above which twelve to fifteen feet of blue clays are exposed. The whole aspect of this horizon at this locality is so unlike its usual condition, that we would be at a loss to determine its stratigraphical position under less fortunate circumstances.

In the vicinity of Panora, Guthrie County, the lower group of the middle coal is well exposed, affording at several localities interesting sections of coal A. At Brumbaugh's Mill, and in the vicinity of the Panora Woolen Mills, the coal is ten to fourteen inches thick, and of good quality. The cap-rock here is more regular than at many localities, and gives a self-supporting roof to the entries, which renders the working of the coal economical and remunerative. The principal banks are Knowlton's, Frazier's, Wilson's and Wasson's. At the latter bank, the uppermost layers of the lower group are exposed in the ravine above the coal-bank, and in the bottoms near at hand a shaft has penetrated the underlying clays and sandstone, to the depth of forty feet below coal A, which I hardly think has yet reached the heavy deposit of sandstone overlying the Redfield coal-bed. At the Panora Mills the same horizons are exhibited, but here presenting some striking modifications. The elevation of the coal above the river level is about the same at all the localities — twenty to twenty-five feet — which indicates a gentle rise of the strata as we ascend the stream northwesterly. Messrs. Hanyan and Nichols, at the latter locality, have caused a shaft to be sunk in the bed of the river, which encountered the same beds noted in the shaft at Wasson's bank, a mile and a half

below. Coal A, also outcrops in a ravine near Panora Mills, but the coal is reduced to a two-inch seam. Above the coal, massive beds of sandstone and shales occur, which are seen to advantage opposite the mills. Should the strata continue to rise as we ascend the valley, the upper beds of the lower coal-measures would be brought to the surface a few miles above Panora. Indeed, this seems to be really the case.

Some miles northwest of Panora, at Shaw's bank, a coal-bed has been opened in the river bank but little above low-water mark. The entry was closed with rubbish, precluding any actual examinations, and in consequence only the most meagre and unsatisfactory data were gained respecting the physical characters of the bed and its stratigraphical position. Three miles above Shaw's, on Spring run, a coal-bed has been opened on lands belonging to Mr. John Clark. The bank, however, was concealed by the debris from the disintegrating sandstone which immediately overlies the coal. Still higher up the valley, in the northern part of Guthrie County, and in Carroll County, sandstones and clays are seen in many of the bluffs, which frequently give exposures of an hundred feet in hight. Here and there, thin, interrupted carbonaceous bands occur in the ferruginous grits and clays, and thin sheets of gravel are interstratified with the finer materials.

At Mount's coal-bank, seven miles below Raccoon Rapids, (section twenty-eight, township eighty-one, range thirty-two, Guthrie County) a one-foot bed of coal has been opened, overlaid by black, fossiliferous shales, and light-colored clays with concretionary band at top, upon which rests a soft sand deposit. And three miles and a half above (section twenty-four, township eighty-one, range thirty-three), apparently the same bed shows itself in the right bank of the Middle Raccoon, characterized by the same shales and organisms found at Mount's bank. There are other coal-banks in this vicinity, which are doubtless referable to the same bed.

On Musquito creek, five miles east of Panora, at Howell's bank, coal A is again met with, affording a twelve-inch bed, and agreeing in all essentials with the banks near Panora, although the bed at this locality is high above the level of its outcrop on the Middle Raccoon.

The North Raccoon river passes nearly through the middle of Dallas

county in a northerly and southerly course, cutting across the middle coal-measures nearly at right angles to the northern border trend of this series. Ascending the valley from its confluence with the South Raccoon, the strata ascend or uprise to the northward at a much more rapid rate than the fall of the stream in the opposite direction; and reaching a point a few miles north of Adel, the most northerly exposures of the lower members of the middle coal appear in the ravines high above the river. Beyond the borders of the *middle series*, horizons are encountered which present a marked contrast to the strata found along the lower course of the stream, in some respects recalling the beds on the Middle Raccoon above Panora.

One or two miles east of Adel, on Hickory and Miller's branches, the upper beds of the middle group are finely exhibited. On Hickory branch the upper sandstone of the middle group furnishes a very good freestone, which is extensively quarried for building purposes. Just above this bed, at one or two places, the same black shale of the upper group is imperfectly exposed; and four feet below the sandstone a thin carbonaceous band appears, which is the representative of coal B. In the section on Miller's branch the same beds are displayed, and in the lower portion of the bluff a local development of black shale is found, but which is not a reliable horizon. A short distance north of Adel, on Butler's branch, at the base of a low bluff composed of sandy shales and sandstone, a twelve-inch bed of coal is said to occur.

At Chaney's coal-bank, four miles north of Adel, coal A appears, which is here twelve inches thick, overlaid by the clays and thin, fossiliferous limestone layers which form the top of the lower group. Lower down the ravine a still lower bed of coal outcrops in the banks of the stream, which probably belongs to the lower coal-measures.

North of Chaney's the middle coal-measures have disappeared and, although exposures of clay and sandstone are not unfrequent, no coal is again met with, to my knowledge, before reaching the southern border of Green county. On Brown's branch, seven miles below Rippey, Green county, a ten-inch bed of coal makes its appearance, and in the river bank near the mouth of the branch, an eighteen-inch coal-bed is said to occur, which, however, is only exposed at low water. Two and a half miles below Rippey, at Bussy's bank, an eighteen-inch coal-bed is mined, which bears a close resemblance to the upper coal-bed on Polecat creek, near Boonsboro, on the Des Moines.

The northern limits of the middle coal-measures may be defined by a line passing through the middle of the north half of Guthrie and Dallas counties, in an east-and-west direction, nearly to the Des Moines river, thence trending southeast through Dallas, Polk, and into Warren county, nearly parallel with the course of the Des Moines, as far as it has been traced. To the north of this line the lower coal-measures appear at the surface, and stretch northward into Green and Carroll counties. The northern boundary of the upper coal-measures, in this part of the State, is parallel with that of the middle series, and is definitely defined by the divide which separates the Raccoon rivers from the Three River district to the south. Therefore, the middle coal-measures occupy a belt of country about fifteen miles wide and extending east and west forty-five miles or more.

It has been demonstrated that the middle and upper coal-measures possess no thick beds of coal. Although coal occurs in these upper measures, the beds are thin, and it is only where they are locally thickened, as at Marshall's bank in Guthrie, that they present good, workable beds. However, the upper bed of the middle coal-measures is very regular, with an average thickness of twenty inches. Wherever it is found in the country of the South Raccoon, it can be easily mined, and is, probably, the best bed in the two upper divisions of the coal-measures. It doubtless can be reached by boring, at many places to the southward of Lonsdale's bank in Guthrie county, but to the east and north and westward it has been swept away by the denuding agencies which exposed the lower groups of the middle coal-measures, and, still farther to the northward, revealed the upper portion of the lower coal-measures. In the counties immediately to the southward of Guthrie, this bed is buried beneath the limestones and shales of the upper coal-measures.

The lower coal-measures are the great repository of mineral fuel, and to this series we must look for the main supply of coal in the State. Although an extensive tract of country bordering upon the Des Moines is underlaid by the lower coal-measures, the

the general southwesterly inclination of the strata, in connection with the ascent of the surface in the same direction, has carried this productive series beneath the middle and upper coal-measures, and, with the exception of the Redfield uplift, they are wholly lost to view in the southwestern portion of the State. At present we have no reason to believe that the lower measures are any less productive in their southwestern extension than they are along the Des Moines.

In the valley of the Raccoon and on the lower courses of the South and Middle Raccoon rivers, the horizon of the Des Moines coal, or upper bed of the lower coal-measures, may be reached by boring at variable depths, depending upon the stratigraphical position of the locality at which it is desired to seek this bed. It is not improbable that below Redfield this bed may be found above the level of the South Raccoon, or within a limited distance beneath the surface of the valley. But to the eastward it gradually sinks deeper and deeper beneath the level of the streams until reaching the mouth of Bulger creek, at which point it probably lies at a depth of one hundred and fifty feet, or thereabout, below the river. Between the Bulger and the Des Moines, the strata slowly rise eastward, which possibly brings this coal horizon within sixty to eighty feet of the level of the Raccoon river at the mouth of Sugar creek. And ten miles in a direct course east of Sugar creek this bed gains the surface in the banks of the Des Moines river at the city of Des Moines. But it must be borne in mind that all beds of coal are more or less variable in thickness, particularly if they extend over large areas; therefore, the above estimates indicate the horizon of the coal rather than the actually known presence of the fully-developed bed. It is known that below the Des Moines coal all the heaviest beds of the lower coal-measures are found. Dr. White has described many of these coal-banks, and they compare favorably in all respects with the coal of corresponding horizons of other States.

GEOLOGY OF THE MIDDLE REGION OF WESTERN IOWA.

The country embraced in the three central tiers of counties lying between the Missouri and Des Moines rivers, possesses natural features generally common to the western half of the State. However, on a more careful examination of the ground, both with reference to the elimination of its topographical as well as its geological features, we find certain peculiarities, on the one hand, common to both the northern and southern portions of this region, which, when viewed at the extreme opposite points upon the east and west, present little in common with one another. But in this intermediate region the more distinctive surface features which characterize the extremes give way, and the result is a blending, or rather a toning down, so to speak, of the more prominent and widely diverse topographical features which are no where to be found more beautifully displayed than in Western Iowa.

The streams of the western watershed have a westerly flow, and seek their outlet in the Missouri. In this part of the State the streams take their rise in the great plateau which separates the waters of the Mississippi from those of the Missouri. In Shelby, Audubon, and the southern portions of Carroll and Crawford counties, several streams take their rise, which flowing southward, reach the Missouri within the borders of the State of Missouri. Of these may be mentionod the three principal branches of the Nishnabotany and Whitted's creek,* Musquito, Keg and Cooper creeks. To the northward, the Boyer, Willow and Soldier rise in Sac and Ida counties,

* Whitted creek rises in Carroll county, and flowing southwesterly falls into the West Nishnabotany a few miles below Harlan, in Shelby county. I could not learn that this beautiful little stream possessed a name, and hence I have suggested the above name in honor of Mr. P. J. Whitted of Exira, Audubon county, who was one of the first surveyors in this part of the country, and whose name has been thoroughly identified with the progress and best interests of these counties from their earliest settlement to the present time.

and passing diagonally through Crawford, Harrison and Monona counties reach the Missouri along the middle border of the State. The Little Sioux and its principal tributaries, the West Fork and Maple river, head in the northern part of the State, and drain the fine region embraced in Ida, Woodbury, and the western portion of Monona counties. Along their upper course the streams become mere drainage depressions, though their character as such is always distinctly marked. Upon the head-waters of the numerous small rivers and creeks which traverse this portion of the western watershed, we do not find the streams taking their rise in lakelets, as in the country east of the grand divide; on the contrary, they are divided into a multitude of drainage channels which mark their delicate ramifications to the very crest of the watershed between the two river systems, and by this means a system of the most complete drainage is effected. These upper ramifications have been called "draws," and not inappropriately, as their beds are not usually occupied by a continuous channel, for they are seldom fed by springs; but their chief use is to collect the surface waters, and hence it is only during the spring and autumn seasons that their beds are flooded. In the summer their waters shrink into little dark pools, and their beds are carpeted by a tall, nutritious herbage, quite in contrast to the lower grasses of the surrounding prairies. These streams of green herbage follow all the graceful meanderings of the channels to their very sources, and impart a refreshing feature to the prairie landscape.

The Raccoon river system is tributary to the Des Moines, and is the most considerable, both as regards the size of the streams and the area which they drain, that occupies the country between the Des Moines and the grand-divide upon the east slope. The courses of the four principal branches, the North, Middle, Bushy Fork and South Raccoon, are nearly at right angles to those of the streams previously mentioned upon the western watershed and parallel with the divide. All, with the exception of the North Raccoon, take their rise in Guthrie and Carroll counties; while the latter passes through the entire length of Sac county, to the north, and heads in Buena Vista and Pocahontas counties. The peculiarities of the drainage upon the two watersheds are widely different; upon the western, we meet with a multitude of small branches, while in the country east

of the great divide the larger streams possess comparatively few small affluents. Before we go further, let us make a brief examination of the deposits in which the varied topographical features of the region are moulded, and which will enable us the better to understand the origin of the present appearance of the surface in this section of the State. The superficial deposits which occur in the western part of the State are the drift and bluff. In the country between the grand divide and the Des Moines, the drift is largely developed, consisting of blue clays, and yellow, sandy clays, which latter is usually spread over the greater part of the surface. Upon the west slope the drift rapidly diminishes in thickness, and is overlaid by the peculiar yellow clays of the bluff. This latter deposit reaches its greatest development on the western borders of the State, when it attains a somewhat variable thickness, probably at many localities not less than two hundred feet. The fine nature of the material which comprises the bluff, seems to furnish conclusive evidence of its lacustrine origin. On the other hand, the coarse materials which enter so largely into the composition of the drift, were deposited at the bottom of the great fresh-water sea at the close of the glacial period. The bluff clays abut upon the Missouri bottoms in ranges of steep bluffs, which, when visited from the valley, or looking either up or down their course from some eminence, it requires but little effort on the part of the imagination to transform the whole landscape into one of lofty mountain ranges and great plain. Although in the region of the drift upon the east watershed we do not meet with such bold, exaggerated surface features; nevertheless, that section possesses its strongly marked peculiarities, which furnish a striking contrast to the country bordering the Missouri.

Descending the water-courses towards their confluence with the Missouri, the valleys gradually descend, and narrow intervals rise from the margins of the streams to the gentle border slopes of the uplands. Along their lower reaches, the streams are eroded to the depth of two hundred feet and upward, and their exit from the uplands is guarded by the massive hights of the great lacustrine deposit. Between these streams the surface is rolling, though seldom broken. The streams themselves are bordered by steep, grassy

banks, and their beds, with few exceptions, are filled with quicksands or equally treacherous mire. The uplands are remarkably free from boggy land, and "sloughs" are encountered only in the low bottoms along the streams. In the immediate neighborhood of the Missouri bottoms, where the uplands are abruptly terminated, the surface is usually broken, and the bluffs are penetrated by deep, narrow ravines, shaded by dense forest growths, whose existence one little suspects until their canon-like beds are overlooked from the ridges above. The Missouri bottoms form one of the most remarkable peculiarities of the West. They extend the entire length of the State, and are more or less variable in width. In Harrison County, between the Boyer and Little Sioux, the bottoms have a width of eight miles; and in Monona and Woodbury Counties they crowd inland a distance of twelve miles or more, and the bluffs which abruptly define the eastern margin, do not again approach the river until within a few miles of Sioux City, at Floyd's Bluff, where they form a conspicuous headland overlooking the turbid waters of the Missouri for miles. The bottoms rise in low benches, which, in form, have all the characteristics of true terraces, although they are but little elevated above the general level. These benches, however, are composed of exceedingly fine materials, and in this respect they differ greatly from the terraces, or "second bottoms," along the streams of the Mississippi watershed. Like true terraces, they are most elevated along their outer margins, and slope inland, giving rise to the little lakes and channels which not unfrequently skirt the base of the bluffs and meander through the bottoms, affording a natural drainage. Throughout the entire extent of the bottoms, the soil is of unsurpassed fertility, and the day is not distant when this immense tract of alluvial lands will hold a foremost place in the agricultural interests of the West.

As has been previously mentioned, the greatest development of the bluff deposit occurs in the Missouri river bluffs, where it ranges from one hundred to two hundred feet in thickness. To the northward, however, the deposit gradually diminishes in thickness, and in the neighborhood of Sioux City, it is reduced to half its maximum thickness in the counties to the southward. It crowns all the cretaceous hills, and gives to the region about, that peculiar character of

topography pertaining to this deposit. Indeed so markedly is this manifest that the presence of the cretaceous formation can hardly be said to have taken more than an insignificant part in giving the country its present configuration.

Underlying the bluff material along the Missouri valley, at many localities, we find a thin layer of sand, with pebbles and boulders, distinctly arranged in layers; and which, in turn is underlaid by the clays of true Drift epoch. But more frequently the thin stratum of modified drift material is found resting immediately upon the rocky strata, with no intervening clays; and sometimes even the gravel-bed disappears, and the base of the bluff comes in immediate contact with the consolidated rocks, as observed in the environs of Sioux City. However, if we ascend any of the valleys of the larger inland-streams, as the Little Sioux and the Boyer, as we recede from the Missouri river bluffs eastward, we shall very soon witness a gradual increase in the development of the gravel-beds; and soon low outliers protruding from beneath the bluff deposits, will add an unusual element to the landscape, and however inconspicuous these bunches may be they are always sure to arrest the eye and gain our interest, if no other than this very obscurity. On the Little Sioux the gravel-beds are found fifty feet above the stream, overtopped by twice that thickness of bluff. And at Dennison, at the confluence of the two main branches of the Boyer, similar exposures are found, from which is obtained the gravel for the manufacture of the concrete brick at that place. Also near Dennison, on Judge Bassett's farm, certain layers of these deposits are found sufficiently cemented, to answer for laying up in rough walls. Generally speaking, however, the gravel deposits are too wasted to have more than a slight influence in modifying the nature of the soil, which is still decidedly of bluff origin.

In the country bordering upon the Nishnabotanys, the bluff presents some of its most characteristic features. The divides are massive and rounded in outline, and descending into the valleys by those long, graceful slopes, it is not unfrequently difficult to draw the demarkation between bottom-land and upland. But on approaching the grand divide, the drift is frequently found high in the slopes,

the line of its outcrops studded with boulders, and giving a sort of angularity to the topography which is wholly foreign to the bluff.

Ascending the east branch of the Boyer, the bluff clays continue to compose the great bulk of the uplands, and sweeping over the watershed in Carroll and Audubon counties, burying deep beneath its mass the underlying deposits, it forms a heavy capping upon the divide between the South Raccoon and Brushy Fork, and tips the crest of the ridge between the latter stream and Middle Raccoon, upon the east watershed. At this point, which is the eastern border of the bluff in this section, the topography assumes a totally different aspect, and in many respects essentially peculiar to that section of the country drained by the Raccoon rivers.

But to return to the west watershed, we will next ascend the main branch of the Boyer. Starting from Denison, our route thence to the northeast corner of Crawford county traverses the beautiful upland upon the east side of the Boyer, and parallel with its course. The bluff-clays continue to impart to the soil and to the surface-outline of the country its well-marked peculiarities until we have passed beyond the borders of Crawford and entered Sac county. Here the country becomes changed. The surface, instead of presenting those smooth, graceful slopes and finely-comminuted soil everywhere met with and common to the bluff wherever it exists, stretches to the northeastward in a barely perceptibly-rising plain, traversed by long files of low wave-like ridges or swells, whose crests are paved with boulders and the slopes strewn with gravel. We have hardly missed the presence of the familiar lacustrine deposits ere we find ourselves environed by entirely different geological and topographical phases. We are again standing upon the great divide, overlooking almost an immensity of prairie, the horizon to the east, west and south presenting a continuity as unbroken as that at sea, but which to the northward is interrupted by the heavy drift-ridges whose outlines are sharply defined against the background of deep-blue sky at that quarter. Every step of the way thence to Wall Lake exhibits the uncovered drift deposits; and reaching the bluffs overlooking the North Raccoon at Grant City, and throughout its course below, well-defined terraces, or "second bottoms," border

either margin of the valley, which greatly enhance the scenic effect and afford beautiful rural situations.

The dividing ridge in this region has a generally northwest and southeast direction. Between Audubon and Guthrie, and in Carroll county, it forms a sinuous ridge, from the crest of which the drainage "draws" descend upon either slope, on the one hand to join the numerous affluents of the Nishnabotany and the Boyer, and upon the other to augment the tributaries of the Raccoon rivers. But as we pass along the divide to the northward, in the northern portion of Carroll county, the drainage of the two watersheds is interlocked, so to speak, by the head-waters of the Middle Raccoon and the east branch of the Boyer; and here the divide is as sharply defined as the ridge of a gable roof. Further to the north the ridge expands into a gently undulating plateau, which is traversed by low ridges of drift, producing an entirely different configuration from what it possesses to the southward. These ridges are composed of the loose material of the drift, and form the highest land in this part of the State, with an elevation above the level of the sea, probably, of not less than fifteen hundred feet. The broad, shallow depression intervening between the knobs or ridges of drift, possess a rich, black, gravelly soil, which differs in many respects, excepting in fertility, from the soils of the west watersheds. It will have been already seen that the difference in the soils of the east and west watersheds is due to the difference in the nature of the immediately underlying deposits in the two sections. Wherever the bluff clays are found, a fine, light-colored, durable soil is produced, which is particularly well adapted to the growing of cereals; and in the region of the drift, east of the dividing ridge, the soil is of a loamy nature, though possessing many varieties, susceptible of early tillage, and returning abundant harvests to thorough cultivation.

The Raccoon rivers are deeply excavated into the drift and coal-measures; their valleys are narrow and bordered by steep bluff ascents, and usually terraced. But along that part of the courses of the South Raccoon and Bushy Fork bordered by the bluff deposits, either these "second bottoms" are wholly obliterated or only obscurely displayed — a peculiarity, as heretofore observed, common to these deposits wherever they are found associated. The moment, however,

the streams pass beyond the influence of the bluff, the benches which rise step-like upon the sides of their valleys assume definite outlines, and hence continue to impart to the valleys a prominent and pleasing feature in their formation and appearance. The uplands are level, or but gently undulating, and instead of sweeping down into the valleys by more or less steep, smooth slopes, as is the case with the uplands of the bluff country, they are always abruptly terminated upon the brink overlooking the valleys from a hight of one hundred to two hundred feet. The quality of the soil in the valleys proper varies according to the location. Immediately bordering the margins of the streams, the low intervals occur, which are made of sediments, sand, &c., the deposit of the freshets. The lower terrace is usually enveloped in a fine, loamy covering, of remarkable fertility. The earlier or higher terraces, on the contrary, are composed of coarse, rearranged materials derived from the disintegration or wearing away of the drift which once filled these valleys — for the valleys are evidently of very remote origin, extending far back into the past to a time prior to the glacial or ice period. These higher benches possess the warm, gravelly soil, so common in the valleys of many of our rivers which are tributary to the Mississippi. In the valley of the North Raccoon, below Granite City, in the counties of Calhoun, Carroll, Green and Dallas, and also in the valleys of the South and Middle Raccoons, the terrace formations may be advantageously studied. But they are seen only in the valley of the North Raccoon, as at Adel, near Mr. Gibson's, above New Jefferson, and in the vicinity of Morlan's, Calhoun, county, where they present some of their most conspicuous and diverse peculiarities.

In connection with the terraces, interesting spring phenomena are frequently observed, which have attracted considerable notice. In Greene, Carroll and Calhoun counties it is not uncommon to meet with limpid streamlets trickling down the slopes toward the river, and sometimes they have formed for themselves deep channels in the loose material of the surface over which they flow. Tracing these little streamlets to their sources, they are invariably found to issue from the gravel-bed immediately at the point of junction with the impervious blue clays of unmodified drift.

It is only at those localities where the sheet of gravel has been interrupted in its descent to the lower levels of the valley, bringing to the surface in its stead (it may be but a narrow band) the underlying clays of the drift, that natural springs may be expected. Many times the springs issue almost at the brow of the bluffs, and upon the steep slopes peaty deposits are in process of formation from the partial decomposition of the luxuriant herbage growing in the wet spots.

Wells of excellent water may be obtained at almost any point by sinking a shaft down through the modified materials to the upper surface of the drift clays, and usually at a moderate depth from the surface of the ground. In the country of the west watershed, rills of water are not obtained at so short a distance below the surface; there the great thickness of the bluff clays must be penetrated before the lower, water-saturated gravel bed is reached. This would prove a serious disadvantage in that section were it not that the bluff material possesses that tenacious quality which enables excavations to be made at any depth in its mass without incurring the risks of slipping or falling in or the expense of curbing.

The distribution of forests upon both watersheds seems to have been governed by the influences. The annual fires which sweep the prairies of the interior, unchecked, have doubtless had most to do in preventing the general growth of forests in this region. The groves are usually found in such situations as afford them the best natural protection from the devastations of the fires. These situations are variously located, but usually the densest timbered lands are confined to the lower bottoms bordering the streams and in the deep gullies which penetrate the uplands. Considerable bodies of timber skirt the Missouri bottoms, but between this belt and the foot of the bluffs the level stretch of the bottoms is interspersed only at long intervals by lone cottonwoods or clumps of willow. Upon many of the streams of the western watershed various belts or little groves are not unfrequent, and they contribute the most redeeming features to the landscape. Groves are not always confined to the river margins, however, for it is not a rare occurrence to meet with them upon the upland ridges, though in these situations their gnarled, charred trunks bear painful evidence of their struggles with the fires. A few miles north of

Exira, in Audubon, a considerable tract of the upland is covered with a scattered growth of oaks and underbrush. And in Crawford, Harrison and Monona counties, many of the divides are covered with low, bushy oaks, which spring from roots as large as those of the mature forest tree. Since the settlement of this part of the State, fine groves of young timber have grown up where fifteen years ago the luxuriant herbage of the prairies was the only vegetation. In the northwest portion of Shelby county there is a large body of forests on Mill creek and its affluents, which is said to contain about ten thousand acres; it is the largest body of timber in this region. Upon the east watershed the valleys of the Raccoon rivers and their affluents afford considerable bodies of timber — enough, indeed, to supply the demand for many years to come. Upon the upland in this portion of the State handsome groves planted about the farms already break the continuity of the horizon-like islands; and if farmers would give more attention to the planting of artificial groves, in a few years the country would wear a very different and far more inviting appearance.

Fruit-trees are said to thrive throughout this section of the State; the great difficulty to be encountered in their cultivation, is to check the rapidity of growth which is so fatal to the hardiness of the young tree. It must be borne in mind, however, that there are few localities in the thirteen counties of this district which have been settled for a longer period than twelve to fifteen years; and experience teaches that the introduction of fruit-trees into a new country is almost always attended with many discouragements. Now, that nurseries have been established in various parts of the State, and the trees acclimated and accustomed to the soil, in a few years we may reasonably hope to see as fine orchards upon our prairies as are to be met with in any of the older States in the same latitude.

Little attention has been given to the introduction of the cultivated grasses. But there can be no doubt, in view of the experience of the older settled portions of the State, as to the practicability of converting immense tracts into the finest meadows in the world. To-day, however, the whole prairie is a common, natural pasturage and meadow. Upland and valley alike are clothed with nutritious herbage, affording a boundless range; and rivulets, brooks and

rivers furnish a never failing supply of water. In fine, there is diversity enough to please all tastes and suit all interests. There is a variety of soils, but the same grains may be produced from any of them with almost equally remunerative results. And now, that these counties will soon enjoy the facilities afforded by three main railway lines which traverse their territory east and west, this section of our State will possess advantages second to those of no similar district, and open to enterprise which it is so capable profitably to sustain.

REPORT

OF

GUSTAVUS HINRICHS

STATE CHEMIST.

REPORT OF CHEMIST.

To Dr. C. A. White, *State Geologist:*

Sir — The accompanying Report contains the principal results of my chemical work for the survey. It will be most convenient to divide this Report into the following chapters, according to the subjects treated of:

I. Chemical Report on the Fuel of Iowa.

II. Chemical Report on the Water and Rocks of Iowa.

III. On the Valuation, Composition and Proximate Analysis of Iowa Coals.

IV. On the Mineralogy of Iowa.

GUSTAVUS HINRICHS.

Iowa City, February 24, 1868.

CHEMICAL REPORT ON THE FUEL OF IOWA.

CHAPTER I.

In this chapter the chemical composition, physical properties and heat-giving value of our Iowa fuel will be given, particularly in regard to coal.

The fertile soil of the State can furnish an abundance of digestible fuel, food for the stomachs of the present population and several millions more. Below the surface of this soil there is an almost inexhaustible supply of very good indigestible fuel, food for the iron stomachs of hundreds of steam boilers, which one day will be busy in this State, doing the hard work of millions of hands; the joint labor of the human hands, supported by the product of the soil, and of the iron hands, fed by the fuel from below the soil; this is the measure of the future wealth of the State. Hence the prominence given to the geological and chemical investigation of the fuel of the State in the labors of the present Geological Survey of Iowa.

I. On the Classification of Fuel.

Whenever any fuel is heated to a certain temperature, it will burn, provided at the same time the air has free access. The result of this combustion is a two-fold one; the material apparently disappears (leaving only a small amount of ashes) and heat is produced at the same time. In other words, the fuel has been changed into two gaseous products, carbonic acid and water, and in this transformation heat was given off.

We burn the fuel merely in order to obtain this heat yet it can not be set free except by converting the fuel into the above mentioned two substances, carbonic acid gas and water.

These two substances form a considerable part of the atmosphere surrounding the globe, and every combustion increases this amount. While thus the amount of combustible matter of fuels is continually diminished by the increasing wants of man, the question naturally arises: can not these products of combustion be re-converted into fuel? Can not fuel be manufactured? No doubt it can be done; chemists have succeeded to decompose both products above named, so as to reproduce combustibles. Even the twelve per cent of pure carbon contained in our common limestone can very readily be extracted from the same by chemical means. But the power necessary for this purpose is heat, so that unless this heat be obtained at a very low price, these chemical processes can not be utilized in the arts, or fuel can not be manufactured.

Fortunately there is one source of heat costing nothing, that is the heat of the sun. Fortunately there is one chemical apparatus, costing nothing, but most eminently adapted to the work of re-decomposing the products of combustion given to the air; this apparatus is the plant. Just as soon as but a leaflet is above ground, the young plant under the power of the sun's ray commences its attack upon the products of combustion contained in the air; the result of this labor is vegetable matter, combustible, and in proportion as the chemical work of the solar ray and atmospheric air goes on in the cell of the plant, this increases continually. It is this action which gives us our forests, our peat and our coal!

Until heat can be obtained cheaper than the free all-reaching ray of the sun and the raw-product can be had for less than nothing, the present quotations of a liberal atmosphere; until then fuel will not be produced except as the result of vegetation.

Force being as indestructible as matter, we here discover the origin of the heat produced by combustion. For since the heat of the sun acting upon the carbonic acid and water in the air makes the fuel, this latter when burning reproduces not only the former matter (carbonic acid and water,) but also the force, heat. We may, therefore, say that the vegetable tissue is air woven by the sun's ray.

It may be well to notice that this circulation of force and matter is perfect; solar heat and the products of combustion produce the combustible; this latter in being burnt, re-produces both the

materials of which it was made, and the heat which wove these materials together.

In burning a branch of last season's growth, we set free the sunbeams of that season; in burning a tree a thousand years old, we set free the solar ray that came to our earth a thousand years ago; in burning coal, the product of a vegetation which flourished millions of years ago, we liberate the beams of the sun which came to this globe millions of years before the appearance of man.

All our fuel is undoubtedly of vegetable origin. But as vegetation is of two tolerably distinct kinds, aquatic and terrestrial, the fuel resulting must vary accordingly. The plants growing on the land need a special, firm texture to support their own weight; those growing in the water are almost completely held up by the buoyancy of the liquid, and are therefore devoid of woody fiber. As the forests on the land, so dominates the sea-weeds among the plants of the deep; they are often hundreds of feet in length, and of considerable thickness.

Plants may be used as fuel immediately after being cut down (our fire-wood), or they may have been buried in the sea or among the rocks for a greater or less length of time (fossil). Accordingly we obtain the following general classification of fuel:

PLANTS.	GROWN ON.	NAME.	AGE.	FUEL.
Land-plants	Dry ground.	*Trees*	Fresh.	*Wood*
Land-plants	Dry ground.	*Trees*	Fossil.	*Lignite* and brown coal.
Land-plants	Wet ground.	Mosses, heather, etc.		*Peat*
Sea-plants		*Sea-weeds*	Fossil.	*Coal* proper
Sea-plants		*Sea-weeds*	Fresh.	Not much used

All of these varieties of fuel are found in Iowa, except Brown coal or Lignite.

Just as well as our forests continually produce an increase of wood, so we know our peat-bogs annually to add to the store of peat; and the immense regions of sea-weeds in the oceans prove that coal also is continually being formed on our globe. This view was but a few years ago advanced by the distinguished German chemist, F. Mohr, of Bonn on the Rhine. In the course of my investigation of the Iowa coals, I have discovered several facts which

add considerably to the already overwhelming evidence brought forward by the author of this theory.

We shall now consider the chemical composition of these various fuels, indicating the exact place of our Iowa fuels in the series. Thereafter we intend to show how the valuation or heating effect of these fuels is determined. Finally, the results of the several analyses of Iowa coals will be given by counties.

It may not be improper to give a short synopsis of the history of the coal, particularly as this, after Mohr's labors, appears remarkably simple, and also because our Iowa coal-field seems particularly adapted to prove the correctness thereof.

In order to make this chapter of interest to the general reader, I shall leave out everything of an abstruse nature; but for the sake of completeness, these matters will be given in a separate chapter.

II. ON THE COMPOSITION OF FUEL.

The chemical elements which constitute by far the greatest portion of all fuel, are *Carbon*, *Hydrogen*, and *Oxygen*.

The first of these we have almost pure in charcoal; it burns without producing any flame while producing a very high degree of heat. The greater the proportion of carbon in any fuel, the deeper black will be the color of the same, and the more intense will be the heat produced by its combustion, but the less flame will result.

The second of these elements, hydrogen, is the very opposite; not solid but a gas, and even the lightest body we know; when burning it is all flame, producing a great quantity but relatively not so high a degree of heat, as carbon. Hydrogen constitutes one-ninth by weight of water, about one-sixth by weight of common illuminating gas. Hence the greater the per centage of hydrogen in any fuel, the more flame when burning. That part of the burning fuel which is sufficiently heated will decompose, giving off its hydrogen and some carbon, as a gaseous substance, more or less like illuminating gas; as soon as this meets the air, supplied by means of proper draft, it will burn, constituting the flame of all these combustibles.

The third principal element of our fuels, oxygen, may be considered an unproductive part of the fuel. When constituting a part of the

fuel, it costs a corresponding amount to us, while in the air we could have it free of cost; and as the heat of combustion only results from the carbon or hydrogen uniting with oxygen, it is furthermore evident, that any oxygen united with these other elements in the fuel prevents those parts thus already provided with oxygen from producing any heat. A fuel is therefore so much the better the *less* the amount of oxygen it contains.

Omitting for the present the consideration of those elements present in small quantities, we may express the average composition of the various fuels, referred to one hundred carbon, in the following figures:

FUEL—DRIED.	Carbon.	Hydrogen	Oxygen.	Total.
Wood	100	15	90	203
Peat	100	10	60	170
Lignite	100	8	30	138
Bituminous Coal	100	7	15	122
Anthracite	100	2	5	107

The fuels abundant in Iowa are in *italics*

According to the remarks just made, it will require much more wood than coal to produce the same heating effect, on account of the great proportion of oxygen in the former. The amount of hydrogen corresponding to 100 carbon gives a fair representation of the inflammability of the fuel.

The fuel, as commonly used, is not artificially dried, but contains a greater or less amount of moisture. A portion of the heat developed by combustion of the fuel is therefore wasted in driving off the moisture. All fuel, furthermore, contains a very noteworthy amount of ashes, which also, in various ways, diminishes the effectiveness of the fuel. Nor can we finally consider the fuel as merely constituted of the above elements thoroughly mixed up, they are chemically combined. To increase the difficulty still more, it has hitherto not been possible to ascertain the exact way in which these elements are combined. Thus it seems, that very little can be ascertained chemically in regard to the exact value of the various fuels.

But when fuels are used for heating purposes, they are, as mentioned above, always more or less decomposed before they are totally consumed. The heat in the fire-place decomposes the fuel into a volatile and a non-volatile portion; the former when burning constitutes the flame, the latter when cooled constitutes the coke, (or, in the case of wood, charcoal.) Hence, it is not at all the fuel as it is thrown upon the grate that burns, but rather the products resulting from the fuel when exposed to the heat of the fire-place. Although we therefore may be ignorant of the exact arrangements of the elements in the cold fuel, we may, nevertheless, be able to estimate its heating effects, if we succeed in ascertaining the products wherein the fuel is decomposed previous to its actual combustion.

Now this is what the so-called proximate analysis of fuel attempts to do. By exposing the fuel to heat, being careful to exclude the air from it, we ascertain the amount of volatile matter in the fuel; this subtracted from the total weight taken, gives the per centage of coke. By separate operations both the amount of moisture and of ashes is determined; subtracting the former from the volatile, gives the amount of volatile combustible matter, which I for brevity call bitumen; subtracting the per centage of ashes from that of the coke, we obtain the amount of non-volatile combustible matter, which is almost pure carbon, and therefore is called carbon. By means of an extensive series of experiments, I have succeeded in perfecting this method of analysis to be fully equal in exactitude to that of the elementary analysis; so that the analysis made by me will not only have a relative value, but fix the absolute value of the coals analyzed. The detail of this method and the investigation leading thereto appeared in the *American Journal of Mining*. [See Chapter III.]

As an average from which the various samples of Iowa coals but slightly deviate, I may give the following percentage composition:

COMPOSITION.

VOLATILE — PER CENT.		COKE — PER CENT.	
Bitumen	.45	Carbon	.45
Moisture	.05	Ashes	.05
Total	.50	Total	.50

Total combustion, 90 per cent.

In the Report of Prof. Whitney (vol. 1, pt. 1, page 399) it is stated that the Iowa coals contain from 45 to 50 per cent of carbon. This statement has been copied in Bailey and Hair's popular "*Iowa State Gazetteer*," Chicago, 1865, page 22. The actual per centage of carbon given by Whitney on the subsequent pages, as the result of his own analyses, range all the way, and regularly, from 39 to 55 per cent; that is, instead of varying only 5 per cent, the variation is fully 16½!

In commencing the more critical study of the Iowa coals, I very soon discovered that notwithstanding this great variation in the composition of the raw coal, the combustible itself varied but very little, being composed of about 40 of bitumen and 54 of carbon. This discovery was first mentioned by me in the "report of progress" for 1866, and is in detail published in the *American Journal of Mining*, for November 30, 1867. [See Chapter III.]

The direct consequence of this discovery is *that the heating effect of our various Iowa coals is measured by their per centage of combustible matter*; for if this latter is of the same composition in our Iowa coals, it follows that the heating effect is proportional to the amount of this combustible. The per centage of combustible in Iowa coals I have therefore called the *value* of these coals.

Furthermore, two coals will have the same heating effect, if they contain the same weight of this combustible; hence I call such weights of the various Iowa coals as contain the same amount (100) of combustible matter, the caloric equivalents of these coals.

If we had a certain weight of the pure combustible contained in Iowa coals, but free from both ashes and moisture; if this weight could be had for one dollar, then the raw Iowa coal, containing on the average 90 per cent of this combustible, would be worth 90 cents for just that weight, and 111 pounds of the same coal would produce the same amount of heat, as would be obtained by burning 100 pounds of the pure combustible.

Since this is an entirely new method of valuation of coals, it will be necessary to give an example in order to be fully understood by the reader:

For instance, the coal from Henry Shock & Co.'s mine on section

eight, township seventy-two, range fourteen, near Chillicothe, Wapello County, gave by my analysis:

	No. 346. Top.	No. 371. Bottom.
Specific gravity	1.361	1.308
Weight of 1 cubic foot	84.82 lbs	81.50 lbs.
Volatile matter	46.36 per cent.	47.79 per cent.
Coke	53.64 per cent.	52.21 per cent.
Bitumen	38.55 per cent.	41.67 per cent.
Carbon	46.47 per cent.	48.34 per cent.
COMBUSTIBLE	85.02 per cent.	90.01 per cent.
Ashes (red)	7.17 per cent.	(white) 3.87 per cent.
Moisture	7.81 per cent.	6.12 per cent.
	100.00 per cent.	100.00 per cent.

REFERRED TO THE COMBUSTIBLE — 100 PER CENT.

Bitumen	45.36	46.32
Carbon	54.64	53.68
Ashes	8.44	4.30
Moisture	9.19	6.80
Equivalent	117.63	111.09

It may be seen from this analysis that the combustible of the top and bottom part of this coal-bank is very nearly the same; containing about forty-six parts of bitumen in each one hundred of combustible. The top coal contains eighty-five per cent of combustible, the bottom coal ninety per cent of the same; hence, if a certain weight of the top coal is worth eighty-five cents, the same weight of the bottom coal will be worth ninety cents, for heating purposes; the same weight of the pure combustible would be worth one dollar. This is what is meant by saying the per centage of the combustible expresses the value of our Iowa coals.

Again, in order to get one hundred pounds of pure combustible, it is necessary to take nearly one hundred and eighteen pounds of the top coal, or one hundred and eleven pounds of the bottom coal. In other words, one hundred and eleven pounds from the bottom of this mine contains as much of the heating material, or are capable of yielding as much heat, as one hundred and eighteen pounds from the top part of the mine; that is, one hundred and eighteen of the top coal are equivalent in regard to their heating or caloric effect to one hundred and eleven pounds of the bottom coal. This is what is meant by the caloric equivalent given in my analyses of Iowa coals.

Both of these two values, on which the practical importance of the analyses of Iowa coal depends, are the result of my own investigations. They were therefore not given in any analyses of Iowa combustibles previous to my own.

Finally, it will be observed, that the *color of the ashes* of the top coal is red; that of the bottom coal is white. The red color in the ash being due to iron oxide in the same, resulting from pyrites (iron combined with sulphur) in the coal, it is evident that the top coal contains a considerable amount of sulphur, the bottom coal hardly any. Hence the bottom coal is good for blacksmithing purposes, the top coal not; if used for mere heating purposes, the top coal will be more destructive to grate and boiler than the bottom coal.

The guide of the analyses in regard to the amount of coke or gas that the coals may yield was given in the older analyses also; but since my analyses are made according to a method giving strictly reliable results, the estimates here given for gas and coke may prove a more safe guide for those who either would manufacture coke, in order to enable them to ship coal to greater distances, or who would select a coal for a gas works.

I have dwelled thus lengthily upon this sample in order that the people may be enabled to understand the meaning of the figures given as the result of my analyses of Iowa coal, particularly since these two expressions of value and equivalence never before have been connected with proximate analyses of coal. This valuable practical result I claim as one discovered during the progress of the Geological Survey of Iowa.

In order to compare our Iowa coal with those of other parts of the world, so as to test the popular opinion that our Iowa coals are of an inferior quality, I have analyzed the following seven samples of fuel, contained in my private cabinet of minerals. For the sake of completeness, I have also added my analysis of the most volatile solid fuel, asphaltum. It must be observed, that these analyses are comparable, having all been executed according to my improved method.

COMBUSTIBLE — 100.

NAME AND LOCALITY.	Carbon.	Bitumen.	Ashes	Moisture.	Equivalent.	Value.
Asphaltum	26	74	4	?	104	96
Peat, from Ireland	36	64	2	16	118	85
Bituminous wood, from Salzhausen, Hessia	31	69	5	10	115	87
Brown coal, from Arbesan, Bohemia	36	64	3	11	114	88
Brown coal, from Bilin, Bohemia	40	67	16	00	123	81
Bituminous coal, from Beutnen, Silisia	51	49	21	5	126	80
IOWA COALS, average	50	50	5	5	110	90
Cannel coal, from Wigan, England	61	39	10	3	112	89
Anthracite, from Pennsylvania	94	6	2	2	104	96

[For the sake of perspicuity the decimals have not been given.]

The excess of the equivalent above 100 expresses the amount of impurities [ashes and moisture] in the coal. For the same kind of fuel its heating effect will therefore be the greater for equal weights, the less this equivalent exceeds one hundred. Now in this regard our Iowa coals are as good as any, for the average shows only ten parts of impurities for 100 parts of combustible. Though in particular cases this amount is frequently exceeded, it is also very often much less. Thus the coal from the top of the bank at Business Corner, Van Buren county, has an equivalent of only 102.73: that is, for each 100 of combustible this coal contains only 2¾ of foreign matter, or less than the Anthracite analyzed. The equivalent of the coal from the bottom of Richardson's mine, two miles west of Fairfield, Jefferson county, is a little lower yet, only 102.37, and indeed the lowest of any Iowa coals yet analyzed; that is, it is the purest of all samples investigated, containing not even 2½ parts of non-combustible matter for each 100 of combustible, or less than one pound in forty pounds of pure combustible matter.

Nor is the kind of ashes in our Iowa coals of a more obnoxious quality than that of other coals. The ashes from the bottom coal of Henry Shock & Co's mine, Wapello county, or from the bottom coal of the Iowa Coal Company's mine at Oskaloosa Station, Mahaska county, and from many other samples of Iowa coal, is as pure white as the ashes from the English cannel coal, analysis of which is above given. Nor is the ash of any Iowa coal more ferruginous, or the corresponding coal, more sulphurous than corresponding coal from

other regions; the simple fact of the matter is, that everywhere we have both poorer and better qualities of coal in these respects, and while none of our Iowa coals is worse than poor coals from other countries, there are no bituminous coals better in any country than the best coals of our State, both in regard to the amount and quality of the impurities of the fuel.

Again, it will be observed that the amount of carbon in the various combustibles analyzed ranges from 40 to 94. The average would be:

Peat and brown coal, 40 per cent carbon.

Bituminous coal, 50 per cent carbon.

Anthracite, above 90 per cent carbon.

It therefore appears that our Iowa coals are as rich in carbon as the average of bituminous coals the world over. We have among the numerous samples analyzed found one sample almost identical with the genuine cannel coal from Wigand, England, mentioned above; this coal is from the top of the Alpine Coal Company's mine, at Alpine, on the Des Moines river, in the southeastern township of Wapello county. This will become plain by comparing the results of my analysis:

	CANNEL COAL.	
	From Alpine, (top, No. 336.)	From Wigand, England.
Bitumen	40.37	39.05
Carbon	59.53	60.95
Combustible	100.00	100.00
Ashes, [grey]	8.09	[white] 9.53
Moisture	4.72	3.39
Equivalent	112.81	112.92
Value	88.65	88.56

The correspondence in the composition of these two samples, the one from England, the other from the Des Moines Valley, is, to say the least, most remarkable; at any rate this Iowa coal is as good as the English cannel coal here analyzed.

The column headed "Value" in the preceding table has not the same signification as it has for our Iowa coals, for the per centage of bitumen in the combustible of these fuels varies very much, so that

an equal per centage of combustible for the various kind of fuel does not imply an equal heating effect. Indeed we know, that while one pound of carbon, by complete combustion, will produce heat sufficient to heat eighty-one pounds of water from the freezing to the boiling point, or to convert about twelve pounds of water into steam, the various gases constituting the volatilized bitumen have a different heating power — some producing less, others producing more heat than an equal weight of pure carbon.

According to the determination of the late Prof. Forchhammer, of Copenhagen, as stated in his lectures, one pound of the various fuels will by combustion raise the temperature of the following number of pounds of water from the freezing to the boiling point:

Wood, air-dry	22 lbs
Peat	25 lbs
Brown coal	29 to 36 lbs
Pit coal....(Bituminous coal)	50 to 60 lbs
Anthracite	70 lbs

While these figures state the amount of heat that *can* be obtained, but which actual practice falls very much short of, we have some experiments of the Prussian Chemist Brix determining the number of pounds of water actually converted into steam by means of one pound of fuel in the same heating apparatus; his results were:

Wood	4 to 5 lbs
Peat	5 to 6 lbs
Brown coal	5 to 6 lbs
Bituminous coal	6 to 7 lbs
Charcoal, dry	7½ lbs

Since one pound of pure carbon, if completely utilized, would convert twelve pounds of water into steam, this last figure shows how much even carefully conducted experiments fall behind this theoretical standard.

By means of these figures we see, that for equal weights the heating effect is smallest for wood, greater for peat, still greater for brown coal, and that bituminous coal, or rather pit coal (steinkohle of the Germans) is only surpassed by anthracite in its heating effect.

Since now my extensive analyses have proved that our Iowa coals are fully equal to the average of bituminous coal, we must consider the popular opinion that Iowa coals are not as good as others, a mistake caused by comparing our bituminous coal to a fuel like anthracite. The fact is, that the composition and hence the value of the coals of this State, as far as investigated, is fully equal to that of the true stone coal all the world over; and if the workable banks in our State are not as thick as those of some other countries, we have them close at hand and can run the railroad-track right into the mine, while in those otherwise more favored regions they have to dig two thousand feet deep in order to reach the coal.

III. GENERAL RESULTS ON THE SOUTHEASTERN PART OF THE IOWA COAL-FIELD.

In the course of my reductions of the analyses of Whitney and Blaney, I frequently found a considerable difference between the composition of the upper and lower part of the same coal bank. At the same time I discovered a remarkable uniformity in regard to the composition of coal from various parts of the field, and reported the same in a paper inserted in the *American Journal of Mining* for November 30. [See Chapter III]. My new method of reduction in revealing such differences in the analyses of others, appeared to me to be a proper instrument to apply to my own systematic analyses in order to discover the general law in regard to the deposit of carbonaceous matter in the vertical, if any exists.

The State Geologist having selected specimens for analyses both from the upper and lower parts of each coal-bank the material thus placed in my hands is very considerable and most valuable as a systematic collection representing the mineral fuel of Iowa. Each specimen bears a green circular label with a number by means of which its full history can be obtained from the catalogue; when analyzed, a rhombic, red label is added, with the same number, thus at the same time increasing the security against any possible loss of the history of the specimen. It is only in this way that a collection of coal is worth all it costs to accumulate the same. In regard to

the present collection of Iowa coals, beside securing the permanent value of the specimens as such, they are also the means which may be used at any time to test the correctness of my analyses.

The portion of the coal-field from which coal has been analyzed forms a strip of land about twenty miles broad in the direction of the Des Moines river from Farmington to Knoxville; this being a distance of more than eighty miles, the part chemically investigated covers about 1,600 square miles of our Iowa coal-field. Of course many more analyses will have to be made even for this portion of the field; beside this investigation will have to be extended to the whole of the coal-field.

The most important result of my investigations consists in the discovery of two chemically distinct banks of coal, traced the one for seventy, the other for fifty miles along the Des Moines river. This is, as far as I know, the first time that the chemical analysis of specimens in the laboratory has been the means of tracing a coal-bank across the field.

Bank First.—The existence of this bank I base upon the identity of the coal in mines, both at the bottom and at the top of the same. In the following I give the final result of my analyses of these specimens, referred to the combustible taken as 100. The "numbers" are those put on the labels of the specimens in the collection; the first always referring to the sample from the upper; the second to that from the lower part of the coal bank:

NO.	MINE.	DISTANCE	COUNTY.	BITUMEN.	
				TOP.	BOT.
330,329	Carmine's bank	20 miles	Van Buren	46.4	52.6
385,396	Young & Stubbs' bank	50 miles	Jefferson	46.9	52.4
405,343	Nossaman's bank		Marion	47.2	51.8
	Mean			46.9	52.3

Here, and in all subsequent tables, I give only one decimal to the number of per cent; that is fully as much as can be relied upon, for this decimal expresses the composition within the fractional of one thousandth.

It will be seen that Young & Stubbs' bank, both at the top and at the bottom, coincides with this mean; at Carmine's bank the two figures are a little farther apart; at Nossaman's they are a little nearer together. The mean difference between the bottom and top coal is 5.4 per cent of bitumen more at the bottom than at the top.

In regard to the amount and quality of the ashes I find (always for one hundred combustible):

AMOUNT.			COLOR OF ASHES.	
MINE.	TOP.	BOT.	TOP.	BOTTOM.
Carmine's	8.0	9.5	Blackish brown	Light grey
Young & Stubbs'	4.3	12.5	Brown	Whitish pink
Nossaman's	6.9	22.5	Reddish pink	White and pink
Mean	6.4	14.5	Reddish	Whitish

From this table it will be seen that the top coal always contains less ashes than the bottom coal, while at the same time the ash of the bottom coal is more white, and that of the top coal more reddish.

When it is considered how many circumstances have to conspire in order to produce so close a harmony in so many particular quantities relating to these three mines, it will be understood how I am led to consider this agreement a proof of the sameness of the coal bank.

Bank Second.—The corresponding tables for this bank are:

NO.	MINE.	DISTANCE.	COUNTY.	BITUMEN.	
				TOP	BOT.
370,360	Brown & Godfrey's	20 miles	Wapello	51.3	46.4
390,384	Iowa Coal Co.'s	25 miles	Mahaska	50.4	45.2
348,350	Roberts and Fisher's		Marion	49.4	47.0
	Mean			50.4	46.2

The law of variation in this bank is the reverse of what it is for bank first; for while in bank first, the bottom coal contains 5.4 more of bitumen per hundred combustible, than the top coal, here in bank second, the top coal contains 3.6 more than the bottom coal. It will further be observed that the top coal of bank first (46.9) is almost identical with the bottom coal of bank second (46.2).

For the ashes, we have in bank second:

MINE.	AMOUNT.		COLOR.	
	TOP.	BOTTOM.	TOP.	BOTTOM.
Brown & Godfrey's	9.4	12.0	Red	Pale pink
Iowa Coal Company's	2.9	7.4	Br'wnish	White
Roberts & Fisher's	7.1	9.5	Red	Brownish
Mean	6.5	9.7	Reddish	More whitish

In regard to the ashes, bank second follows the same law as bank first; the lower layers contain the most ashes, but the least of iron (red color) in the same.

From this circumstance, I conclude that bank second belongs above bank first; the correctness of this conclusion is further confirmed by the fact that the upper part of bank first and the lower part of bank second not only agree in the main per centage of bitumen (which is respectively 46.9 and 46.5), but that they actually vary in the same manner, increasing in bitumen toward the northwest; the first bank, top, from 46.5 to 47.2, and bank second, bottom, from 46.4 to 47.4.

The mean of ashes in bank first is 10.1; in bank second 8.8, and as in each bank the amount of ashes increases downward, this is a further proof that bank second is above bank first.

According to these chemical investigations of the lower Des Moines coal-field, the following may, in the absence of my drawings, be given as a representation of this field:

FOR 100 COMBUSTIBLE.

BANK.	PART.	BITUMEN.	ASHES.	COLOR OF ASHES.
Bank 2, or upper,	top	50	7	red
	(increase upward)			
	bottom.	46	8	intermediate colors
Bank 1, or lower,	top			
	(increase downward)			
	bottom	52	10	white

As far as I have examined the specimens, the Van Buren county and the Jefferson county mines belong all to the first or lower bank. All of the samples analyzed from mines in the counties of Wapello, Mahaska and Marion, belong to the second or upper bank, excepting Nossaman's bank in Marion county.

The amount of coal easily accessible along the border of the coal-field is immense; but the great future of this commonwealth depends still more upon the continuation of these riches under the overlying rocks toward the deeper portions of the coal-basin. In the accurate and comprehensive study of the coal I believe we have now a very effective auxiliary for the exploration of this basin; and it may therefore be expected that this auxiliary will be made available.

RESULT OF ANALYSES OF IOWA COAL.

I. VAN BUREN COUNTY.

Number on label.	NAME AND LOCALITY.	COAL BANK		COMPOSITION. *Coal*—100.											COMPOSITION. *Combustible*—100.					COLOR OF ASHES.
		Part.	Thickness in feet.	Spec. grav.	Weight of 1 cub. ft. in lbs	At temperature, Fht.	Per cent.	Increase. In hours	Volatile.	Coke.	Moisture.	Ashes.	Bitumen.	Carbon.	Value.	Bitumen.	Carbon.	Ashes.	Moisture.	Equivalent.	
328	New York Coal Company's Mine, Farmington	T	4	1.31	81.6	72	0.3	2	49.9	50.1	6.4	7.1	49.2	44.0	87.2	49.5	50.5	8.2	7.7	115.9	Dark purple.
332		B	3	1.30	81.1	74	0.0	2	52.1	47.9	6.4	5.1	45.7	42.9	88.5	51.6	48.4	7.5	7.3	114.8	Light purple.
335	Business Corner Mine, H. A. Brewer,	T	3½	.....	.....	.....	1.4	4	52.5	47.5	1.3	1.3	51.1	46.2	97.4	52.5	47.5	1.4	1.4	102.7	Pink.
331	A. Finley, Business Corner	B	3½	.....	.....	.....	1.0	4	51.4	48.6	1.3	4.9	50.1	43.7	93.8	53.4	46.6	5.2	1.4	100.7	White.
333	Rodefer's Bank, S. 10, T. 70, R. 11	T	4	1.27	79.6	76	1.2	4½	51.9	47.1	6.1	2.5	46.8	44.7	91.4	51.2	48.8	2.7	6.7	109.4	Purple.
340		B	4	1.32	82.1	78	0.9	4½	54.0	46.0	6.6	7.2	47.4	38.8	86.2	55.0	45.0	8.4	7.6	116.0	Whitish.
330	Carmine's Bank, S. 13, T. 70, Range 8	T	2½ to 10	1.34	83.4	74	0.3	2	46.7	53.3	5.4	6.9	46.5	46.4	86.7	46.5	53.5	8.0	6.2	114.2	Dark gray.
329		B	3½	1.23	76.4	74	1.1	6	50.3	49.7	4.5	8.3	45.9	41.4	87.3	52.6	47.4	9.5	5.1	114.6	Light gray.
196	Carter's mine, Bentonsport	...	.....	.....	.....	.....	0.0	4	43.6	56.4	1.7	6.9	41.9	49.4	91.3	45.9	54.1	7.6	1.9	109.5	Reddish.
	Mean for County	...	.....	.....	80.6	.....	.....	.....	50.0	50.0	4.4	5.6	47.0	43.0	90.0	51.0	49.0	6.5	5.0	111.5	

JEFFERSON COUNTY.*

392	Shaw's Bank, S. 33, T. 73, R. 9	...	3½	.....	.....	.....	0.8	8	52.2	47.8	2.0	4.5	50.2	43.4	93.5	53.6	46.4	4.8	2.2	106.9	Pink.
399	Coalport Coal Mine, 10 miles E. of Fairfield.	...	4	.....	.....	.....	0.3	2	49.6	50.4	1.2	4.4	48.4	46.0	94.4	51.2	48.8	4.7	1.3	106.0	Nearly white.
393	Richardson's Mine, 2 miles west of Fairfield	T	2½ to 10	.....	.....	.....	0.3	7	48.1	51.9	2.1	5.7	46.0	46.2	92.2	49.9	50.1	6.2	2.4	108.6	White.
382		B	3	.....	.....	.....	1.3	7	49.5	50.5	0.7	1.6	48.8	48.9	97.7	50.0	50.0	1.7	0.7	102.4	White.
383	Young & Stubbs' Mine, 4 miles west of	T	3½	.....	.....	.....	0.5	2	45.5	54.5	0.9	4.1	44.6	50.4	95.0	46.9	53.1	4.3	1.0	105.3	Brown.
396	Fairfield	B	3½	.....	.....	.....	0.5	2	46.7	53.3	0.3	11.1	46.5	42.2	88.7	52.4	47.6	12.5	0.3	112.8	White.
383	Read's Mine, 2 miles southwest of Fairfield	T	3	.....	.....	.....	1.0	7	44.5	55.5	2.5	11.6	42.0	44.0	85.9	48.8	51.2	13.5	2.9	116.4	Brown red.
	Mean for county	...	.....	.....	.....	.....	.....	.....	49.0	51.0	1.4	6.1	46.6	45.9	92.5	50.4	49.6	6.8	1.5	108.4	

III. WAPELLO COUNTY.

346	Henry Shock & Co., S. 8, T. 78, R. 14	T	5	1.36	84.3	70	0.7	4	46.4	53.6	7.8	7.2	38.6	46.5	85.0	45.4	54.6	8.4	9.2	117.6	Red.
371		B	5	1.31	81.5	78	0.5	4	47.8	52.2	6.1	9.9	41.7	48.3	90.0	46.3	53.7	4.8	6.8	111.1	White.
336	Alpine Coal Company, Alpine	T	4 to 10	1.25	82.9	78	0.8	4	48.8	51.2	4.2	7.2	44.7	44.0	88.7	49.4	50.7	8.1	4.7	112.8	Light gray.
334		B	4½	1.29	80.7	72	0.6	4	44.0	56.0	4.9	13.3	39.1	42.7	81.8	47.8	52.2	16.2	6.0	122.2	Light gray.
370	Brown & Godfrey's Mine, Sec. 33, T. 78, R.	T	4 to	1.35	83.9	72	0.5	4	50.7	49.3	7.1	8.0	43.6	41.3	84.9	51.5	48.7	8.1	9.4	117.8	Red.
367			Middle	1.31	81.7	78	0.6	4	51.7	48.3	7.4	4.2	44.3	44.1	88.5	50.1	49.9	4.7	8.4	115.0	White.
369	14, 4½ miles northwest of Ottumwa	B	4½	1.39	86.3	72	0.4	4	45.5	56.5	5.5	10.3	40.0	46.1	86.2	46.4	53.6	12.0	4.1	116.1	Pink.
	Mean for county	...	.....	.....	84.0	.....	.....	.....	47.6	52.4	6.9	7.7	41.7	43.7	85.4	46.8	53.2	9.0	6.8	115.8	

IV. MAHASKA COUNTY.

375	Given Mine, 5 miles southwest of Oskaloosa	T	.....	1.42	88.2	72	0.7	4	41.5	58.5	1.7	12.6	39.9	45.9	85.8	46.5	53.5	14.7	1.9	116.6	White.
395		B	.....	1.45	90.2	70	0.8	4	46.5	53.6	2.9	13.4	44.5	40.2	84.7	52.6	47.5	15.8	3.5	119.3	Pale red, with
390	Iowa Coal Company's Mine, Oskaloosa	T	6	1.29	80.7	75	0.8	2½	51.4	48.6	4.9	2.7	46.5	45.9	92.4	50.4	49.6	2.8	5.3	106.2	Pale red.[white
384	Station	B	6	1.35	83.9	83	0.3	3	45.0	55.0	5.1	6.5	39.9	48.5	88.4	45.2	54.9	7.4	3.8	113.2	White.[partic's
338	Roberts & Co.'s Mine, Oskaloosa Station	T	6 to	1.30	81.0	78	1.3	5	46.0	54.0	3.9	5.2	42.1	48.8	90.9	46.2	53.8	5.7	4.9	110.0	blackish gray.
398		B	8 to	1.34	83.4	77	0.9	3	47.4	52.6	6.4	6.2	41.0	46.5	87.5	46.9	53.2	7.0	7.0	114.3	Whitish.
	Mean for county	...	.....	1.37	85.1	.....	.....	.....	46.3	53.7	4.1	7.7	42.3	46.0	88.3	46.6	54.0	8.6	4.7	113.6	

V. MARION COUNTY.

348	Roberts & Fisher's Bank, S. 28, T. 77, R. 19	T	5 to	1.34	83.3	76	1.0	8	37.1	48.9	3.3	6.0	41.8	42.9	84.7	46.4	50.6	7.1	10.9	118.0	Red.
350		B	6	1.33	82.8	64	0.6	7	49.0	51.0	10.7	7.8	38.3	43.2	81.5	47.0	53.1	9.5	13.2	127.7	Dull red.
345	W. O'Neal's Bank, S. 19, T. 76, R. 19	...	2½ (upper bed.	1.29	80.8	69	0.5	4	45.2	56.8	7.8	9.8	35.4	47.0	82.4	42.9	57.1	11.9	9.5	121.3	Pale red.
358		...	2½ (lower bed.	1.43	89.4	74	0.4	4	43.4	56.6	7.7	10.7	35.7	45.0	81.6	43.8	56.2	13.1	9.5	122.6	Pale red.
405	Nossaman's Bank, S. 34, T. 76, R. 18	T	3	1.33	83.1	76	0.3	3½	46.3	53.7	3.9	6.2	42.4	47.5	90.0	47.2	52.8	6.9	4.3	111.2	Dull red.
343		B	3	1.45	90.1	72	0.4	3½	45.1	54.9	4.8	17.5	40.2	37.4	77.7	51.8	48.2	22.5	6.2	128.2	Pale ochre.
	Mean for county	...	.....	.....	86.0	.....	.....	.....	46.3	53.7	7.4	9.7	38.9	44.0	82.9	47.0	53.0	11.8	9.0	120.8	

VI. POWESHIEK COUNTY.

339	Smith & Borrowman's, T. 78, R. 15	T	.....	1.3	80.8	78	1.2	3	50.2	49.8	8.2	2.4	42.0	47.4	89.5	47.0	53.0	2.6	9.2	111.8	Red.

VII. POLK COUNTY.

400	Redhead, Des Moines City	...	.....	.....	.....	.....	0.7	7	49.5	50.5	4.8	2.3	44.7	44.3	89.0	50.2	49.8	2.5	5.4	107.9	Umbra.

* NOTE.—All coals from this county had been about a week in the warmed room, previous to the execution of the analysis, hence the comparatively small amount of moisture in the same. This applies also coals Nos. 395, 391 and 196, from Van Buren county.

ANALYSES OF IOWA COAL—CONTINUED.

MEANS FOR EACH COUNTY,

(In the nearest whole numbers.)

COUNTIES.	Weight of 1 cubic ft.	COMPOSITION. *Coal—100.* Volatile.	Coke.	Moisture.	Ashes.	Bitumen.	Carbon.	Value.	COMPOSITION. *Combustible—100.* Bitumen.	Carbon.	Ashes.	Moisture.	Equival't.
1. Van Buren	81	50	50	4	6	47	43	90	51	49	6	5	111
2. Jefferson	.....	49	51	2	6	47	46	92	50	50	7	2	108
3. Wapello	84	48	52	7	8	42	44	85	47	53	8	7	116
4. Mahaska	85	46	54	4	8	42	46	88	46	54	9	5	114
5. Marion	86	46	54	7	10	39	44	83	47	53	12	9	121
Mean	84	48	52	5	7	43	45	88	48	55	8	5	113

All terms used in the preceding tables having been explained in the second article on the fuel of the State, only a few remarks on the figures themselves need be added.

The *means* here given for each county are of course liable to change by the investigation of more mines in each county, but the fact that the samples analyzed were not selected, but rather taken at random, together with the fact that the final results indicate a gradual change in the mean of the coals from the consecutive counties, rather proves that the results thus far obtained will not be materially altered by increasing the number of specimens analyzed for each county.

From the last table it will be seen that the Iowa coals are most bituminous in Van Buren county, and that the amount of bitumen decreases slowly in a direction up the Des Moines river. The same is true in regard to the per centage of volatile matter. On the whole, the coals from lower down the river therefore are more baking and also better for gas-making. At the same time they contain the smallest per centage of both ashes and moisture, that is, the coals improve in purity down the river.

As an offset to this advantage of the coals from the lower counties, the coals from the counties higher up Des Moines river contain both a greater per centage of coke in the coal and a greater proportion of carbon in the combustible. For coking, and therefore also for smelting purposes, these latter are thus better than those from the lower counties.

To express this difference in the plainest language, I might say: The coals from the lower counties on the Des Moines river are, on the whole, more bituminous, more baking, burning with more flame, leaving less ashes, than those from the counties higher up the river; but then the latter give more coke, and a more intense heat than the former.

In following any one of the columns downward, it will be noticed that this change is very gradual and of but small amount; on the average, only four per cent difference. It will also be seen that the actually determined mean for the State is very nearly as stated in round numbers in the second article; the only deviation being two per cent greater amount of moisture, and two per cent smaller amount of bitumen.

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It must be borne in mind that the values here referred to are means for counties, and the fact that the coals from Marion county contain ten per cent of ashes must not be understood as meaning that all coals from that county actually contain so much; the mean of ten per cent results from some containing more, others less, than this amount.

Again, though on the whole the per centage of ashes increases in an upward direction along the Des Moines river, it must not be understood that there are no coals in the lower counties with more ashes, no coals in the upper with less ashes. By reference to the preceding table we see that the lower part of Carmine's bank contains $8\frac{3}{10}$ per cent of ashes, (Van Buren county), while the sample from Redhead's mine in the city of Des Moines only contains $2\frac{3}{10}$ per cent of ashes.

All the results of the analyses here reported have been represented on a map, drawn on a scale of four miles to the inch. By a peculiar method, all particulars of any coal-bank are represented to the eye. The publication of such a map must of course be delayed until much more material has become available.

In conclusion I would add one more observation. This fourth article, giving the results of my analyses, is a statement of facts; any one who doubts it has all means of satisfying himself by having repeated the analysis of the identical specimen now in the cabinet of the State University. The statement in regard to the existence and relative position of the two coal-banks, as contained in the third article, is, to a considerable extent, a conclusion. With the increase of the number of specimens analyzed, the basis of that conclusion may change, and with it the conclusion itself may be modified. Again, there is a possibility that two banks might be different, and yet be identical in their chemical composition; at any rate, the impossibility of such a condition of things has not been proved; but making due allowance for all these circumstances, I repeat that the tracing of the two coal-banks along the Des Moines river is the only one yet made that I know of; and although both the novelty of this attempt and the facilities for such purpose, limited number of analyses, calls for further chemical and geological research.

V. THE CHEMICAL HISTORY OF COAL.

The great economical importance of coal, the peculiarities of the distribution of this fuel and the many remarkable physical and chemical characters make the question as to its origin not only one of great interest, but also of great difficulty.

Although many writers on geology consider the complete history elucidated, and with great assurance give detailed accounts of the precise mode of the formation of coal, many eminent authors do not hesitate to acknowledge, that hardly any thing but the mere vegetable origin of coal is demonstrated. Mr. Hunt, states the case with perfect frankness in the recent supplement to Ure's Dictionary, when he says: "That coal is derived from the vegetable kingdom, no longer admits of doubt; but the class of plants to which more especially we are to look for the origin of coal, is still a matter of much uncertainty, and the conditions under which the change is brought about is very imperfectly understood, and indeed, by many geologists entirely misconceived."

The greater part of this uncertainty seems to be due to the apparent neglect of the chemical properties of the coal. Professor F. Mohr of Bonn, Germany, has lately shown, that all known facts in relation to coal are best explained by considering the stone-coal as a result of the carbonization of marine plants, algae, and that this even will explain a great number of well ascertained geological phenomena, which protest against the generally accepted hypothesis that coal is due to land-plants. My own investigations of the Iowa coal have contributed very much to the conviction I now hold, that the theory of Mohr in regard to the formation of stone-coal is the true one; at any rate, the theory of Mohr does not solely rest upon the nature of accidental matters in the coal, but upon a careful investigation of the body of the coal itself.

Referring to the first article, it may be remembered that wood, peat and brown coal were there ascribed to land-plants, coal, to sea-plants. In order to prevent a possible misunderstanding, I shall instead of coal, use the word *stone-coal*, to indicate all true coals from anthracite to our bituminous coal of Iowa.

Forests and peat-bogs grow before our eyes; their origin is well

known. Brown coal has in its mass so plainly the structure of land-plants, that its origin is not questioned; besides, we here in the Mississippi valley know that we are in the very coal-era, for the immense amount of trees brought down to the gulf of Mexico from all parts of this great valley, is now forming a great brown coal deposit, like those now explored on the Pacific coast of this country.

Leaving everything of a purely geological nature to others, I shall confine myself to the consideration of the stone-coal as a substance which could neither have been formed from trees, nor from peat-bogs, nor from brown coal, but only from sea-weeds. It will be the simplest to consider the actual contrast between the properties of wood, peat and brown coal, being the products of woody fibre on the one hand, and the properties of stone-coal, which we stated to be produced from sea-weeds, on the other hand.

First. — If wood is heated in a closed vessel, so that the air can not get to the wood, this latter will never fuse, but only become charred. All are familiar with the fact, that charcoal shows even the nicest details of the structure of the wood from which it was made. So, also, brown coal, and peat, never fuse, but retain their structure.

But most true stone-coals do fuse under these circumstances; all Iowa coals that I, as yet, have analyzed, did fuse; some very easily.

That this marked difference depends on the structure of the substance, we know from the fact, that sugar in charring does fuse, while woody fibre does not; both substances have precisely the same elementary composition, but they differ widely in regard to structure.

This difference between stone-coal and the other fuels is contrary to both the peat-bog theory and the wood theory; but if stone-coal is formed of sea-weeds, this property is a necessity, for all sea-weeds when thus treated, fuse very readily.

Another difference we have, is the fact that wood continues to burn when taken from the flame — stone-coal not; the coals from sea-weeds act in this respect precisely like stone-coal.

Second. — When pulverized brown-coal or peat are boiled in pottassa lye, a deep brown, almost black, solution is obtained; when stone-coal is treated in the same way, the lye remains almost colorless. This coloring matter is called humus; it is also found in our soils, and is a product resulting from woody fibre. Since stone-coal is without humus, it proves itself devoid of woody fibre.

Third. — Stone-coal has always but a few per cent of moisture; brown coal and peat retain a very great amount of moisture with pertinacity. Thus, in the Irish peat analyzed by me, I found sixteen per cent of moisture. In brown coal from Bilin also sixteen; in stone-coal from Silesia, only five; cannel coal from Wigan, only three. All of these specimens had for several years been kept in the same case in the air-heated labaratory, so that they represent these fuels as thoroughly and equally air-dry. Now this is quite general; all chemists are aware of this radical difference between stone-coal and those fuels which we know to be derived from woody fibre. Hence, again the conclusion that stone-coal is not derived from woody fibre.

Fourth. — When stone-coal is subjected to dry distillation in the retorts of the gas-works for the purpose of manufacturing illuminating gas, great quantities of ammoniacal liquid is obtained; in fact, almost all the ammoniacal salts now used in the arts, are thus extracted from stone-coal.

When wood is subjected to the same treatment, no such ammoniacal liquid is obtained; on the contrary, instead of this alkaline liquid, an acid is obtained, called wood-vinegar. Peat and brown coal treated the same way, likewise give an acid liquid.

This great difference forms the basis of Mohr's theory, here advocated; it is indeed utterly impossible to see how the nitrogen necessary to form the ammonia should have got into the woody fibre, if they were the source of stone-coal. On the other hand, sea-weeds are exceedingly rich in nitrogen, and if they were charred in any way, much nitrogen would remain.

That this difference between stone-coal and the other fuels is constant and general has been proved by an extensive series of experiments performed by the German chemist, Kremers.

Fifth. Near the sea-shore we always find the smell of sulphuretted hydrogen more or less perceptible; we know it to be due to

the decay of sea-weeds thrown on the shore. Wood, when thus rotting, does not emit such odor.

The amount of sulphur in the coals is very great; the smell near the gas-works sufficiently known is an abundant proof. Brown coal and peat do not contain so much sulphur; the iron associated with these fuels is more commonly found as carbonate or oxide than as sulphuret.

Sixth. Sea-weeds contain constantly considerable iodine and bromine; land-plants contain rarely any. But the compound of these elements is mostly soluble, and therefore to a great extent washed out of the coal before we get hold of it; still several chemists have proved the presence of iodine in the ashes of stone-coal, and Mohr has lately succeeded in finding even bromine in the coal.

That finally the sea-weeds are a sufficient cause for the production of the vast coal-beds, need not here be proved; it will be enough to state that even a single weed often measures hundreds of feet in length, being provided with branches and leaves of corresponding magnitude; that these weeds abound in all seas; that they necessarily sink to the bottom when they die, and thus decaying under water, must form a carbonaceous mass; that finally peat-bogs are small as compared to large forest regions, and that again these are insignificant when compared to the vast fields of sea-weeds well known to mariners — fields of truly continental magnitude? While on the soil only a limited amount of combustible can be accumulated, there is no limit to this accumulation in the deep.

While thus the chemical nature of stone-coal proves that it never could have resulted from vascular plants or land plants, that is, plants essentially made up of woody fibre, and furthermore, that the chemical nature of stone-coal exactly harmonizes with that resulting from sea-weeds; while further, no land vegetation is adequate to account for the thickness and the extent of the stone-coal fields of the world, and particularly for those of the Mississipi Valley, requiring a vegetation as immense, as uniform and persistent as that of the sea-weeds of the ocean; while considering all this we have purposely omitted to refer to the uniformity in the strata, the regular interposition of marine rocks among the coal-beds, the accompanying fossils, etc. On these grounds Mohr's theory

is also infinitely superior to the commonly accepted one; for not all thinkers are ready to clothe the earth with a more luxuriant growth than now is observed; nor have we a ready command over the creeping centuries; nor have we ever seen vegetable debris piled up in sufficient quantity to form a coal-bed. Geologists are taking a little more care of the crust of the earth of late; they are not quite so ready now, as formerly, to assume that a vast region of land emerged about a hundred times out of the ocean, and sank again.

The very water in the sea, in the constitution of the air it contains, gave Mohr a convincing proof of the continuous formation of coal at the bottom of the ocean, even in our day.

In the preceding I have given a short synopsis of some points of Mohr's theory of the formation of coal; it rests throughout upon well-recognized facts, does not require nature to work otherwise than as we now observe her working, and instead of ignoring the chemical nature of the coal whose origin we wish to discover, it actually made the investigation of this constitution the starting-point.

For Iowa, this theory has a very great importance; for if the older theories are true, then we need hardly expect coal underlying the rocks in the more central parts of the basin; but if Mohr's theory is true, then the coal will extend over the whole of this field. For this reason — and also because this theory seems hardly yet known in America — I have deemed it not improper to give a short synopsis of the same.

My own investigation of the Iowa coals has added four more not unimportant proofs to the theory in four facts which can not possibly be accounted for by the old fanciful views.

The first of these facts is the great uniformity in the composition of a coal-bank over quite a considerable area.

The second is the fact that the upper parts of our Iowa coal-banks contains the most pyrites; the lower parts being very often entirely free from this substance. The sulphuretted hydrogen set free in the carbonizing sea-weeds escapes upward; in meeting the ferruginous waters, pyrites would result, so that these latter would predominate in the upper parts of the resulting coal-bed.

The third consists in the investigation of the fibrous portions often met with in our Iowa coals. These portions look and feel precisely

like charcoal; retain a distinct fibrous structure. By analysis of the same I found them to contain but very little of bitumen, as compared to the closely adjoining coal; and saw, that even after protracted exposure to white heat, they retained their structure; indeed, the coked mass looked precisely as the fibres did before coking, while the coal, wherein they were imbedded, was highly baking.

This shows plainly that the woody fibre irregularly distributed in small portions through some of our Iowa coals never lost its peculiar structure, but merely was charred; that the entirely different substance forming the bulk of our coal, therefore originally also must have been entirely different from these fibrous plants. Of quite particular interest is the fact, that while this fibrous coal upon drying deported itself like other vascular fuels, (wood, etc.,) the mass all around it increased in weight, as I shall now explain.

Fourth. By very careful working I discovered that all our Iowa coals, after having lost their moisture, commenced upon further drying at a temperature a little above that of boiling water, to increase in weight, an increase sometimes amounting to fully two or more per cent. Prof. Whitney had noticed this in some cases; in another place I have shown how he came to miss the general law. This same property I have also discovered in cannel coal from England, and stone-coal from Silesia, so that I consider it a property common to all stone-coals. Neither peat, nor brown coal, nor bituminous wood, did as yet show this peculiar increase in weight; so that this property must be considered a new distinctive property peculiar to stone-coal. It forms therefore an additional impossibility concerning the old theories of coal, and a new link in the chain of facts on which the chemical theory of Mohr rests.

Coal, true stone-coal, was not restricted to a particular period in the earth's history, but it is forming even at the present day in the oceans.

CHEMICAL REPORT ON THE WATER AND ROCKS OF THE STATE.

CHAPTER II.

I. THE WATER.

We are very apt to consider the rocks as permanent, and yet they are continually changing. The principal cause of this change is the moving water in the rocks. When it slowly washes solid matter out of the rocky strata, the land may be gradually sinking and more sudden changes felt over a large extent of territory as an earthquake, may follow; we might here refer to the earthquake which was felt sometime last spring, over a great portion of the Northwest, after a particularly wet season.

To understand the change of the rocks and to investigate their original formation it, therefore, is necessary to carefully analyze the waters they contain. The more direct demand of people possessing mineral springs, thus meets a scientific necessity, in requiring careful analyses of the waters of the State.

During the former geological survey no waters were analyzed. My proximate analyses of the water of the artesian well at Mt. Pleasant (summer 1865) together with an accurate analyses of the water of a spring near the same place, made by me at the order of Dr. Mark Ranney early in 1866 were the only two analyses of Iowa waters executed previous to the present survey.

The most important of the waters yet analyzed is that of the artesian well at Mt. Pleasant, on the ground of the Iowa Hospital for the Insane. The State Geologist procured about six gallons of the water in order to enable me to make a complete analysis of the same. Of this water I have used two gallons this fall to determine the proportion of these substances which are present in considerable quantities. The remaining water will be used in order to determine

those substances which are present in very small quantities. In the bottles I noticed a very fine crystalization of dolomite. This fact is of considerable importance, as it shows that such waters, by percolating the limestone, may gradually change them altogether into dolomitics. For the sake of comparison I take the liberty to make use of the analysis of the Mt. Pleasant spring water, although this analysis is not the property of the survey.

LOCALITIES OF THE WATERS.

The waters analyzed as yet were nearly all from the First Congressional District. They are in the mineralogical collection of the survey, designated by the following numbers inscribed on the labels:

No. 24. Mineral spring, on S. D. Well's farm, on section fifteen, township seventy, range thirteen, near Bloomfield, Davis county.

No. 72. Salt spring, from the largest salt spring at the crossing of Salt creek and the Bloomfield road, in the northeast portion of Davis county.

No. 114. Artesian well, Mt. Pleasant, Henry county; depth of boring, 1,125 feet; temperature of the water (November 6, 1866,) 62° F., while the common well showed only 55° F.—[WHITE.]

No. 120. Water from the Ottumwa school well, sent by Dr. Warden.

No. 460. Well on Kinersly's farm, one mile from Keosauqua, Van Buren county.

The total amount of mineral matter in these waters is very different. In order the better to understand these relations, I add a few determinations of other waters. All figures refer to 10,000 parts of water:

NO.	WATER.	SALTS.	BY WHOM ANALYZED.
....	Croton water, New York	1.0	Silliman
	IOWA WATERS.		
....	Spring water, Mt. Pleasant	3.5	Hinrichs
460	Kinersly's well, Van Buren county	10.9	Hinrichs
24	Wells' spring, Davis county	24.4	Hinrichs
114	Artesian well, Mt. Pleasant	25.3	Hinrichs
72	Salt spring, Davis county	29.7	Hinrichs
120	School well, Ottumwa	39.5	Hinrichs
	OTHER WATERS.		
....	Congress spring, Saratoga, N. Y.	49.6	Schweitzer
....	Ocean (mean of several hundred analyses)	344	Forchhammer
....	Salt well, Luneberg, Prussia	2500	Forchhammer

This latter is one of the most nearly saturated brines known. It is evident that salt spring No. 72 is exceedingly sweet as compared to the Luneburg well. One of the poorest brines used is that of Salzhausen, Germany, containing about 120 parts of salts to 10,000 water, or about four times as much as our salt spring; and even the former brine is only worked by making use of the refuse coal from a coal mine at the same place. In the United States, salt is too abundant that such wells could be utilized.

NATURE OF THE MINERAL MATTER.

In the salt spring (No. 72) and well spring (No. 24), common salt dominates over the other mineral ingredients; yet both waters contain a considerable amount of sulphuric acid. In the Ottumwa well (No. 120) and Kinersly's (No. 460), iron abounds; they are almost vitriolic waters, and altogether unfit for use. The mineral matter of the Ottumwa well was found to consist of—

Ferruginous sediment in the bottle	10.2
Gypsum	10.4
Ferric sulphate, common salt, etc	18.9
Total in 10,000 water	39.5

The spring at Mt. Pleasant contains principally calcium carbonate (65 per cent of all salts); the artesian well water is characterized by the predominance of sulphates; (84 per cent of all its salts are sulphates). These two waters having been accurately analyzed, it may be interesting to report the final result, showing the various mineral ingredients for 100,000 parts of water.

ARTESIAN WELL AND SPRING-WATER, MT. PLEASANT.

The mineral constituents of waters are given first: the elements separately; second, these combined to bases and acids; third, the same estimated as salts. Now, neither the second nor the third method is quite exact, since we do not positively know how the elements really are combined; so that the first mode of stating the results seems to be the safest. Nevertheless, it has hardly come into use, and for some practical applications the third statement is the most convenient.

IN TEN THOUSAND WATER.

ELEMENTS.	SPRING.	ART. WELL.	RATIO.
I. METALS.			
Sodium	0.013	4.585	352
Magnesium	0.063	0.630	1.7
Calcium	0.900	2.750	3.0
II. NON-METALIC ELEMENTS.			
Sulphur	0.028	4.876	174
Carbon	0.409	3.305	0.76
Chlorine	0.020	1.200	60
Oxygen	1.735	10.974	6.3
Total	3.47	25.32	7.3
Sediment in flask		0.40	

The ratio in the last column is obtained by dividing the figures under artesian well by those under spring; or the ratio expresses how many times the water of the artesian well contains the amount of the elements in the spring water. If the elements were present in both of these waters in the same proportion, then 7.3, the ratio of the totals, would be the ratio for the several elements also. In fact, only the ratio for oxygen approaches to this ratio; all others differ very much from 7.3, &c. The ratio for sodium, sulphur and chlorine are particularly great; or in words, the water from the deep (artesian) well contains proportionally much more of sodium, sulphur and chlorine, than the water from near the surface (spring). The two waters, both from the same place, but from very different depths, therefore differ very much, not only in the total amount of mineral matter, but even more so in regard to the quality of the same.

IN TEN THOUSAND OF WATER.

SECOND — *Binaries.*	SPRING	ART. WELL.
Common salt	0.33	1.97
Sulphuric acid	0.07	12.19
Carbonic acid	1.50	1.12
Lime	1.26	3.85
Magnesia	0.605	1.05
Soda	.....	5.14
THIRD — *Salts.*		
Sodium chloride (common salt)	0.33	1.97
Sodium sulphate (glauber salt)	.....	11.77
Magnesium sulphate (epsom salt)	0.21	3.15
Calcium sulphate (gypsum)	.....	5.80
Calcium carbonate (calcite)	2.250	2.55
Magnesium carbonate (magnesia alba)	0.975	.....

The names in parenthesis are added for those of the readers who may not be familiar with the names of the salts.

The amount of salts even in the artesian well may appear insignificant — only about one-fourth of one per cent! But when larger quantities of the waters are used, then these salts become plainly manifest to everybody. The steam-engine at the Iowa Hospital for the Insane is reported to have pumped the water for use at the rate of ten thousand gallons an hour. This is more than eighty thousand pounds an hour, and the insignificant amount of salts is more than two hundred pounds per hour! At that rate the following pounds of the different salts would be brought up with the water each hour:

	Lbs.
Common salt	16
Glauber salt	94
Epsom salt	25
Gypsum and calcium carbonate	67

Or these salts would contain of

Sulphur	39
Carbon	3
Chlorine gas	10
Magnesium metal	5
Calcium metal	23
Sodium metal	37

In the course of ten hours these salts would amount to a ton! Only a small amount of these used in a boiler would quickly produce a thick incrustation; the sulphates would remain pretty long in solution, so that a pretty concentrated brine might result — all of which has been so abundantly experienced that the water is no longer used for such purposes. In the proximate analysis of 1865 the chlorine was not determined. By my recent careful and complete analysis recorded above, it is seen that there is plenty of chlorine, which, in the presence of sulphuric acid and some free carbonic acid, may set free the corroding vapors of hydrochloric acid.

I intend to subject this water to still more scrutinizing analyses; then, together with the investigations of the specimen rock from the boring, the boiler deposits, the corroded iron tubes, and the surface water from the same place will form a whole of well ascertained facts for various levels from the surface to a depth of one thousand one

hundred and twenty-five feet, which I hope will lead to some general results.

One very interesting general result may already here be pointed out. If we calculate the per centage of the various salts in the two waters, we find:

SALTS.	PER CENTAGE.	
	Spring.	Art'n Well.
Sodium sulphate	0	46
Sodium chloride	1	6
Magnesium sulphate	6	12
Calcium sulphate	28	26
Calcium carbonate	65	10

This shows a marked decrease in the proportion of the lime salts, while the magnesium salts, and particularly the alkali, increase as we descend below the surface. The surface-water is a calcareous carbonated water; the water from the deep is sulphated and alkali-water. The latter are by far the most soluble of these salts; and this circumstance causes their accumulation in the deeper waters. Quite a similar change our surface waters undergo in their course toward the ocean. In the rivers there is but a small amount of mineral matter, and the carbonates of lime and magnesia dominate; both become less and less, both being deposited on the way to the ocean, which, like the water from the deep well at Mount Pleasant, only contains the most soluble salts. The more immediate cause of this change in the rivers is the life of aquatic animals; in the rocks the same change is brought about by the constant metamorphosis of the rock itself.

The preceding contains all the results ascertained in regard to the waters of the State. Compared with what remains to be done, it is very little; but compared with what had been done previously it is a good deal. So much is certain, a correct interpretation of the constitution of the rocky framework of the State can only be obtained by a careful chemical study of both the rocks and the waters they contain.

II. THE ROCKS.

The rocks of Iowa belong to only four kinds; they are either calcareous, arenaceous, argillaceous, or carbonaceous. To the first

belong limestones and dolomites, both effervescing (at least) with hot acids. They greatly dominate in the State. The finest arenaceous rock of Iowa is the St. Peter's sandstone, exposed in the northeastern corner of the State; good sandstones are also found in the coal-measures of Southern Iowa, and finely crystalized silicia, that is, quartz, abounds in the geodes found near Keokuk and other places. Shales are the most common representatives of the argillaceous rocks, passing by the dark, more or less combustible varieties gradually into *coal*, the most valuable carbonaceous rock of Iowa. Geologically, coal is as much rock as the limestone underlying the same, or the sandstone above it; it is found stratified like either of these two rocks.

These four kinds of rock are composed of but six different chemical elements. Three of these are *metals*, having, when pure, a lustre peculiar to these bodies; the other three are *metalloids*, being devoid of such lustre. The three metals are *calcium*, *magnesium* and *aluminum*, of which the last two are already quite frequently used in the arts; magnesium, the metal contained in epsom salts, being used for illuminating purposes, since it gives a most dazzling light; aluminum, the metal of clay, remarkable for its beautiful silver-like appearance and its excessive lightness, being not heavier than paper, is considerably used for certain alloys. Calcium has as yet not found any application in the arts. About forty pounds in every hundred pounds of pure limestone is calcium.

The three metalloids are *oxygen*, *carbon* and *silicon*. The first constitutes about one-fifth of the air we breathe, and is really the vital principle of the air; in our rocks it is present in much greater quantity than in the air, for it constitutes about one-half of all of them (excepting coal). The second, carbon, is well known; in charcoal we have it nearly pure. Silicon is very closely allied to the former, sand being composed of silicon and oxygen in nearly equal proportions.

The following table will give a correct idea of the elementary composition of our Iowa rocks, by means of the per centage composition of the purest of each kind. The first three are very frequently met with almost chemically pure in crevices and openings in the rocks, constituting crystals. In limestone we thus find calcite or

calcium carbonate in beautiful crystals. If the limestone contains also the metal magnesium, we usually find the crystals to have a peculiarly pearly lustre, and somewhat curved faces; these crystals are called dolomite. In arenaceous rocks we find under similar circumstances the beautiful crystals of quartz. The other two rocks hardly ever occur quite so pure as here given, except it be carbon as diamond. These pure forms are the minerals corresponding to the rock; they are the rock purified by nature herself:

ROCK AND CORRESPONDING MINERAL.	ELEMENTS.					
	METALOIDS.			METALS.		
	Oxygen.	Carbon.	Silicon.	Calcium.	Magnesium.	Aluminum.
CALCAREOUS ROCKS.						
Calcite	48.	12.	....	40.	....	....
Dolomite	52.2	13.	....	21.8	13.	....
ARENACEOUS ROCK.						
Quartz	53.3	....	46.7	....	....	....
ARGILLACEOUS ROCK.						
Clay, pure	50.	....	25.	....	....	25.
CARBONACEOUS ROCK.						
Carbon, pure	....	100.	....	....	....	....

In dolomite, which in the north of the State forms immense fields contains one-fifth by weight of the metal magnesium; if this is separated, it burns with great splendor. We may now readily conceive what an immense amount of heat and light has some time been produced when those elements, that are now dormant and under our feet, were still uncombined in the atmosphere, perhaps. Tolerably pure limestone contains twelve per cent, dolomite about thirteen per cent of pure coal; every hundred feet of limestone contains enough of pure coal to form a bank of anthracite of ten to twelve feet in thickness. But all of this combustible, both metalic and carbonaceous, is now unavailable, since these elements are in the rock, combined with oxygen; that is they are burnt. The only exception to this rule is the coal; for this reason it has so great economic value.

The coal having been at length considered in the first chapter, I

may here limit myself to the calcareous rocks of the State. Neither the arenaceous nor the argillaceous rocks have as yet been analyzed.

THE CALCAREOUS ROCKS OF IOWA.

The results of chemical analysis of these rocks, are usually stated by the per centage of each of the proximate chemical compounds contained in the same. But it is impossible even for an expert to get a really precise idea of the constitution of such a rock by the full, unreduced result of the analysis. It is as difficult as to obtain an idea of the value of a sum of money consisting of all the various coins of quite a number of nations. This will become much easier by referring these various coins of each nation to one unit as a standard.

Now, this is what I have done for the analysis of Iowa rocks, made by Professor Whitney during the former survey; and in the same way I give the final result of my own analysis of the rocks. I refer the composition to the per centage of the mineral species which undoubtedly make up the rock. The preceding was intended to convey a definite idea of what the species are for our State; and as the non-calcareous rocks also are insoluble, we unite under the heading insoluble the arenaceous and argillaceous part of the rocks under one. Whenever some other matters, like moisture, soluble iron compounds, or alkalies are determined, I sum these up under the heading "others." The character of the rock thus is always essentially given by only three figures, viz.: the per centage of the insoluble, of the calcite, and of the dolomite in the same; the "others" spoken of are only present in small proportions.

As an example, I give my reduction of two of Whitney's analyses:

LOCALITY.	Calcite.	Dolomite.	Insoluble.	Others.
Le Claire, Scott County	3.69	88.69	6.70	0.80
Rock Island, Illinois	98.55	0.58	0.43	.....

These two localities are only about twelve miles distant; the above statement shows at a glance, that the rock at LeClaire approaches to a pure dolomite, while at Rock Island it is still nearer a pure calcite (carbonate of lime, or calcium carbonate).

In order to show the advantage of this form over the one commonly used, I transcribe Prof. Whitney's statement from the report, for the Le Claire rock:

Silica and insoluble silicates	6.70
Peroxid of iron and a little protoxide	0.80
Lime	29.06
Magnesia	19.32
Soda	0.11
SULPHURIC ACID AND CHLORINE — MINUTE TRACES.	
Carbonic acid	43.65
Loss	0.46

This is the direct result of analysis; it is the grain in the ear, and in order to become digestible, I have subjected it to a little grinding, which reduced the complicated statement to but three essential figures, viz:

	Per cent.
Calcite	3.69
Dolomite	88.69
Not calcareous	7.50

If the reader only will take the trouble to get a clear idea of the terms calcite and dolomite — which I trust may be obtained from the introductory lines — the constitution of the calcareous rocks of Iowa will become intelligible.

The geologist represents the result of his exploration of a given field by sections, showing the succession and super-position of the various beds of rock. These sections are either horizontal, showing the surface-formations in a given direction, or they are vertical, representing the order and thickness of the rocks one above the other.

It is evident that not until we are able to give a sufficient number of chemical sections, both horizontal in all directions throughout the State, and also vertical sections of a considerable and well-selected number of localities, not until then can it be said that we really know the nature of the rocks of the State. It is upon the chemical constitution of the rock that the practical application of the same for the various purposes depends; it is by the chemical composition that the mineral riches of the rocks are influenced; and it is the chemical composition of the rocks which determine, to a great extent, the nature of the soil resting on top of it.

It is impossible to represent such chemical sections without proper wood cuts. In the absence of these, the numbers from which such sections are drawn will here be given in a few tables.

In the following tabular sections I insert between each two samples the distance in miles between the places where the rock was taken; these distances are evidently much too great, showing that a great many more analyses will have to be made before the rocks of the State can be said to be tolorably well known:

MISSISSIPPI SECTION.

RESULTS CALCULATED FROM WHITNEY'S ANALYSES.

PLACE.	COUNTY.	DISTANCE.	CALCITE.	DOLOMITE.	INSOL.	OTHERS.
McGregor.... [river	Clayton ..	37 miles ..	0.63	98.41	0.96	.....
Dubuque, 150 ft. above	Dubuque..	21 miles ..	ex. Mag.	95.59	2.46	.....
Hickory Grove.....	Jackson...	44 miles ..	2.24	97.83	0.90	.....
Le Claire.....	Scott.....	12 miles ..	3.69	88.69	6.70	0.80
Business Corner.....	Van Buren	90 miles ..	90.87	4.18	0.57	.....
Rock Island	Illinois...	.. ..	98.55	0.58	0.42	.....

The calcareous rocks along the Mississippi are therefore nearly pure dolomite above Rock Island, and nearly pure limestone below this place. That such is the case, is not new, but no previous statement of these analyses enabled people not instructed in the secrets of chemical analyses to see it so plainly as the above figures show it.

If we disregard the insoluble part of the rock, then we may express the *ratio* between the amount of dolomite and calcite, by one figure alone; the above section then becomes:

PLACE.	COUNTY.	RATIO.
McGregor.....	Clayton ..	156.00
Hickory Grove.....	Jackson...	43.00
Le Claire.....	Scott.....	24.00
Rock Island.....	Illinois...	0.006
Business Corner.....	Van Buren	0.04

Showing in a still more simple and more precise form the remarkable fact of the diminution of dolomite towards the south. In Clayton county the rocks contain 156 parts of dolomite to one of calcite; in Jackson only 43; in Le Claire only 24; below this but a few, or even a fraction of one per cent of dolomite. This gradual decrease of the magnesian ingredient (dolomite) in the rock has not before been made so perspicuous as by this ratio:

CEDAR RIVER SECTION.

RESULTS CALCULATED FROM WHITNEY'S ANALYSES.

PLACE.	COUNTY.	DISTANCE.	Ratio.	Calcite.	Dolomite.	Insoluble.	Others.
Shell Rock Falls	Cerro Gordo	80 miles	3.0	24.50	73.60	0.80	1.10
Independence	Buchanan	100 miles	0.02	97.11	1.82	10 02	.....
Rock Island	Illinois	.....	0.006	98.55	0 58	0 42	.....

These rocks all belong to the same geological formation, but it is seen that the amount of dolomite corresponding to one of calcite in these rocks increases northward from Rock Island, both through various formations, as along the Mississippi river and also in the same geological formation, as in the direction of the Cedar river; only the rate of increase in this latter section is not as great as in the former.

The origin of these peculiar dolomitic rocks is still a mystery, notwithstanding all that has been written on that subject, and we can hardly wonder that it is so when we see that the real constitution of these rocks never before has been properly expressed. It is only when a great fact is clearly recognized by itself, that we can hope at all to account for it.

SECTION FROM JOHNSON COUNTY TO FREMONT COUNTY.

RESULTS CALCULATED FROM MY OWN ANALYSES.

Label No.	LOCALITY.	COUNTY.	DISTANCE.	Ratio.	Calcite.	Dolomite.	Insoluble.	Others.
10	Clark's Mill, Iowa City	Johnson	140 miles.	0.00	96.50	....	3.50	.....
246	Section 20, township 72, range 28	Union.	90 miles	0.00	81.45	trace	13.28	5.27
132	Three miles above Plum Hollow	Fremont	.....	0.006	94.81	6.63	3.65	1.34

So that the calcareous rocks in Southern Iowa are almost pure limestones (calcite).

Besides these sections, based upon quantitative determinations, qualitative analyses have been made sufficient to determine the nature of the calcareous rocks in two more sections in southern Iowa. The presence of dolomite in a rock is usually characterized by a peculiar

aspect, due to small, crystaline, reflecting spangles in the rock. The State Geologist, judging from the appearance of the rocks in southwestern Iowa, concluded the absence of dolomite in the same; the following analyses will show that he was right, or that the calcareous rocks of this region of this State, mostly belonging to the upper coal-measures, are indeed very nearly devoid of dolomite.

CHEMICAL SECTION—FIRST TIER OF COUNTIES.

Label No.	LOCALITY.	DISTANCE.	COUNTY.	PER CENT DOLOMITE.
249	Long Creek township	70 miles.	Decatur	Faint trace.
137	.....	70 miles.	Page (north part)	Faint trace.
135	Wilson's quarry, 3 miles above Plum Hollow	.....	Fremont	Faint trace.
132	Wilson's quarry, 3 miles above Plum Hollow	.....	Fremont	0.63

CHEMICAL SECTION—THIRD TIER OF COUNTIES.

10	Coral Mills, near Iowa City	75 miles.	Johnson	None.
252	Coral Mills, near Iowa City	75 miles.	Johnson	None.
108	Pella	57 miles.	Marion	None.
83	No. 9 of Winterset Section	12 miles.	Madison	None.
84	No. 12 of Winterset Section	12 miles.	Madison	Trace.
77	Above building layer	44 miles.	Madison (west line.)	Trace.
85	Building layer	44 miles.	Madison (west line.)	Trace.
91	Lewis	34 miles.	Cass	Faint trace.
118	Merrett's quarry, 6 miles north of Council Bluffs	.....	Pottawattamie	Faint trace.

The preceding embraces all the systematic knowledge of Iowa Rocks hitherto brought to light. I hardly need to say that it is very little positive knowledge for so vast a field! The chemical sections run are few in number, and the point really determined in these few lines, are very far apart. In this field very much remains to be done.

An artesian well 1,125 feet deep, has been bored at Mount Pleasant, Henry county, for the Iowa Hospital for the Insane. A very complete set of the borings has liberally been presented to the State University. Of these I have analyzed the following nine portions, corresponding to the depth indicated, thus giving us some fixed points in an admirable verticle section of the Iowa rocks, of more than a thousand feet.

VERTICAL SECTION AT MT. PLEASANT.

Depth in feet.	CHARACTER OF CALCAREOUS ROCK.	Ratio.	Calcite.	Dolomite.	Insoluble.	Others.
160	Dolomitic limestone.....	0.5	30.07	15.22	48 74	5.35
200	Magnesian limestone.....	0.03	75.70	2 20	20 33	1.76
300	Calcareous dolomite.....	1 .8	6.37	11.21	79.96	5 22
400	Calcareous dolomite....	.....	.....	.....	75.16	4.78
500	Calcareous dolomite..... ...	2.1	2.93	6.25	82.88	7.93
600	Calcareous dolomite.....	2.2	12 34	27.29	59.14	1.37
718	Nearly pure dolomite..... ..	26.0	1.16	30 17	66 79	.....
990	Nearly pure dolomite..... ..	28.1	2 29	64 40	27 19	5.98
1095	Magnesian dolomite, infinite.	.....	.....	82 69	6 26	0.06

One thousand one hundred and five feet were, by the Geologist, supposed to correspond with the Hudson shales which outcrop near Dubuque. From Mount Pleasant to the direction of the outcrop of these shales in northeastern Iowa is nearly one hundred and ten miles. The vertical thickness of rock of one thousand one hundred feet at Mount Pleasant thus corresponds to one hundred and ten miles in a horizontal direction at right angles to the line of outcrop; or one mile in a horizontal direction northeast from Mount Pleasant corresponds to ten feet in the vertical direction at Mount Pleasant. On Hall's geological map of Iowa, the outcrop of the dolomite (Le Claire limestone) is very nearly sixty miles distant from Mount Pleasant; accordingly it might here be met at a depth of six hundred feet. The above chemical section of the boring shows the dolomite to be at seven hundred and eighteen feet; so that we may suppose the rocks to be very uniform in their extent below the surface. A very noteworthy circumstance forms the regular increase of the ratio; the relative amount of dolomite is slowly increasing from three hundred to six hundred feet, corresponding to a slow increase in the surface rocks for a distance of thirty miles. Now this is not observable in the Misissippi section; but in the Cedar river section a similar increase was noticed. Again, in the short distance of twelve miles, between Rock Island and Le Claire, the rock almost suddenly changes from pure limestone (calcite) to dolomite; then twelve miles would correspond at Mount Pleasant to one hundred and twenty feet in depth; and it must be a very striking coincidence that my analyses find at a depth of six hundred feet only a ratio of two, and about one hundred and twenty feet deeper

a sudden increase of this ratio to twenty-six. It may therefore be considered as tolerably well proved by this chemical section that the rock corresponding to Hall's so-called Le Claire limestone commences at Mount Pleasant at a depth of very near seven hundred feet.

This fact is of great importance in regard to the dip of the coal-bearing rocks of the State; and for this reason I intend to analyze still more of the borings of the artesian well at Mount Pleasant.

In conclusion, I would add, that the excess of magnesia in my analysis of the sample from the depth of one thousand ninety-five feet, corresponds to the excess of magnesia in Whitney's analysis of the Dubuque dolomite.

ON THE COMPOSITION, VALUATION AND PROXIMATE ANALYSIS OF IOWA COALS.

CHAPTER III.

The following two papers have appeared in the *American Journal of Mining*, of New York, for November 30, December 28, 1867 and January 4, 1868.

I. ON THE COMPOSITION AND VALUATION OF IOWA COALS.

Before entering upon the analyses of the numerous samples of coal submitted to me by the State Geologist, Dr. C. A. White, I carefully reviewed the analyses of Prof. Whitney, recorded in Vol. I. of the Geology of Iowa.

Prof. Whitney has determined the proximate constituents of sixteen samples of Iowa coal, and reduced the same to 212° F; that is, while excluding the moisture, he retains the ashes of the coal in his final statement.

Thinking that the combustible part of the coal alone can be considered as the mineral, so that the ashes as well as the moisture ought to be excluded as accidental and really injurious constituents of the coal, I reduced the analyses of Whitney to the combustible = 100; the result of this reduction is given in a diagram, the scale of which is 1 millimeter to each per cent (or 100 = 100^{mm} = 1 decimeter.) The fixed part of the combustible we will call carbon, the volatile we term bitumen. The figures at the lower line indicate the order in which these analyses are recorded in the Geology of Iowa, Vol. I., Part 1, pp. 397–415 (1858).

I regret that the diagram here referred to can not be printed in this publication; I must, therefore, be satisfied by inserting the table from which the diagram was constructed.

TABLE OF REDUCED RESULTS.

COMBUSTIBLE OF = 100. ASH EXTRA. ANALYSES OF PROF. WHITNEY.

No.	LOCALITY.	BITUMEN.	ASH.
1	New Buffalo	47.14	25.76
2	New Buffalo	44.13	10.27
3	Rock Island	41.54	1.24
4	La Salle, lower seam	41.96	7.11
5	La Salle, upper seam	42.59	13.91
6	Hillsborough, Cox' bank	47.17	4.05
7	Hillsborough, Crail's bank	41.14	2.56
8	Farmington, two miles above	44.53	6.87
9	Farmington, half mile from	42.16	7.94
10	Iowaville	45.55	4.42
11	Business Corner	45.18	8.47
12	Fort Dodge, west bank of river	46.58	7.92
13	Section 18, township 88, range 28	44.92	9.22
14	Section 13, township 88, range 28	45.94	23.44
15	Eldora, Hardin county	45.01	10.30
16	Newton, Jasper county	48.38	6.30
	Mean of all	44.00	

A mere glance at this table shows that the great difference between these Iowa coals is due to this varying per centage of ashes, while the per centage of the carbon and bitumen in the combustible remain essentially the same in all the coals, deviating but little from the mean of

$$\left.\begin{matrix}\text{Carbon } 56\\ \text{Bitumen } 44\end{matrix}\right\} \text{Combustible} = 100.$$

which mean is represented by the straight line A B in the diagram.

If, instead of comparing all the coals of Iowa, we limit ourselves to the coals of any one county, the uniformity of the combustible becomes still more apparent.

WEBSTER COUNTY.

No.	WHITNEY.		HINRICHS.	
	Bitumen.	Ash.	Bitumen	Ash.
12	43.16	7.34	46.58	7.92
13	41.13	8.44	44.92	9.22
14	37.21	18.19	45.94	23.94
Mean	40.50		45.82	

The deviations from the mean values are, according to

	No. 12.	No. 13.	No. 14.
Whitney	+2.66	+0.63	—3.29
Hinrichs	+0.76	—0.90	+1.12

Or, according to my reduction, the several samples differ hardly more than the possible errors of the analyses. The proper comparison of these deviations we obtain by taking the sum of their squares; these are for Whitney's figures, 18.2966, for mine only 1.4020, or fully thirteen times less! According to Whitney's statement these three samples of coal from three different localities in Webster county appear to differ by fully six per cent in the amount of bitumen; according to my reduction there is only an extreme variation of one and one-half per cent.

It is therefore manifest that by throwing out not only the moisture (as Whitney has done), but also the ashes, as accidental, then these coals, analyzed by Whitney, differ not more in regard to the composition of the combustible than the errors of the different analytical determinations of the same sample of coal:

Of Illinois coal, analyzed by Whitney, we have the following:

No.	Locality.	WHITNEY.		HINRICHS.	
		Bitumen.	Ash.	Bitumen.	Ash.
3	Rock Island	41.03	1.12	41.54	1.24
4	La Salle, lower	39.17	6.64	41.96	7.11
5	La Salle, upper	37.39	12.21	42.59	13.91
		39.20	...	42.03	.....

which show the following deviations from the mean:

	No. 3.	No. 4.	No. 5.
Whitney	+1.83	—0.03	—1.84
Hinrichs	—0.49	—0.07	+0.56

Dr. Blaney, Chemist of the Illinois survey, has analyzed thirteen samples of coal from Mercer county, Illinois, which fully confirm the uniformity of the combustible for that county, although the result, as stated by him, show an apparent variation of 14 per cent (from 19.2 to 33.3) in the amount of bitumen!) [See Illinois Report, 1866, Vol. I, p. 276.]

MERCER COUNTY, ILLINOIS.

No.	BLANEY.		HINRICHS.	
	Bitumen.	Deviation.	Bitumen.	Deviation.
3	29.8	—0.05	36.52	+0.12
4	28.6	—1.25	36.86	+0.46
5	33.4	+3.55	38.38	+2.98
6	31.2	+1.35	35.61	—0.89
7	30.8	+0.95	35.16	—1.24
8	19.2	—10.65	35.04	—1.36
9	30.8	+0.95	36.67	+0.27
10	30.0	+0.15	35.21	—1.19
11	31.2	+1.35	37.32	+0.92
12	32.2	+2.35	36.43	+0.03
13	31.2	+1.35	36.28	—0.12
Mean...	29.85	.....	36.4	.....
Sum of squares.....		140.41	.....	15.64
Probable error.....		2.50	.....	0.83

The sum is, by my calculation, reduced to one-ninth, the probable error to one-third, of what they are for Blaney's values; and the example No. 8, deviating fully 10 from Blaney's mean, shows only a deviation of 1½ according to my reduction.

These examples are deemed sufficient to prove that even over a considerable area we may consider the relative proportion of carbon and bitumen in our Western coals as constant.

Thereby these proximate analysis of coals acquire a new and more important value; for if the combustible part in the coals, compared with one another, is of the same composition, its heating effect will necessarily be the same for equal weights of combustible; or, in other words, the value of these coals will be proportional to the per centage of this combustible in the raw coal.

Furthermore, the heating effect of two weights of different coals will be the same if both contain the same amount of this combustible (say 100); the amount of moisture and ashes, calculated for 100 combustible and added to this will therefore be the caloric equivalent of these coals, or represent such weights of the raw coal as will produce the same heating effect, namely that of 100 pure combustible.

Thus the coals, numbers twelve and fourteen, from Webster County, Iowa, contain respectively 80.6 and 73.4 of combustible; hence these figures express the value in cents of a weight of the

coal equal to one dollar's worth of pure combustible; furthermore, the amount of moisture and ashes is per 100 combustible respectively 24.1 and 36.3: hence the caloric equivalents of these coals would be 124.1 and 136.3, that is, it would require 124.1 pounds of the former and 136.3 pounds of the latter, to produce as much heat as 100 pounds of the pure combustible, free from ash and moisture.

This valuation of coals we believe as accurate as any other theoretical one in use; and it has this advantage, that it needs no extra work beyond that of the proximate analysis, which for many reasons, ought never to be omitted.

To directly compare our valuation with that based upon the reduction of lead, I may refer to the seven hundred analyses of Austrian coals recorded in Jahrbuch der K. K. geologischen Reichsanstalt, Bd. X., Heft 3, Wien, 1859. Here we find six analyses of coals from Mihalkovitz, in Moravia, by W. Mrazek, viz.:

	Ashes.	Water	Combustible.	Lead reduced by 1 Coal.	Lead reduced by 1 Combustible.
1 Bank, upper	17.4	1.01	81.59	23.99	29.40
1 Bank, lower	4.9	1.06	94.04	28.35	30.17
2 Bank	5.5	1.18	93.33	27.18	29.13
3 Bank	5.1	0.89	94.01	28.45	30.27
4 Bank	2.9	1.02	96.08	27.58	28.70
5 Bank	6.8	0.08	93.12	27.21	29.16
Mean				27.13	29.47

The deviations from the mean are, according to the reductions of

Mrazek, —3.14 +1.22 +0.05 +1,32 +0.45 +0.08

Hinrichs, —0.07 +0.70 —0.34 +0.80 —0.77 —0.31

Of which the latter are all very much smaller than the former, and hardly surpass the deviations between different determinations of the same sample. Practically, one hundred of the combustible matter in any of the above coals reduced the same amount of lead (29.5 parts).

If we, therefore, calculate the caloric equivalent from the per centage of combustible matter in these coals, as shown above, and divide this by the equivalent determined by the lead-reduction, we ought to get the same quotient always. I find this quotient to be respectively

12.63 12.96 12.75 12.97 12.53 12.63

of which the mean is 12.74.

Dividing my equivalents of these coals, or respectively

122.6 106.3 107.2 106.4 105.5 107.4

by this quotient 12.74 we ought to obtain the same equivalent as directly determined by Mrazek; we find the equivalents:

	OBSERVED.	CALCULATED.	DIFFERENCE.
1 Bank, upper	9.7	9.72	—0.08
1 Bank, lower	8.2	8.34	+0.14
2 Bank	8.4	8.41	+0.01
3 Bank	8.2	8.35	+0.15
4 Bank	8.4	8.25	—0.13
5 Bank	8.5	8.43	—0.07

It thus appears that the extra reduction determination of Mrazek was superfluous, for the comparison of the value of these coals; for my equivalent calculated from his proximate analysis fully agrees with the equivalent directly determined by him.

The preceding is determined sufficient to warrant the following deductions:

1. The ashes as well as the moisture of coals are to be considered as impurities, the combustible part being the real mineral species.

2. This combustible part of our Western coals is very uniform in composition, even for considerable parts of the coal-field.

3. For such portions of the coal field the value of the coal is measured by the per centage of combustible, and

4. The caloric equivalent, that is, the number of pounds of coal having the same heating effect as 100 of the pure combustible, is obtained by the proportion

Equivalent : 100 = 100 : value.

Or by dividing the value into 10,000.

Having completed an extensive series of analyses of coals from Iowa, conducted according to a uniform method, the result of a special series of experiments, I am in the position to add to this notice, that not only the general uniformity over considerable areas is confirmed, but the change in this composition in the various parts of the coal-field seems to lead to still more general results.

Thus by comparing the Iowa coals with those of Illinois, analyzed

by Prof. Blaney, I find, after reducing these latter analyses, that in the Illinois coal-field the per centage of bitumen appears to increase westward. For I find, as means, for

NO. OF ANALYSES.	LOCALITY.	PER CENT BITUMEN.
4	Grundy county, Illinois	32
8	La Salle county, Illinois	33
2	Marshall county, Illinois	35
16	Warren and Mercer counties, Illinois	36

These analyses, all executed by Prof. Blaney, may be considered comparable. So also the following analyses of Prof. Whitney, given above.

No. 3, 4, 5.....Illinois.....Mean 42 per cent bitumen.
The other 13 .....Iowa.....Mean 44 per cent bitumen.

From my own analyses, recorded in Chapter I, Section 4, it appears that westward in the Iowa coal-field, the amount of bitumen again decreases (about 4 per cent.)

As far as the facts in regard to this very important question are known, it seems that *the greatest amount of bitumen is found in that part of the coal-field near the course of the Mississippi, and that also on the whole the amount of bitumen is greater for Iowa coals than for Illinois coals.* (See *American Journal of Mining*, Feb. 1, 1868.)

II. ON THE PROXIMATE ANALYSIS OF COALS.

Coal is not a simple chemical combination, expressible by a chemical formula; but it is the final residuum of vegetable matter having been exposed to a long-continued and complex process of addition and subtraction. An elementary analysis will therefore not teach us much in regard to the nature of the combustible; for who would dare to make any conclusion concerning the peculiar combination of the elements thus determined? Even the heating effect calculated from this elementary analysis is not more trustworthy than the valuation by the reduction of lead.

The proximate analysis, on the contrary, enables us to learn something in regard to the real nature of the fuel. The moisture and the ashes are both not only diluents of the fuel, but in themselves obstacles to the effectiveness of the same; the vaporization of the moisture causes a serious loss of heat, while the ashes, by hindering

a complete combustion, and by the heat they contain when dropped through the grate, constitute another loss. By furthermore determining the total amount of volatile matter, we learn both the per centage of coke in the fuel, and the amount of carbon (fixed combustible) and bitumen (volatile combustible matter). Although neither of these two products can be considered as simple chemical compounds, it is nevertheless of the utmost practical importance to know these two quantities, because of the great importance of coke and gas in the arts. The yield in gas of a fuel is no doubt measured by the per centage of bitumen, at least for coals from the same basin — coals which therefore may be supposed to have passed through nearly the same chemical history.

In taking charge of the chemical labors of the Geological Survey of Iowa, I had grave doubts in regard to the value of this proximate analysis of coals. No investigation as to its accuracy, nor as to the best method of conducting the work, had come to my knowledge. The European chemists seem almost exclusively to rely on the elementary analysis, while in the great Government surveys of this country the proximate analysis seems to have been almost as exclusively practised. But while the former may readily be turned into approximate determinations of the heating effects of the fuel, the latter have, to my knowledge, never been used for such purposes, nor was it at all apparent that they ever could be thus made useful.

In regard to the first condition of all quantitative determinations, that of giving constant results for the same substance, but few observations were accessible, and these rather increased my first distrust. Thus Whitney nowhere, in his report on the coals of Iowa, (Geology of Iowa, Vol. I, Pt. I), gives any data whatever in regard to this most important question, although he devotes a very large space to the subject. Only the final results are given; but whether the individual determinations deviated much or little from the same, can not be ascertained; or, in other words, the degree of accuracy or reliability of his reported results is altogether unknown. The report of Dr. James V. F. Blaney on the coals of Illinois (Geology of Illinois, Vol. I, 1866, p. 258–277) insists on the great correspondence of the amount of bitumen volatalized to varying circumstances, but only in

general terms: no experimental data being brought forward. Fortunately, this chemist gives for four samples of coal the direct result of two determinations (see p. 275); but the differences between these two determinations on the same sample are respectively:

3.04 1.50 1.32 0.07

per cent, the mean of which is 1.48, or very nearly one and a half per cent. This result certainly was not calculated to incline me favorably to the proximate analysis of coals.

On the other hand, the usual applications of coal demand such analysis, and my reduction of the analysis of Whitney and Blaney proves, by the results obtained, that the determinations must be more reliable than the above figures would indicate.

It thus became necessary for me, before making any proximate analysis of the many samples of Iowa coals put into my hands by the State Geologist, Dr. C. A. White, to make a rather extensive and thorough search into the method itself, in order to study its exact value. Since I, in these determinations according to the varied circumstances for the same sample of coal, obtained values ranging from 41.77 to 57.31 per cent for the amount of volatile matter, it seems not only that such investigation was sufficiently called for, but even that it shows the proximate analysis to be worthless: a variation of 15.54, or rather 16 per cent for the same sample, seems to condemn the method admitting of such results.

In the determination of magnesia, as large variations could be obtained by exposing the crystalized double phosphate to varied conditions; and yet this determination, properly executed, is one of the most accurate known in analysis.

It is easily seen that the following elements will modify the result of the amount of volatile matter driven off from a sample of coal contained in a covered platinum crucible: weight of coal and of crucible; degree and duration of heat; condition of coal. I hope to show that this determination, notwithstanding all these elements, admits of an accuracy of one-tenth of a per cent, equal to that of weighing a gramme exact to the milligramme.

The sample of coal used for this purpose was not selected, but taken at random. It was labelled No. 350, and is from the bottom of

Roberts and Fisher's Bank, which bank is five to six feet thick, seven miles west of the town of Pella, in Marion county, Iowa. From this sample a very pure piece, free from any visible admixture of either gypsum or pyrites, was selected. By means of 2.760 coal, in coarse fragments of about 1-10 cubic centimenter and a 50-gramme flask, the specific gravity of this coal was found to be 1.328.

A. DETERMINATION OF THE VOLATILE MATTER.

SOURCE OF HEAT.—A common Bunsen burner was used (red heat), and also a gas burner with six jets, surmounted by a French *soufflet cylindrique* (white heat), care being taken to keep the gas-cock in the same position by means of an arm of ten inches in length. These two sources of heat we will denote respectively "B B," and "Blast."

The time was usually measured by means of a small sand-glass, running exactly three and one-half minutes; this duration we will denote by *t*. Thus BB*t* means that the crucible was exposed to the constant flame of the Bunsen burner during three and one-half minutes.

INFLUENCE OF QUANTITY OF COAL.

1. Coal pulverized, not dried; heat: BB*t*; cooled and weighed then blast, *t*; then weighed again.*

NO. OF EXPER'T.	WEIGHT.	VOLATILE, PER CENT.	DEVIATION.	CRUCIBLE.
d	5.360	48.24	—1.14	19.2
n	1.910	49.58	+0.20	19.2
e	1.147	49.87	+0.49	11.6
o	1.031	49.85	+0.47	9.4
	Mean.....	49.38	.....	.....

2. Coal in small fragments; heat as in 1.

h	3.743	48.30	—0.94	19.2
g	1.130	50.18	+0.94	9.4
	Mean.....	49.24	.....	.....

* Weight = coal taken in grammes; crucible = weight of the same. Deviation per cent from the mean given. These quantities are given in the same order in all subsequent tables, unless stated otherwise.

For the same heat, the amount volatilized is the greater, the smaller the mass heated; whether the coal is in small fragments or pulverized hardly makes any difference; but since the bitumen passed off more regularly when the coal was pulverized, while, when in fragments, slight explosions sometimes occurred, the coal should be pulverized for the determination of the bitumen.

3. Coal, pulverized, between 1 and 2 grammes; heat as above,

NO. OF EXPER'T.	WEIGHT.	VOLATILE, PER CENT.	DEVIATION.	CRUCIBLE.
n	1.910	49.58	—0.19	19.2
c	1.147	49.87	+0.10	11.6
o	1.031	49.85	+0.08	9.4
Mean.....		49.77	.....	.....

giving, as probable error of a single determination, only 0.108 per cent, or only 1 milligramme for 1 gramme of coal. This is not greater than that of the weighing itself, in which fractions of a milligramme were usually neglected.

4. Coal, pulverized (new portion), and between 1—2 grammes. Heat: BB*t*; immediately thereafter Blast *t*, without cooling.

NO. OF EXPER'T.	WEIGHT.	VOLATILE, PER CENT.	DEVIATION.	CRUCIBLE.
a′	1.160	50.86	+0.14	9.4
n′	1.040	50.58	—0.14	11.0
Mean.....		50.72	.....	.....

Another determination was made (*o*′); but on account of side-draft while over BB the crucible cooled several times; correspondingly the result deviated much, being only 49.10.

From 3 and 4 we conclude, that if the substance taken is from 1 to 2 grammes, the result will be constant for the same mode of heating.

INFLUENCE OF DRYING THE COAL BEFORE IGNITION.

5. Coal, fragments; heat, BB*t*; not cooled; Blast *t*.

NO. OF EXPER'T.	WEIGHT.	VOLATILE, PER CENT.	DEVIATION.
t	1.361	48.49	+0.76
u	1.060	47.26	—0.47
v	1.030	47.43	—0.30
Mean.....		47.73	.....

with the probable error of one single determination 0.45.

Comparing this with 4 (same heating) it appears that about 3 per cent less volatilized by previous drying, and also that the accuracy of one determination is four times less than when the coal is ignited without previous drying. In the arts the coal is not artificially dried before coking. For all of these reasons the amount of volatile matter is best determined on undried coal.

6. In general, I found, as means,

4 dried coals gave 47.97 per cent volatile,

10 undried coals gave 49.87 per cent volatile,

confirming the above.

INFLUENCE OF COOLING AFTER THE IGNITION OVER THE BUNSEN BURNER, AND BEFORE THE IGNITION OVER THE BLAST-FLAME.

7. *Coal*, pulverized, not dried; *heat*; BB*t*; then Blast *t*, without cooling.

NO. OF EXPER'T.	WEIGHT.	VOLATILE PER CENT.	DEVIATION.
x	1.314	49.01	—0.02
y	1.156	49.05	+0.02
Mean.....		49.03	.....

which compared with the corresponding case 3, giving the mean 49.77 and maximum deviation 0.19, shows that by the intermediate cooling about $\frac{3}{4}$ per cent more is volatilized. This probably is due to the fact that the crucible upon cooling is filled with atmospheric air, which, upon renewed ignition, must burn a corresponding amount of the coal.

INFLUENCE OF REPEATED HEATING, THE CRUCIBLE BEING AFTER EACH IGNITION COOLED AND WEIGHED.

8. *Coal*=r= 1.628 in crucible 19.2 was dried, then ignited, (BB*t*) and lost 41.77 per cent. Being ignited again in the same way, it lost 2.76 per cent, or, in all, 44.53. Being successively ignited 7 times, BB, each time for 6 minutes, the total loss was 52.39, or, on the average for each of these 6-minute BB ignitions, 1.12] two of the determinations nearest this average were 1.06 per cent).

Hereafter the same was 5 times for 3½ minutes exposed to the blast; the volatile passed off amounted to 57.31, giving for each of these last ignitions the average loss of 0.98 per cent.

It now had been ignited 14 times, each time having been cooled and weighed; and we have 14 ignitions, 57.31 volatile: 1st ignition 41.77 volatile; hence average for each of the 13 ignitions 1.195 or 1.2 per cent.

This series of experiments shows that it is impossible to heat coal until no further loss is sustained; for it is apparent that each heating (after complete cooling) produces, on the average, more than the additional volatization of 1. On 1 gramme coal taken, 1 per cent carbon burnt requires about 30 milligrammes or 20 cubic centimeters of oxygen. We may therefore consider these successes almost equal losses due to a real combustion.

INFLUENCE OF PROTRACTED HEATING.

9. Coal, pulverized, not dried; heat, always first BB *t*, and then immediately, without cooling, transferred to blast-lamp.

NO.	WEIGHT.	BLAST.	VOLATILE.	DIFFERENCE	DIFFERENCE PER MINUTE.
a′+n′	(mean)	3 min.	50.72	0.57	0.19
c′		6 "	51.29	1.04	0.35
b′		9 "	52.33	1.95	0.65
d′		12 "	54.28	2.93	0.16
k′		30 "	57.21		

By comparing each with the first mean, we obtain for each minute-blast after the first 3, respectively,

0.24 0.39 0.27 0.20

showing less difference than the above.

The volatilization, after the three first minutes-blast, is therefore increasing ¼ to ⅔ per cent for six minutes, and then very slowly decreasing to about ¼ per cent for half an hour. At this rate the loss is 12 per hour.

It is apparent that this loss is less than when cooled in the intervals, but it proves that a slight current of air must get at the coal in the covered crucible.

At any rate it is demonstrated, that the rule which is sometimes given, to heat until no further loss is sustained, demands an impossibility.

INFLUENCE OF THE DEGREE OF HEAT.

10. *Coal*, pulverized, not dried; *heat*, BB*t*; cooled and weighed; then Blast *t*; cooled and weighed again.

		AFTER BB.		AFTER BLAST.	
n	1.910	48.08	+0.42	49.58	—0.18
e	1.147	47.69	+0.03	49.87	+0.11
o	1.031	47.23	—0.43	49.85	+0.09
Mean.....		47.66		49.76	
Probable error..		0.284		0.108	

showing that the higher temperature gives the most accurate results.

RESULT.

From this investigation we conclude:

The total volatile matter of coal is determined with accuracy (1 *mgr. on* 1 *gr. coal*) *by taking* 1 *to* 2 *grammes of undried pulverized coal, heating it for* 3½ *minutes over a Bunsen burner* (*bright red heat*) *and then immediately, without cooling, for the same length of time over a blast gas-lamp* (*white heat.*)

B. DETERMINATION OF THE MOISTURE.

A flat-bottomed iron pan, of 20 centimeters in diameter, was filled evenly to the depth of 1½ centimeters, with sand, and the latter was covered with a copper plate, on which the watch-glass containing the coal was placed. A thermometer (scale to 370°C.) was, by means of a rubber stopper, inserted in an iron arm of the tripod supporting the iron pan, and held with its bulb about half a centimeter above

the copper plate. By means of a Bunsen burner it was found very easy to keep the thermometer perfectly constant at 115°C. This apparatus I consider a good substitute for Fresenius' iron plate.

The coal to be dried was finely pulverized, direct experiments having convinced me that the application of fragments was not only very much slower, but also erroneous, on account of the peculiar property of bituminous coal treated of below.

In order to show the accuracy of this method, I transcribe the following examples from my journals:

No. of coal.	Weight of portion.	Time.	MOISTURE.		Mean.
			Per cent.	Deviation from Mean.	
390 e	0.961	1 hour.	4.888	—0.004	4,892
390 f	0.919	1 hour.	4.896	+0.004	4,892
390 e	0.961	2½ hours.	4.16	+0.01	4.15
390 f	0.919	2½ hours.	4.14	—0.01	4.15
339 e	1.452	1 hour.	8.26	+0.07	8.19
339 f	0.975	1 hour.	8.12	—0.07	8.19
339 e	1.452	3 hours.	7.16	+0.17	8.19
339 f	0.975	3 hours.	6.83	—0.16	8.19
338 e	1.415	1 hour.	3.852	—0.029	3.881
338 f	0.805	1 hour.	3.911	+0.030	3,881
338 e	1.415	2½ hours.	3.287	+0.123	3,164
338 f	0.805	2½ hours.	3.042	—0.122	3,164
338 e	1.415	5½ hours.	2.722	+0.088	2,634
338 f	0.805	5½ hours.	2.546	—0.088	2,634

These results — a few taken from among a great number of determinations — show that the loss (called moisture) decreases regularly after the first hour of drying, that is to say, while the coal loses in weight during the first hour, it steadily gains in weight thereafter. It appears furthermore, that the accuracy of a determination, expressed in the smallness of the deviations from the mean, is greatest at the end of the first hour of drying, least after about three hours of drying, and thereafter increases again as expressed in the diminution of the deviations after five and one-half hours drying in coal No. 338.

On account of these peculiar properties of our bituminous coal, I put down as moisture the loss in weight of the finely-pulverized coal after one hour's drying at a temperature between 105° and 110°C.

C. ON THE SLOW OXIDATION OF COAL.

This increase in weight after the first hour's drying I have found in *all* Iowa coal investigated as yet. I have also found it to occur in a sample of coal (steinkohle) from Beuthen, Silesia, which showed a loss of 3.62 per cent at the close of one hour, and in four further hours' drying gained again 0.42 per cent; also in cannel coal from Wigan, England, which gained 0.42 per cent. It was not noticed in brown coal from Bilin, Bohemia, nor in brown coal from Arbesan, Bohemia, nor in bituminous wood from Salzhausen, Germany, nor in peat from Ireland, nor in anthracite from Pennsylvania. I am therefore inclined to believe this to be a property peculiar to pit-coal (steinkohle).

On page 401 of Vol. I. P. I. of the Iowa Geology, Prof. Whitney remarks: "A remarkable fact, in connection with the determination of the water present in the specimens of coal has been noticed. In numerous instances, after the sample, in the form of a coarse powder, had been dried for several hours in the air bath, at a temperature a little above that of boiling water, during which time it had gradually lost weight until all the water seemed to have been expelled, on continuing the operation for some time longer a slight increase of weight would become perceptible, and the coal would continue to grow heavier until a gain of several tenths of a per cent of the original weight had been made. This appears to be owing to the slow oxidation of the sulphur which all these coals contain in a finely divided state, disseminated in invisible particles through the mass, and, perhaps, partly in combination with iron."

It is evident that Prof. Whitney failed to discover this property as a general one, because he had the coal in coarse fragments. The want of correspondence in the results of determinations of moisture in the same sample, dried at the same time, but of different weights, made me apply the coal in the form of powder. Thereby the turning point was reduced from "several hours" to less than one hour; the "numerous instances" extended to all samples investigated; the "slight increase of several tenths of one per cent" became often two and even four per cent! Instead of numerous exceptions we now discovered a general law.

We have failed, as yet, to notice any "sulphur" disseminated through the Iowa coal; what popularly is called sulphur is pyrites. Prof. Whitney has given no proof of the existence of real "sulphur" in the coal. It is therefore unsatisfactory to ascribe this property of the bituminous coals to such "sulphur."

Pyrites might well be the cause of this phenomenon; the red ashes obtained in many cases (in Van Buren County, Iowa, invariably from the upper part of the coal-bank), may well be ascribed to pyrites disseminated through the coal in invisible particles. 2 FeS_2 will give Fe_2O_3, $+4SO_3$, by exactly doubling their weight.

In order to decide the question, I select the following results from my analyses:

INFLUENCE OF TIME OF DRYING.

Top-coal.	Number of samples,	4	3	2
	Time of drying,	2	3	4–5 hours.
	Mean gain per cent,	0.45	0.71	0.96
Bottom coal.	No. of samples,	3	5	2
	Time of drying,	2	3	4 hours.
	Gain, per cent,	0.49	0.50	0.96
Mean of above.	No. of samples,	7	8	4
	Time of drying,	2	3	4–5 hours.
	Gain, per cent,	0.46	0.63	0.96
	Gain, per hour,	0.23	0.21	0.24

or, on the whole, for nineteen samples of coal, very nearly proportional to the time, this being not more than four hours. It also appears, that no essential difference is apparent in regard to the position of the sample in the coal-bank.

By this means we may compare the following determinations, referring to 2, 3, or 4 hours drying. We find:

COAL. PLACE	NO.	HOURS.	INCREASE TOTAL	PER CT. PER HR.	DIFFERENCE	COLOR OF ASHES.
Top	390	2	0.75	0.38	0.22	Pale brown
Bottom	384	2	0.35	0.16		White
Bottom	395	4	0.80	0.20	0.04	Red and white
Top	375	4	0.64	0.16		White
Top	346	3	0.68	0.23	0.08	Reddish brown
Bottom	371	3	0.45	0.15		White
Top	336	3	0.76	0.25	0.06	Gray
Bottom	334	3	0.58	0.19		Gray
Top	333	3	1.17	0.39	0.09	Pink
Bottom	340	3	0.91	0.30		Light gray
Middle	357	3	0.55	0.18	0.03	White
Top	370	3	0.46	0.15		Reddish

Except in the coal from the last mine, we notice that the more ferruginous ash does correspond to a slightly greater increase in weight; but we notice also that this difference is but very small as compared to the total amount of increase, being only one-fifth to one-third of the whole. Arranging these coals in the order of this hourly increase, we find the color of the ashes not at all forming a regular series from white to red, as it ought to be if this increase was mainly depending upon the oxidation of the pyrites. Besides, the mean of the 4 white-ash coals is 0.16 per cent hourly increase, while the mean of the 4 coals showing the greatest increase is only 0.33 per cent, or double the former.

Coal, 333	Increase,	0.39	per cent.	Ash:	pink.
" 390	"	0.38	"	"	pale brown.
" 340	"	0.30	"	"	light gray.
" 336	"	0.25	"	"	gray.
" 346	"	0.23	"	"	reddish brown.
" 395	"	0.20	"	"	red and white.
" 334	"	0.19	"	"	gray.
" 357	"	0.18	"	"	white.
" 375	"	0.16	"	"	white.
" 384	"	0.16	"	"	white.
" 371	"	0.15	"	"	white.
" 370	"	0.15	"	"	reddish.

The greater increase of the pyritiferous coals is accounted for by the oxidation of the pyrites they contain; the comparatively great increase of coals giving a pure white ash seems to force the conclusion upon us, that *the bitumen of the coal itself oxidizes*, and that to this oxidation the main increase of all these bituminous coals must be ascribed. Remembering now our result regarding the deportment of bituminous coal from Silesia, anthracite from Pennsylvania, brown coal from Bohemia, (all of which gave ashes very nearly of same shade, and all of which had been in my air-heated laboratory for two years), it seems not unlikely that this is another characteristic chemical difference between bituminous coals and other fossil coals.

In conclusion I will only give two additional determinations, showing a very considerable increase in weight, and also that *the process of oxidation is completed in about six hours for two-thirds grammes of coal.* For No. 329, containing 8.30 per cent of gray ashes, gained, in 5½ hours, 2.05 per cent of its original weight. Coal No. 348, with 6.00 per cent red ashes, weighed 0.693.

		Change: Weight. Per cent.	Total loss: Per cent.
After ⅔ hour,	0.630	loss 0.063—9.091	9.091
" 2 hours,	0.625	" 0.005—0.722	9.813
" 5½ hours,	0.656	gain 0.031—4,474	5,339
" 8¾ hours,	0.656	" 0.000	5.330

D. DETERMINATION OF THE ASHES.

The best way to determine the ashes in coal I found to be the coking of the finely pulverized coal in a small platinum dish (weighing about 8 grammes) with subsequent incineration of this coke in the same vessel. The incineration takes place with great ease and rapidity, and the results are perfectly satisfactory. Thus 3.022 grammes of coal No. 333 gave 2.35 per cent, and 5.263 grammes of the same coal gave 2.58 per cent, deviating from the mean 2.46 by +0.11.

In regard to the ashes of our Iowa coals, I have found that they are very much more uniform in their distribution throughout the coal-fields than usually thought possible. In Van Buren county, I find the "bottom" coal giving a white or light colored ash, the "top" coal of the same bank a red colored ash; a fact, which I intend to make use of in a subsequent paper on the origin of our coal. I also find the amount of ashes to increase quite evenly (in this county), toward the margin of the coal-field, from about 2 to 7 per 100 combustible.

E. DETERMINATION OF SPECIFIC GRAVITY.

Coarse fragments, freed by means of a sieve, from all small particles, and averaging 1–10 cubic centimeters in volume, were introduced into a fifty-gramme flask, provided with thermometer stopper. The constants for this flask, for temperatures varying from 50° to 80° F. had been carefully determined.

The given specific gravity corresponds to the coal perfectly soaked, so that all its pores were filled with water. That required, on the average, twelve hours, permitting two determinations per day, one in the morning, another in the evening.

That this is not at all trifling, may be seen from the following example. 2.760 grammes coal (No. 350) gave the specific gravity 1.309 at 64° F., immediately after filling the flask with water; after about twelve hours soaking, the specific gravity had increased to 1,328, for the same temperature. According to this latter determination, a cubic foot of this coal would weigh 82.76 lbs.; according to the former, only 81.58, or 1.18 lbs. less. This shows a considerable degree of porosity of the coal; and indicates the absurdity of giving the weight in pounds of a cubic foot of coal with four decimals, although no statement in regard to temperature or time of weighing is made. Such accuracy we meet with in some of the official reports.

F. CALCULATION OF RESULTS.

Referring to my paper in No. 22 of the *American Journal of Mining*, it may be sufficient here to state, that beside the per centage composition of the coal, it is proper to reduce the composition to the combustible = 100, in order to obtain a proper comparative estimate of the character of the fuel itself (in regard to the proportion of bitumen and carbon) and of the amount and quality of the impurities ashes and moisture). It has also been shown in the paper referred to, that for considerable areas of the coal-field, the sum of the constituents on the scale of combustible = 100 is the proper caloric

equivalent, and that the per centage of the combustible in the fuel gives a proper estimate of its value.

According to this method a considerable number of analyses of Iowa coals have already been made. It is believed that the results will be strictly comparable for the entire coal-field of Iowa, and that the conclusions, both practical and theoretical, will deserve some confidence.

THE MINERALOGY OF IOWA.

CHAPTER IV.

The following mineral species have come under my personal observation:

ELEMENTS:	1 Coal.
	2 *Sulphur* (cryst).
OXIDES:	3 Quartz.
	4 Chalcedony.
	5 Hematite.
	6 Limonite (and Ochre).
	8 Wad.
SULPHIDES:	9 Galena.
	10 Blende.
	11 Pyrites.
CARBONATES:	12 Calcite in very many varieties and forms.
	13 Smithsonite.
	14 Dolomite.
	15 *Aragonite.*
	16 *Cerusite.*
SULPHATES, anhydrous:	17 *Celestine.*
	18 Barytes, hydrated.
	19 Gypsum.
	20 Epsomite.
	21 Alum.
SILICATES:	22 Kaolin (and fire-clay).

By reference to the Report on the Geological Survey of Wisconsin, Volume I, 1862, where, in chapter V, Prof. Whitney gives the mineralogy of the lead region, we may consider the italicised species

Sulphur, Aragonits, Carusite, Celestine, the first three having been (found in well crystalized specimens) as not before identified in Iowa.

It will be most convenient to consider the minerals of the principal localities separately.

1. THE DUBUQUE LEAD REGION.

1. *Galena.*—Lead sulphide, PbS; the "*mineral*" of the miners. This ore occurs in two sets of lodes, nearly at right angles to each other. The principal lodes run east and west, the secondary lodes run north and south; some have an intermediate course, and are called quartering lodes. The galena from these lodes may be readily distinguished.

In the east and west lodes the ore is usually imbedded in the clay, which more or less fills the cavity produced by the disintegration of the rock (magnesian limestone). The ore itself is darker, shows frequently good cubes ("dice mineral" of the miner), has a good, regular, cubical cleavage throughout. The ore is sometimes of very considerable dimensions.

In the north and south lodes the ore occurs usually in sheets, rarely more than three inches thick, tightly imbedded in the rock. It is of a lighter color, never shows any well-defined cubes, nor any distinct, regular cleavage. It is more compact, so as to give a somewhat ringing sound when struck; hence it is also called "steel mineral." It is said to yield more lead, to be more easily reduced, and to contain more silver than the east and west mineral. On the south fork of the Little Makoqueta river much of the north and south mineral is mined.

In the quartering lodes the characters of the ore are also intermediate.

Crystaline forms observed are the cube and the octohedron; the latter always in combination with the former. Very fine cabinet specimens may be seen in the cabinet of amateurs and miners at Dubuque. Some specimens have cubes only on one side, while the other is studded with octohedra, retaining but small cubical faces. The largest cube I have observed is in the cabinet of Mr. James Beach, Dubuque; it measures $4\frac{1}{2}\times4\frac{1}{2}\times6\frac{1}{4}$ inches, has the corners unequally replaced by octohedral faces, and weighs $16\frac{1}{4}$ pounds.

2. *Blende.*—Zinc-sulphide, Zn S; the "Black Jack" of the miners. It is not as abundant as the former; more common on the east side of the Mississippi. Only the ferruginous, black variety has been observed; no finely-developed crystals, although the masses exhibit the peculiar dodecahedral cleavage very well.

The disintegration of the blende takes place according to the directions of cleavage. Several specimens, partly disintegrated to carbonate, showed this feature very finely. In some of these specimens of carbonate, the dodecahedral rhombohedron of 120 degrees is easily recognized.

3. *Pyrites.*—Iron disulphide, Fe S_2; "mundic" of the miners. Also this mineral is much more abundant in the eastern portion of the lead region of the Upper Mississippi than in the Iowa district of this region. I have observed it in most beautiful and regular octahedra of about one-tenth of an inch; also dodecahedra have been observed by me. I do not remember to have seen a single cube of pyrites from this region. This form is dominating in the geodes in southern Iowa, and the pyritohedron I have seen in pyrites from a coal-mine twelve miles south of Davenport.

3. *Cerusite.*—Lead carbonate, PbO_3C. The galena often has a white coating of amorphaus lead carbonate. In the quartering lode of Messrs. Burton, Hill & Co., I found some very good, though small, crystals of cerusite, right on the galena, in fissures of the mineral.

5. *Aragonite.*—Prismatic, calcium-carbonate, CaO_3C. Mr. Woodman, of Dubuque, has obtained some very fine specimens, beautiful groups of small crystals, from a cave seven miles south of Dubuque, and one mile west of the river. I discovered some, almost microscopic crystal, right on the galena, in fissures of the ore, at the above-mentioned mine of Burton, Hill & Co, five miles north of Dubuque.

6. *Calcite.*—Rhombohedral calcium-carbonate, CaO_3C, the "Tiff" of the miners. It is very common in the diggings. The scalenohedron R3 is at times found very finely developed, in combination with the vertical hexagonal prism and the fundamental rhombohedron; the crystals often projecting three and more inches.

In the pools of the caves large cakes, consisting of an agglomeration of acute rhombohedra with parallel axes, are formed by slow crystalization. The surfaces of these rhombohedra are never smooth, being studded with smaller rhombohedra of the same form and in parallel position.

Rock-milk, pure white, associated with Wad, has been found in specimens from the Peacock mine.

Stalactites and *Stalagmites* of considerable size are still seen in Dubuque; *Satin*, *Velvet Spar*, forming beautiful arborescent forms, may be seen in the local cabinets.

The most remarkable calcite crystal I have observed is a scalenohedron from the Peacock mine. It is about three inches by two, and at a distance of $\frac{3}{4}$ inches below its surface, a perfectly parallel scalenohedron is finely marked by very small crystals of pyrites.

7. *Smithsonite.*—Zinc-carbonate, ZnO_2C. The common amorphous variety, resulting from the blende, is quite frequent; the miners call it "dry bone." From the iron of the black-jack it is always yellowish or reddish.

Very finely crystalized Smithsonite is rare, but has been observed; some crystals were fully $\frac{1}{32}$ inch in diameter.

8. *Barytes.* — Barium-sulphate, BaO_4S or *heavy spar*. Good tabular crystals of bluish tint have been observed, from Peacock mine.

Gypsum. — Hydrated calcium-sulphate, CaO_4S+2H_2O. It is not common in the lead-mines; usually in small, scaly coatings, and tabular crystals; also bunches of fibrous gypsum (Peacock mine.)

10. *Sulphur, S.* — Beautiful crystals, about $\frac{1}{8}$ inch in diameter, fine yellow color, on galena, probably from the St. John's diggings, four to five miles north of Dubuque. Beside the terminal plane (OP), and the fundamental pyramid (P); also $\frac{1}{2}$P distinctly observed.

While at the Hickock mine (July, 1867) I discovered a considerable amount of *solid* sulphur and dry bone, on blende. The pieces were often as large as a small pea, quite compact, exhibiting some lustre, but no distinct crystalization. The shaft, wherein these specimens were obtained, was only about twenty feet deep.

11.—*Wad*, impure manganese-oxide. Associated with rock-milk at the base of stalactites from the Peacock mine. Also found at the mine of Burton, Hill & Co.

12.—*Limonite*, hydrated ferric-oxide, $Fe_2O_3+3H_2O$. Impure, not fine specimens, quite common. Yellow ochre rather abundant. Goethit, in fine scales, doubtful.

The order of succession of these minerals, as resulting from a careful and minute study of all the specimens of the survey and a great many most excellent specimens in the cabinets of gentlemen at Dubuque, is for the Dubuque lead region essentially.

Rock: Galena limestone ($_a$ dolomite).

1. *Pyrites.*	———	———	———
———	2. *Galena.*	———	———
———	———	3. *Blende.*	———
4. *Limonite.*	———	———	———
———	5. *Cerusite.*	———	———
———	———	6. *Smithsonite.*	———
———	7. *Sulphur.*	*Sulphur.*	———
———	———	———	8. *Calcite.*
———	———	———	9. *Gypsum.*
———	———	———	10. *Barytes.*

Several of these occur more than once in the series; in the above is given the order of their *first* occurrence.

On the east side of the river the order of the sulphides is apparently the reverse. In a great number of very fine specimens from Galena, Illinois, and from Wisconsin (some of which I studied in the cabinet of Mr. Woodman, of Dubuque, the order of the sulphides is blende — galena — pyrites; while for the Iowa lead-region it seems to be, pyrites — galena — blende. It must be stated, though, that the specimens from Illinois were rather finer than any from Iowa I have been permitted to study.

On one fine specimen, observed on board a Mississippi steamboat, I noticed calcite partly between galena and pyrites. Part of the galena was coated with calcite, and over the remaining galena surface, and part of the calcite, pyrites had been deposited in octahedra and dodecahedra.

2. THE GEODE REGION.

For the location and extent of the region where the "*geode bed*" occurs in Southern Iowa, we refer to the published Geology of Iowa.

A great number of geodes, particularly from Bentonsport, Van Buren county, have been closely studied. These geodes varied from one inch to one foot in diameter; many were quite globular, and many are flattened. The wall varies very much in thickness, and this thickness is not at all proportionate to the dimensions of the geode. The outer surface is always uneven, rough. At times it contains a number of good, more or less corroded, cubes of pyrites. No other minerals have been noticed on the outside of the geodes.

The following minerals have been observed on the inside of the geodes:

1. *Chalcedony* forms always the outer crust, often more than an inch thick. Some geodes contain no other mineral; then the chalcedony is of a peculiar mammellar structure, and often shows, in its fracture, agate-like bands. Colors are usually not showy; pale gray, bluish-gray, and yellowish-gray predominate; greenish and reddish tints have been observed. Some of these chalcedonic specimens are very fine.

2. *Quartz*, silicon di-oxide, SiO_2. — It occurs always implanted on the chalcedony. Nearest the latter the quartz is only crystaline, but farther toward the interior of the geode the structure of the quartz becomes more regular, and the inner free surface is always formed of fine crystals. Very often these radiate from a common center, forming bunches in various parts of the geode; the center is always a tube.

The most common crystaline form is the hexagonal pyramid, implanted on the inner surface of the geode; but the rhombohedran of 94° is also quite common, often very large (half an inch along the edges!) In a lot of geodes from Hamilton, Illinois, collected by Mr. Safford, a regular gradation from this rhombohedral quartz to the peculiarly rounded chalcedony could be traced; pure quartz rhombohedra — the same very thinly coated with chalcedony — this coating thicker, so the edges appear quite rounded; finally the rounded forms of chalcedony.

In many geodes the hexagonal prism is very finely developed, both in combination with the rhombohedron, and with the hexagonal pyramid; in many this pyramid had only the alternate (rhombohedral) faces well developed, the others being often rudimentary. This, together with the occurrence of the rhombohedron alone, again is in favor of considering the rhombohedron as the fundamental form.

Some geodes contain a great number of loose quartz crystals, up to half an inch in length. The fine, transparent crystals of this kind belong to the most evenly-developed, and most beautiful rock crystals I have seen. These loose crystals have always a hexagonal prism of some length; and in some geodes this is combined with the rhombohedron alone, in others with the hexagonal pyramid, usually with the two rhombohedral halves unequally developed, but at times the hexagonal pyramid is also perfect.

In a few geodes, thick short quartz crystals (prism and pyramid) were found densely studded with minute pyramidal quartz crystals, so as to form rounded bunches of exquisite beauty.

The colors of quartz in these geodes is various — from clear transparent to white, yellowish, dark-yellow, yellowish-brown, red; some few have a fine rose color.

3. *Calcite* occurs quite frequently, often filling the whole cavity of the geode, usually resting on quartz. Sometimes the crystals are very large and beautiful, but the surfaces have a somewhat silky luster, due to the partial disintegration in the direction of the cleavages. The principal forms observed are:

1. The fundamental rhombohedron of 105° 5′.
2. The first obtuse rhombohedron or $\frac{1}{2}$R of 135°. In one geode from Keokuk several of these occur, one having a diameter of three inches, and a hight of one inch.
3. The veritical hexagonal prism; the longest observed is $3\frac{1}{2}$ inches ($1\frac{1}{2}$ inch diameter); the thickest, $2\frac{1}{2}$ inches in diameter (and 3 inches long).
4. The common scalenohedron, R_3 of 104° 38′ and 144° 24′ in the terminal edges; only subordinate in combinations with No. 3 and No. 6.
5. The scalenohedron $\frac{3}{2}$ R_2, having the terminal edges of 164°

and 130½°. This with the prism of 2½ inches diameter and 3 inches height.

6. The scalenohedron $\frac{4}{5}R_3$, having the terminal edges of 146° and 128°; in another geode, in combination with the hexagonal prism of 3½ inches length and 1¼ inches diameter.

4. *Dolomite.* — $(Mg,Ca)\ O_3C$. Very fine varieties of pearl spar have been observed in several geodes. Some portions had been converted into limonite, without losing the characteristic form. The largest crystals of this kind I observed in a geode from Hamilton, Illinois; the edges being nearly half an inch long.

5. *Pyrites* occur quite frequently in these geodes — almost always in the form of small, very regular cubes. Only very few had their corners finely truncated (octahedral). The largest cubes were found on the outside of a few geodes.

In one geode a mass of pyrites (one inch by one and one-half inches) represents on its surface a peculiar foliaceous structure. The angless do not correspond with selenite, nor do they quite coincide with rhombohedral calcite; yet the mass seems to be a pseudomorph.

The pyrites is but rarely quite unaltered in these geodes; it occurs frequently converted into

6. *Hematite*, Fe_2O_3, and also into

7. *Limonite*, retaining the form perfectly and often including a small nucleus of unaltered pyrites in the middle.

8. *Ochre*, particularly the yellow, fills some cavities almost entirely.

9. *Blende* has been observed, in one geode as much as half an inch cube. Smithsonite has not been noticed by me.

10. *Kaolin* or porcelain clay is found as a fine, perfectly white powder in many geodes.

11. *Incrustations* of various colors and compositions are frequently coating quartz, calcite and others. Calcareous incrustations are the most common, and as far as observed are usually local, speaking for infiltration.

The general order of succession of these minerals, in the geodes observed by me, is

1. *Chalcedony.*

2. *Quartz* — often again coated by chalcedony; and again on this latter beautiful and minute quartz crystals have been observed.

3. *Pyrites* and *Blende*, the former often converted into hematite, or even limonite.

4. *Calcite* — sometimes intergrown with quartz, also in a few instances coated with chalcedony.

Dolomite appears to succeed the calcite.

5. Incrustations and Kaolin. — In a few cases pyrites has been observed right in the chalcedony of the outer crust.

A few acicular crystals were observed in one geode, in pure quartz. These crystals look precisely as *fleches d'amour*, or acicular crystals of *Rutile*, TiO_2. In the hope of getting more material, a final examination has been delayed.

FORT DODGE, WEBSTER COUNTY.

1. *Gypsum*, quite abundant. The most common is the gray, massive variety; it burns white. The snow-white gypsum from this region is nearly chemically pure, and shows needles of gypsum-crystals.

Separate selenite crystals, not very regular, but of the common arrow-head variety, have been examined from the same county.

2. *Celestine*, strontium sulphate, SrO_4S. — Bluish columnar; no fine crystallizations. Columns vertical; one to three inches long, the thickness of the deposit.

3. *Pyrites*, in globular masses.

4. WAVERLY, BREMER COUNTY.

1. *Calcite*, very clear, finely crystalized, hexagonal prism with the first obtuse rhombohedron $\frac{1}{2}R$ of 135°; diameter about $\frac{3}{4}$ inch.

Calcite Geodes from this place show a fine, almost silky lustre, and the rhombohedra of 83° ($\frac{2}{3}R$) and of 124° ($\frac{2}{3}R$) and also the common scalenohedron (R 3) together with the vertical prism.

The variety of *Anthraconite* is quite abundant at this place. It is very fetid when struck, has a fibrous to columnar, at times radiated structure; the free extremities of the crystals show the rhombohedron of 83° ($\frac{2}{3}R$). Associated with this Anthraconite is

Dogtooth spar, showing the common scalenohedron (R 3), some projecting fully half an inch.

With the first-mentioned hexagonal prisms of calcite occurs.

2. *Barytes*, bluish tables, containing small crystals of

3. *Pyrites*.

5. IOWA FALLS, HARDIN COUNTY.

1. *Calcite*, Scalenohedra (R3) and probably also (−2 R 3), terminated by the obtuse rhombohedron ½R. Often one-half inch long.

2. *Fire-Clay*, very pure; associated with a pure white *marly clay*.

The fire-clay consists of pale-reddish sand, 16 per cent; clay 84 per cent; containing water and volatile matters 34 per cent.

The white marly clay (much more plastic than the former) consists of:

Alimuna	27.85	
Silica	26.66	
Water	13.28	
Giving clay		69.79 per cent.
Lime	9.45	
Carbonic acid	7.42	
Giving calcium-carbonate		16.87
Hygroscopic water		12.00
Organic matter and loss		1.34
		100.00

6. VARIOUS LOCALITIES.

Alum from Albia, Monroe county.

Barytes from Elk Creek, Decatur county.

Barytes from Madison county, West Line.

Calcite from quarry opposite State University, at Iowa City, west bank of Iowa river. Very beautiful fundamental rhombohedra (R), also having their lateral edges bevelled according to R3, and finally this scalenohedron alone. In some specimens, one cavity may be filled with one of these forms, another cavity, an inch or so distant, contains the other form exclusively. The largest crystal, about two inches long, very regular, R3 and R combined.

Dendrites, from Anamosa, Jones county, on slabs; from Dubuque, on an orthoceras.

Epsomite, or epsom salt, efflorescent incrustations from near Burlington.

Flint, Madison county.

Hematite, near Keosauqua, Van Buren county.

Pyrites, pyritohedra, from James' coal-bank, 12 miles below Davenport.

Tutenmergel, very good specimens, from Webster county and from Page county.

Crystallites; these peculiar concretiona have been obtained from near Burlington and Iowa City. I think they are pseudomorphs after gypsum or celestine.

GLOSSARY.

The law authorizing the present geological survey provides that a glossary shall accompany each volume of reports.

Alluvial — That which is deposited by the washing of rivers along their course.

Amplexus — A genus of fossil corals.

Anticlinal — A given line or ridge *from* which the strata dip in both directions.

Arenaceous — Sandy, containing sand.

Argillaceous — Clayey, containing clay.

Aulosteges — A genus of fossil shells.

Axophyllum — A genus of fossil corals.

Black-haw — Viburnum prunifolium.

Black-locust — Robinia pseudo-acacia.

Bluff-deposit — The formation composing the Missouri river bluffs. See article on "Lakes of Iowa, past and present."

Beyrichia — A genus of minute fossils belonging to the same order with crabs and lobsters.

Borers — The larvæ of an insect that deposits its eggs upon the bark of the black-locust. When the larvæ are hatched they bore their way into the body of the tree in such numbers as to destroy it.

Bottom — A Western term, applied to the low, flat, alluvial lands so common along western rivers.

Coal-measures — A name for that assemblage of carboniferous strata which contains the coal.

Conglomerate — Gravel and sand consolidated into rock.

Cottonwood — Populus monilifera.

Cranberry — common — Vaccinium macrocarpum.

Cranberry — high-bush — Viburnum oxycoccus.

Crania — A genus of fossil shells.

Cretaceous — The name of a geological age. The chalk of Europe belongs to the cretaceous age.

Crustacean — Belonging to one of the animal sub-kingdoms. It embraces insects, lobsters, crabs, star-fishes, &c.

Cryptacanthia — A genus of fossil shells.

Cryptoceras — A genus of fossil shells.

Cythere — A genus of minute fossils, related to Beyrichia.

Drift — The formation which contains the boulders.

Drifting — Digging a way horizontally into, or within a mine.

Fauna — A term used in geology to signify the aggregate of all the animal remains.

Ferruginous — Containing iron.

Fault — A break in the continuity of strata by the lifting or settling of one part of them.

Geodes — Hollow, concretionary, stony masses, usually lined with crystals.

Grit — Coarse sandstone.

Habitat — The naturally chosen place of habitation or growth of an animal or plant.

Hydreionocrinus — A genus of fossils belonging to the same order with star-fishes.

Inoceramus — A genus of fossil shells.

In situ (latin) — In place.

Lacustrine — Formed by, or belonging to a lake.

Marlite — Limy clays, usually in indistinct layers; common among the coal-measure strata.

Meekella — A genus of fossil shells.

Micaceous — Containing mica.

Nautilus — A genus of shells, both fossil and recent.

Protozoan — belonging to the lowest branch of the animal kingdom.

Pinna — A genus of fossil shells.

Shaft — A perpendicular way into a mine.

Sphagnum — A genus of mosses, several species of which usually grow profusely upon peat-marshes.

Stratum (plural, *strata*) — layers, or beds of rocks.

Synclinal — A given line or longitudinal depression, *toward* which the strata dip in both directions.

Timber — A term applied in the West to all native groves or bodies of forest-trees.

Tomoceras — A genus of fossil shells.

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