VOL. III

ANNUAL REPORT
1893

IOWA,

GEOLOGICAL SURVEY.

VOLUME III.

SECOND ANNUAL REPORT, 1893

WITH

ACCOMPANYING PAPERS.

GEOLOGICAL CORPS:

Samuel Calvin, A. M., Ph. D., State Geologist.
Charles Rollin Keyes, A. M., Ph. D., Assistant State Geologist.
G. E. Patrick, A. M., Chemist.

DES MOINES:
PUBLISHED FOR THE IOWA GEOLOGICAL SURVEY.
1895.

PRINTED BY THE KENYON PRESS,
DES MOINES, IOWA.

GEOLOGICAL BOARD.

Special and Temporary Assistants.

H. Foster Bain	Coal
S. W. Beyer	Artesian Waters
E. H. Lonsdale	Clay
A. C. Spencer	Building Materials
A. G. Leonard	Lead and Zinc
W. H. Norton	Local Geology
J. L. Tilton	Local Geology
A. J. Jones	Local Geology
C. H. Gordon	Local Geology
F. M. Fultz	Local Geology
A. G. Wilson	Local Geology

N. E. Newman	Secretary
F. C. Tate	Draughtsman

CONTENTS.

LIST OF ILLUSTRATIONS.

FIGURE.

ADMINISTRATIVE REPORTS.

SECOND ANNUAL

Report of the State Geologist.

IOWA GEOLOGICAL SURVEY,
DES MOINES, December 29, 1893.

To Governor Horace Boies and Members of the Geological Board:

GENTLEMEN:—I have the honor to present to you a report of the operations of the Iowa Geological Survey for the past year. During the year 1893 progress has been made as rapidly as circumstances would permit. In laying out the general plan of the work of the Survey the State has been roughly divided into two halves, separated approximately by the Des Moines river. The eastern, or more correctly, the northeastern part, has been under the general supervision of the State Geologist. In the western, or southwestern portion, the work has been carried on under the immediate direction of the Assistant State Geologist, in whose report will be found a fuller statement of the operations in that quarter of the State. On account of the very great importance of the coal deposits of Iowa, when compared from an economic point of view with any other single mineral product, the energies of the Survey have been directed to their investigation as one of the principal lines of work. These investigations have been pursued both in the field and in the laboratory. The field work has been done by the Assistant State Geologist aided by other members of the Survey; the researches in the laboratory have been conducted by the Chemist. All geological phenomena connected with the accumulation and formation of coal, as well as its areal and stratigraphical distribution, have received deserved attention. But while the coal has been one of the chief objects of investigation, the clays, building stones, lime-burning rocks, soils, and other geological deposits of the coal-producing counties possessing an economic interest have not been neglected. Inasmuch, indeed, as the clay industries of Iowa are destined soon to take high rank as sources of public and private wealth, the clay deposits, particularly south and west of the margin of the Carboniferous outcrops, have been the subject of special investigation. Since, however, all the work in the southwest half of the State has been done under the immediate direction of Dr. Keyes, reference should be made to his administrative report for fuller details of what has been undertaken and what accomplished in the counties occupied by deposits of the Carboniferous and Cretaceous periods.

All the material requiring special chemical analysis has been examined by Professor Patrick. The extent and general character of this work is fully outlined in the accompanying report of the Chemist.

In eastern and northeastern Iowa, embracing the region occupied by Cambrian, Silurian and Devonian strata, the work has been pushed. I have personally given more than three months to active field work, beginning in Allamakee county in the extreme northeast, and carrying the observations into Winneshiek, Clayton, Fayette, Dubuque, Delaware and Jones counties. The greater portion of the time was spent in Allamakee. The other counties mentioned need to be examined somewhat more in detail before it will be possible to prepare a satisfactory final report on their geological resources. It is in Allamakee county that we find the earliest of Iowa's Paleozoic strata. Omitting for the present the Sioux Quartzite of Lyon county, with respect to the age of which a definite opinion cannot yet be expressed, it may be said that in Allamakee are exposed the foundations upon which all the geological strata of the state have been built up. The Cambrian and Silurian strata of northeastern Iowa pass under a large proportion of the state, probably under it all; and it so happens that some of them possess a very direct economic interest, even in counties where they are buried under many hundreds of feet of younger sediments. The artesian waters of eastern Iowa have their source either in the Saint Peter or the Saint Croix sandstones; and usually the first question asked by the prospector for natural gas has respect to the depth of the Trenton limestone beneath the point chosen for the location of his well. Allamakee county furthermore is unlike the greater part of Iowa, in that it lies within the driftless area. The effects of erosion during the immeasurably long period since this corner of Iowa was permanently elevated above sea level, have been nowhere obscured, as in other portions of the state, by a mantle of glacial detritus. The river valleys have been cut something like six hundred feet below the level of the adjacent divides, and the edges of the geologic strata have been exposed to an extent unapproached outside the driftless area. Some of the formations thus exposed yield building stones of a quality unexcelled in the Mississippi valley, some are rich in deposits of lead ore, extensive beds of iron ore occur in certain localities, ocher suitable for mineral paint is found in large quantities, while lining the valleys and spreading over even the highest hills are soils unique in origin and unsurpassed in fertility. For these reasons Allamakee county was properly selected as a typical area to be thoroughly studied and used as a standard with which adjacent areas might be compared. Certain geological questions can be studied and settled in Allamakee county better than elsewhere on account of the unusual facilities which the peculiar topographic features of the region afford. The determination of certain geological problems in one area at once affords a key to the explanation of geological phenomena elsewhere, and hence careful work in one locality is often the best and surest way of reducing the expense of pursuing satisfactory investigations in others.

Mr. H. F. Bain has spent considerable time in investigating the coal deposits east of the Des Moines river and along the Mississippi in Scott and Muscatine counties. He has also made some geological observations in Mahaska and Keokuk counties with the view of ascertaining more in detail, during the coming season, the economic resources of these districts.

Mr. A. G. Leonard spent several weeks in the lead and zinc regions of northeastern Iowa with the view of determining the extent of the present industry, and of learning more particularly the extent of the ore deposits. This work will be continued at the beginning of the coming season.

Mr. F. M. Fultz, of the Burlington high school, has made observations in Des Moines county with special reference to the distribution of the different geological formations. This work will form the basis of the more strictly economic work of the county. Incidentally he has also given attention to some unusually fine glacial scorings which have been discovered in this part of the state.

Partly gratuitously and partly at a nominal sum above expenses, Professor Wm. H. Norton, of Mt. Vernon, has given to geological investigation the time that could be spared from his work in Cornell college. His duties with the Survey led him to study in detail the geological structure and the points of economic interest in Linn county. His researches have brought out many things that will be of interest to students of geological science not less than to those who are interested in geological deposits only so far as such deposits may become sources of immediate or prospective wealth. Professor Norton has also collected information regarding certain artesian and other deep wells, and has given considerable time to the study of outliers of Carboniferous strata in counties belonging within the proper Silurian and Devonian areas of Iowa.

Volunteer Assistants.—In Delaware county, Professor A. G. B. Wilson of Hopkinton, has been devoting the time he could spare from his regular duties to geological work. His time is given freely without pay, and his investigations will furnish detailed information with regard to the geological resources of a very important area.

Professor F. D. Merritt has made notes on the geology of Fayette county, giving special attention to soils and Pleistocene deposits.

Dr. P. J. Farnsworth has collected data respecting the geological phenomena of the region about Clinton, in Clinton county. Professor F. M. Witter has rendered similar service in Muscatine. Mr. Fred M. Irish began work about Dubuque, but owing to press of other duties he was only able to continue his investigations for a few months. The work of all these volunteer assistants can be utilized to the great advantage of the Survey, and I desire here to make acknowledgment of my appreciation of their services; they have not only given their time without pay, but in most instances have generously borne their own expenses.

Mapping.—In Great Britain and on the continent of Europe accurate topographical maps are not only made the basis for geological mapping, but used in the field, they greatly facilitate the process of geological investigation. The United States Geological Survey has devoted a considerable share of its energies to the making of topographic maps as a basis for geological work. By a large proportion of geologists correct maps are regarded as absolutely essential to successful field investigation.

In Iowa elaborate topographical maps are out of the question. This work cannot be carried on extensively unless the scope and purposes of the Survey were very greatly enlarged. Work, however, in this direction has been undertaken on a limited scale. Three areas of the state, of rather small extent, have been thought worthy of mapping with the purpose of representing accurately in selected typical areas, embracing a limited number of square miles, certain geological facts of special importance.

The first of these areas, including about fifty square miles, covers the gypsum field about Fort Dodge. The field work in this area was done by Mr. E. H. Lonsdale and Mr. Fred Hess. The great commercial value of the gypsum made it desirable to ascertain the areal extent of the deposit, and to learn accurately its relation to other geological formations. Inseparably connected with these questions of areal distribution and stratigraphical relations are questions of its age and origin. Dr. Keyes estimates the value of the entire gypsum deposit, when manufactured and ready for use, at many millions of dollars. The importance of the area in question demands the employment of the best known methods of investigation in order that the highest attainable accuracy in the matter of geological facts and details may be secured.

The second area was chosen in Marion county, and the reason for selecting it lies in three important facts. First, the genetic history of the Coal Measures must be clearly appreciated before correct information regarding the distribution of the coal seams can be secured and recorded. Second, the rocks exposed along the Des Moines river in Marion county throw light of the highest importance on the history of the Coal Measure strata. Third, the geological structure of a very large area in central Iowa is such that the few square miles thus thoroughly studied, when described and illustrated, will enable the intelligent reader to appreciate the structure of many hundreds of square miles of which the smaller area stands as the typical representative. The topographical work in the Marion county area was done by Prof. C. D. Jameson who, with several of his students, gave his services without pay. The region is one unusually difficult to map, but its very roughness affords the desired facilities for studying its geological structure.

The third region mapped topographically is in northeastern Iowa. This region is representative of a large area in the eastern part of the state; but apart from its representative characters, its peculiarities of topography and geological structure as already described demand much more of time and expense than would be bestowed on an average area of similar extent. The topographic work was done by Mr. John G. Ratcliff, of Waukon, who furnished the map complete. The work, however, was undertaken by Mr. Ratcliff as a labor of love and not as a source of profit. His long residence in Iowa, and his experience as surveyor and railroad engineer rendered him familiar with every square mile of the area studied. He had run lines of levels in almost every direction throughout the region for prospective railroads, and all his notes were available without cost for the purpose of making the desired map. Upon undertaking the map he put special leveling parties in the field obtaining additional data for drawing the contours of the various ridges and ravines. He took a great deal of time from urgent private business to personally conduct investigations for the same purpose, besides which he gave all the time requisite for the office work on the map.

The work of the Survey is now inaugurated. A large share of the unavoidable preliminary investigations have been made. A few representative areas of special importance have been mapped. Data have been collected and the geological formations correlated over large areas that can now be worked up in detail with comparatively slight expense. In other words the foundation work that is preparatory to detailed investigation, and of necessity must come first has been done for a considerable portion of the state. Final investigations respecting coals, clays, building stones, and artesian waters are well advanced, as well as those relating to the geology and geological resources of a number of counties, and all this has been done notwithstanding the fact that the Survey has been in existence less than a year and a half.

During the past year the first volume of reports has been published and distributed according to law. This report although necessarily general in its scope has been received with expressions of favor, both within the state and beyond its limits. While contributing to our knowledge of the geology and geological resources of Iowa it at the same time reflects credit on the intelligence and progressive spirit of a state already distinguished for its exalted position in all that relates to the intellectual elevation of its people.

A second volume, less general than the first and more directly concerned with economic questions, is in the hands of the printer. The body of this report has been prepared by Dr. Charles R. Keyes. It relates wholly to problems connected with the resources of our great coal field, and I feel assured that like its predecessor, it will prove an acceptable contribution to the literature of the important subject with which it deals and will further help to place Iowa before the world in the position she deserves as a state highly favored in the quality and intelligence of her citizenship as well as in the value and extent of her geological resources.

From almost every county urgent requests have come for immediate investigation of geological resources. It has been impossible to grant such requests. That would have required a force ten or twelve times as great as the appropriation for the Survey could support. Furthermore, a due regard for economy requires that the work must be pursued according to some definite plan; each district of the State will be examined in time, and only when the details are all in will we be able to present fully the information which the people of each separate district are anxious to receive.

SAMUEL CALVIN,
State Geologist.

REPORT OF DR. CHARLES R. KEYES.

IOWA GEOLOGICAL SURVEY,
DES MOINES, December 29, 1893.

SIR:—I have the honor to submit to you the following report of the work done under my direction during the past year.

As it has been thought advisable to divide the state in a general way into two parts, an eastern, or more correctly a northeastern half and a western, or southwestern half, with the dividing line approximately coincident with the Des Moines river, I have confined my efforts chiefly to the latter district. Being in charge of the office it was necessary to assume duties which prevented somewhat the undertaking of as much field work as might otherwise have been possible had circumstances been different.

As stated in the last annual report, the organization of the Survey was not effected until late in July, 1892, when the Geological Board held a meeting to adopt plans by which operations could be begun. Although field work was commenced at once, two months or more elapsed before a suitable office and the necessary equipments for successful work could be provided. The short time remaining, before winter put a stop to all outdoor work, was occupied chiefly in making general reconnaissances upon which detailed work could be based when field operations were resumed in the spring. There has been, therefore, practically only one field season which could be devoted to the fundamental purposes of the survey.

During the several months of winter when investigations in the field had to be suspended entirely, the work of organization was continued. Plans for the field work of the ensuing season were mapped out, and the preliminary arrangements made. Forms of various kinds for records in the office were constructed. Circulars were prepared and sent out for giving and obtaining practical information in regard to the coals, building stones, clays and other useful mineral substances. Measures were taken to elaborate a system by which accurate statistics and facts could be collated concerning the different industries depending upon the natural resources of the state. Preparations were made for collecting, preserving and exhibiting to the best advantage the native wealth in what it is hoped will prove a permanent cabinet. Arrangements were effected by which the publications of the official surveys of the different states, of the federal government and of the various learned societies, would be received by the Survey, and there is now the beginning of a valuable reference library of geology. Besides an unusually large amount of routine work connected with the office and a heavy correspondence incidental to the organization of the Survey a considerable proportion of the matter published in the First Annual Report was prepared. The accumulated notes on the coal deposits were also written up as far as material would permit and the editorial work assumed.

As soon as the season opened field work was resumed. Several lines of work have been carried on in connection with other duties.

Coal.— Since the organization of the Geological Survey the coal deposits have received special attention and the investigations connected with them have formed one of the principal lines of inquiry. Work begun in the autumn of the first year was continued until the close of the field season. With the aid of several assistants, operations were resumed the following spring and continued without cessation during the year. During this period the coal seams and the strata associated with them were examined over most of the state. In the field work, in addition to personal examinations, assistance was rendered by other members of the Survey, and the notes bearing upon the subject which had been taken by them in connection with other duties were freely drawn upon.

The magnitude of the undertaking and the amount of labor which has been expended may be more fully appreciated when the fact is taken into consideration, that the area of the Coal Measures in Iowa is somewhat over twenty thousand square miles, and that isolated basins of Carboniferous outliers and the region bordering the productive Coal Measures which must be gone over in tracing the limits of the formation occupy fully five thousand square miles or more. The coal deposits are too extensive to be discussed in a single volume. The first part, now in press, forms a volume of 536 pages with 18 plates and 220 figures. It is somewhat preliminary and general in character and is intended to supply immediate demands for information. It is expected that later, studies on the nature and adaptabilities of the various coal beds, the most economical methods of mining the coal and the aerial extent of the individual seams will be carried on.

Gypsum.— Although regarded principally as a collateral subject, work in regard to the gypsum beds of Iowa has been continued. The investigation of the deposit, as exhibited in the vicinity of Fort Dodge, may now be regarded as nearly complete. The area covered by the gypsum contains approximately twenty-eight square miles. The main body varies in thickness from two to thirty feet or more, with an average of perhaps sixteen feet. The Des Moines river and some of its tributaries have removed a considerable portion of the gypsum, yet there remain quantities sufficient to supply all demands for many years to come. At the lowest estimate the mass of gypsum which is found available in the region is not less than sixty millions of tons. The value of the product when brought to market at the present figures would be more than a hundred and fifty millions of dollars. The gypsum production has greatly increased during the past year and now amounts to fifty thousands of tons annually. The area has recently been mapped, in relief, by Mr. E. H. Lonsdale and Mr. Fred Hess, and a map has been prepared showing the distribution of the deposit, and its relation to the associated formations. A complete report on the subject is now ready. In it will be discussed all the information on the subject which is of practical importance.

Sioux Quartzite.—This is a very hard thoroughly vitreous rock whose occurrence has long been known in the extreme northwestern corner of the state. It is locally called Sioux "granite." It differs, however, from ordinary granite in not having in its make-up the more destructable constituents found in that rock and is consequently much more durable. Heretofore it has been known to extend over only a few acres in this state. Recent visits to the locality have shown that the rock covers a number of square miles at least. There are, therefore, in the state inexhaustible quantities of the most durable building stones. Its beautiful color and the ease with which it is quarried has caused it to become quite popular, and its use throughout this and neighboring states is rapidly increasing. Not only is it of importance economically, but its interest from a scientific standpoint is also great. A little additional work in the region will enable a full discussion of the subject to be made ready soon.

County Work. — Detailed mapping and investigation has been undertaken in several counties. Those which have been the subject of special personal consideration during the past year have been selected on account of work which had been previously done in them in person. By extending the investigations the information obtained years ago may be utilized to great advantage.

In Des Moines county there was finished up some work which was begun several years ago during a residence at Burlington. Much valuable data was brought together then and certain areas carefully mapped. With some special attention to the subject from a more strictly economic point of view, the report on the county has been completed. During the past year Mr. F. M. Fultz, of Burlington, has been supplementing the information which had already been acquired before the organization of the Survey and looking up certain points which needed further consideration. With some additional personal work which will be done early during the coming season it is expected that a report on the entire county will be ready for publication before the end of another year.

Another county which presented similar favorable conditions was Marion county. The greater part of the geological structure of this region had been carefully worked out some years ago during the construction of a detailed section of the Coal Measures in Central Iowa. The principal line of investigation was along the Des Moines river which traverses Marion from northwest to southeast. During the past year supplementary work has been taken up in this region. Professor Jameson has made a topographical map of a selected area, which will be used in constructing a relief model illustrative of the structure and arrangement of the coal-bearing strata of Central Iowa. The entire county is now practically mapped as regards the distribution of the different formations. Many facts relating to the economic resources have been brought together. A report on this district is in preparation and the work is well towards completion.

Webster county is another district which afforded very favorable opportunities for taking up the work of the district as a whole. When the examinations of coal and gypsum were undertaken in Webster county, full notes were made respecting the other deposits of economic value. The collateral work thus finished probably embraced nearly half of the entire amount necessary to be accomplished in order to prepare a full and complete report on the natural features of the county. The mapping is practically finished.

Mr. S. W. Beyer has undertaken to investigate artesian waters. The subject involves not only the collection of data concerning the depth of flowing wells now existing in the state, but also the preservation of records of all deep borings and prospect holes, as well as information regarding mineral springs. Among the chief points considered in each case are the nature and thickness of each stratum passed through in making the boring, the depth and lithological characters of the water-bearing stratum, the rate of flow and the temperature of the water. An examination of the drillings is made wherever possible. Special attention has been given to the fundamental conditions regarding water supplies of this kind as applying particularly to Iowa. The borings are all located on maps of a suitable scale as fast as the records are obtained. By means of connected sections the water-bearing strata may be located accurately for each district. The depth at which the principal horizons should be encountered may thus be calculated approximately for any particular place. Furthermore, the limits of the different areas which will supply flowing wells may be determined. The preparation of the report on the work done is now well advanced towards completion.

In addition to the investigations on the artesian waters some local area work has been also taken up. The territory examined has Story county for a center. The principal work in this direction has been done in Boone county. The greater part of this district has been gone over and detailed information obtained in regard to its mineral wealth. In Marshall county work has also been started and considerable progress made.

Mr. H. F. Bain, in addition to other duties which have been referred to, has spent a part of the past season in investigating the coal deposits in certain of the counties lying in the southeastern part of the state. Mr. Bain also paid particular attention to the resources of Appanoose county. He will probably continue these investigations with the object of making a complete report on the district. At the close of the field season several weeks were devoted to the study of the Cretaceous deposits of northwestern Iowa. A detailed geological section was made along the Sioux river from Sioux City to the extreme northwestern corner of the state. One of the chief results of this work, besides making out the stratigraphical relations of the different beds, was the discovery in Iowa of the Fort Pierre member of the Cretaceous. From the clays of this formation and the chalks of the Niobrara which are found directly beneath, a good grade of Portland cement may be manufactured. Tests on these materials are now being made. While in this portion of the state the relations of the Sioux quartzite were also studied.

Mr. E. H. Lonsdale has undertaken an investigation of the clays. During the field season he has visited all the industries based upon clays in the western half of the state. Examinations of the deposits and the methods in use were noted. During the coming season it is expected that a similar examination of the clays will be extended over eastern Iowa. An account of the work done is already well advanced. A similar statement of operations conducted during the coming season will also be prepared. With this account of the clay industries will be incorporated a full description of the clay deposits of the entire state and the geological formations in which they occur. The properties of the different clays and all facts of economic value pertaining to the working and preparation of them will be fully discussed.

Previous to the beginning of the clay work, Mr. Lonsdale investigated the material resources of Montgomery county and has in preparation a comprehensive report. From this county as a center, investigations were also pushed into the neighboring counties and many valuable notes obtained.

Mr. A. C. Spencer, began, early in the summer, to study the coal deposits and general geological features of certain counties in southeastern Iowa. Later in the season he spent several weeks in Webster and Humboldt counties in tracing the boundaries of the Lower Carboniferous limestones and the Coal Measures.

During the summer months Mr. A. J. Jones worked in the northern part of the Iowa coal field studying the coal deposits and the associated clays, the latter with special reference to their adaptability for the manufacture of the various kinds of clay products.

Mr. C. H. Gordon, formerly of Keokuk, devoted two months time to making out the geological features and economic resources of Van Buren county. A complete report of this district is now nearly completed. Several weeks were also put in in Lee county in the continuance of lines of work begun during several years residence.

Prof. J. L. Tilton, of Simpson College, Indianola, has given such attention to field work in Warren county as his other duties would permit. One of the principal lines of work taken up was the construction of a detailed section along Middle river from Ford to Winterset in Madison county. The object was to connect accurately the Lower Coal Measures, where well understood, with a typical Upper Coal Measure section and at the same time to ascertain the thickness of the strata. Preliminary work having for its ultimate aim the determination of the useful deposits of the county was also begun.

In the office, Mr. F. C. Tate has acted as draughtsman and has been engaged continuously in preparing maps and illustrations for the reports as they have been made ready for publication. Miss Nellie E. Newman has acted as secretary to the Survey. Respectfully submitted,

CHARLES R. KEYES,
Assistant State Geologist.

TO PROF. SAMUEL CALVIN,
State Geologist.

REPORT OF PROF. G. E. PATRICK.

IOWA AGRICULTURAL COLLEGE,
Ames, December 29, 1893.

SIR:—I have the honor of presenting to you the following report of the work done by the chemical division of the Survey during a portion of the past year.

The work was begun in a small way in May (1893), analysis of a few samples—as many as were sent in—being made during that and the two following months; but regular, consecutive work was not begun until toward the middle of August, when the analysis of the coals of the state was taken up.

COAL ANALYSES.

This constitutes the greater part of the chemical work thus far done. The samples were collected by others and were sent to me by the Assistant State Geologist, Dr. Keyes. The methods of analysis are given below and the results obtained have been reported to Dr. Keyes, and will doubtless be included in his report.

METHODS EMPLOYED IN THE ANALYSIS OF COALS.

The samples having been finely pulverized and tightly bottled, the several determinations are made as follows:

MOISTURE. Five grammes, spread thin on a watch glass, are dried for one hour at 103 to 108 degrees C. The loss is reckoned as moisture.

VOLATILE COMBUSTIBLE MATTER AND COKE. Four grammes of the coal are heated in a closely covered platinum crucible over a low Bunsen flame until the volatile matter is nearly expelled, then over a blast lamp for one and a half minutes. The loss, less moisture, is the volatile combustible matter. The residue in the crucible is the coke.

TOTAL SULPHUR. Eschka's method, modified by substituting $K_2 CO_3$ for $Na_2 CO_3$ and by increasing the proportion of the flux. (Hundeshagen, Jour. Anal. Chem., v. VI, p. 385.)

SULPHUR IN SULPHATES. Calvert's method: two grammes of the very finely powdered coal are heated with a concentrated solution of sodium carbonate in the steam bath, with frequent stirring, for at least ten hours—longer if needful for complete extraction; after filtering, SO_3 in the filtrate is determined as usual.

SULPHUR IN SULPHIDES AND ORGANIC COMPOUNDS. This is found by deducting the sulpur in sulphates from the total sulphur.

ASH. Three grammes of the coal are heated gently over a low flame until smoking ceases, and then at a red heat until combustion is complete.

During the coming season the heat values of these coals also will be determined by means of a calorimeter; and, at the request of Dr. Keyes, portions of all the samples analyzed have been preserved for this purpose.

MISCELLANEOUS.

Under this head are included analysis of limestones, fire clay, sandstone, glass sand, and other materials named below. All of these samples were sent me from the office of the Survey, by the Assistant State Geologist. All samples received to date have been analyzed and reported upon.

SUMMARY OF ANALYSES.

The list of samples analyzed to date is as follows:

173 samples of coal.
2 samples of alleged ironstone.
6 samples of limestone.
1 sample of bituminous shale.
1 sample of fire clay.
1 sample of sandstone.
1 sample of glass sand.
1 sample of cement or stucco material.

SOIL INVESTIGATIONS.

Work in this line has progressed but little farther than the collecting of samples of soil from various parts of the state; no analyses have as yet been made, but this work is now being entered upon.

To the chemist was intrusted the collecting of the soil samples, as well as their analysis.

In investigating the soils of a state it is obviously a matter of first importance, as well as one of considerable difficulty, to secure for laboratory study samples that are truly representative of rather large areas of country, rather than merely of small fields or single quarter sections. To be able to select localities to furnish such representative samples, collectors must be well acquainted with the soil of extensive areas in various parts of the state. For traveling collectors to obtain this acquaintance would involve the expenditure of much time and money. These considerations led the writer to the thought of enlisting the aid of intelligent and painstaking farmers, already known to him as such, through association in certain experimental work in which the farmers have co-operated with the Experiment Station.

To about sixty of these farmers, located in nearly as many counties, the following circular letter was sent:

IOWA AGRICULTURAL COLLEGE,
LABORATORY OF AGRICULTURAL CHEMISTRY.

DEAR SIR: The Directing Board of the State Geological Survey have made arrangements whereby, under authority of the Board of Trustees of the College, a considerable number of soils of the state are to be submitted to chemical analysis, at this laboratory and under direction of the writer. Pursuant to this plan, Professor Calvin, Chief of the Survey, has requested me to secure for this purpose samples of such soils as it seems to me desirable to investigate.

The most economical way of getting these samples is through correspondence, and I naturally turn for assistance in this matter to the farmers, and others, who have already shown their interest in the scientific study of agricultural problems by co-operating with me in the study of sugar beet culture in Iowa.

My purpose in this letter is to ask you if you will assist in the present work, by collecting samples of the representative soils in your vicinity and sending the same to me by express — charges to be paid at this end. If you reply (by enclosed postal) that you will, I will immediately send you printed directions telling exactly how to proceed in taking the samples. Do not collect any until you receive these directions. The labor of collecting the samples will be but trifling, as I shall only wish to study the *best* and the *poorest* soils that occur, over any considerable area, in your vicinity. Those who collect samples will receive credit therefor in the Report, when published; and what is more, will feel the satisfaction of having helped in a good cause.

A reply by return mail will be greatly appreciated. Yours truly,

G. E. PATRICK.

As expected, responses came promptly from nearly all expressing a willingness to give the desired aid. To each thus responding, the following circular was immediately sent:

DIRECTIONS FOR TAKING SOIL SAMPLES.

The soil selected for sampling should be as far as possible in its natural condition, not modified by recent applications of manure. The purpose is to obtain a sample representing the *best* and another representing the *poorest* soil that occurs *over a considerable area* in your vicinity — i. e., in your own or adjoining townships.

Having selected a field or area, of several acres' extent if possible and apparently uniform in character, *that can be taken as representing either type* (the best or the poorest soils, using those terms as just explained) proceed as follows to take samples from five (5) different spots, quite widely separated within the field or area — the five samples to be subsequently mixed together to produce a true average sample.

Remove decaying grass, leaves, etc., from the surface. Then take the sample in form of a block or cylinder, with vertical sides, down to a depth of nine (9) inches by measure — provided the true soil or "surface soil" extends to that depth, as it does nearly everywhere in Iowa. If in any case it should not extend to that depth — as shown by a marked change in color and character — then take the sample only to the depth of said change, measuring and noting down the depth. But in no case take the sample to less than six inches' depth, however shallow the soil may be, for above that depth it cannot escape the plow. * * * As the most practicable way of taking a sample, I advise using a common spade, taking care to dig down *vertically* and to take for the sample *all* that comes from the hole.

The object of taking five samples is to eliminate local variations and thus secure a true average of the field or area.

Mix the five samples together very thoroughly, on a large cloth or stout paper, crushing the larger clods with the fingers. When the mass is thoroughly mixed fill from it one of the paper bags which I send you by this mail, tie the bag at top as though it were of cloth, and attach a tag bearing your own name (the collector's) and also the word Best or Poorest, as the case may be. * * * The aid which you will thus render in promoting the chemical study of Iowa soils will be greatly appreciated by the undersigned and will be duly credited in the report of the work when published. Yours truly, G. E. PATRICK,
Agricultural College, Ames, Iowa.

About two weeks after this circular was sent out the ground became frozen, rendering the collection of samples somewhat difficult; this probably accounts for the fact that only twenty-eight of the farmers have sent in samples — the others will probably do so in the spring. These twenty-eight sent fifty-eight samples of soil, from twenty-six different counties of the state. Following are the names, addresses, and number of samples sent by each:

J. F. Grawe, Waverly, Bremer county, two samples.

Geo. Gadbois, Salix, Woodbury county, two samples.

Jas. Sullivan, Stuart, Guthrie county, two samples.

Fred Direlbess, Logan, Harrison county, two samples.

A. M. Bingham, Jessup, Buchanan county, two samples.

W. H. Steimel, Eagle Center, Blackhawk county, two samples.

J. Wernli, Le Mars, Plymouth county, two samples.

Jos. Beath, Corning, Adams county, two samples.

S. S. Beers, Judd, Webster county, two samples.

David Wild, Springville, Linn county, two samples.

E. F. Iseminger, Marathon, Buena Vista county, two samples.

J. M. Lehman, Cumberland, Cass county, two samples.

W. C. Goodrich, Lehigh, Webster county, two samples.

Jas. Pempble, Wapello, Louisa county, two samples.

C. C. Plater, Red Oak, Montgomery county, two samples.

W. O. Tice, Monroe, Jasper county, three samples.

John Barnard, Muscatine, Muscatine county, two samples.

S. H. Tally, Belleville, Jefferson county, two samples.

H. Gadmer, Quinby, Cherokee county, two samples.

H. A. Saunders, Grand Junction, Greene county, two samples.

John Klein, Keota, Keokuk county, two samples.

C. D. Miller, Denison, Crawford county two samples.

D. D. Ronan, Waukon, Allamakee county, three samples.

J. O. Overholt, Havelock, Pochahontas county, two samples.

L. Skeels, Wallingford, Emmet county, three samples.

T. H. Drake, Fruitland, Muscatine county, two samples.

S. G. Tyrrel, Riceville, Mitchell county, one sample.

Judd Storm, Nevada, Story county, two samples.

Work upon these samples is now begun, and the results will be reported in due time. Respectfully,

G. E. PATRICK.

TO PROFESSOR SAMUEL CALVIN,
State Geologist.

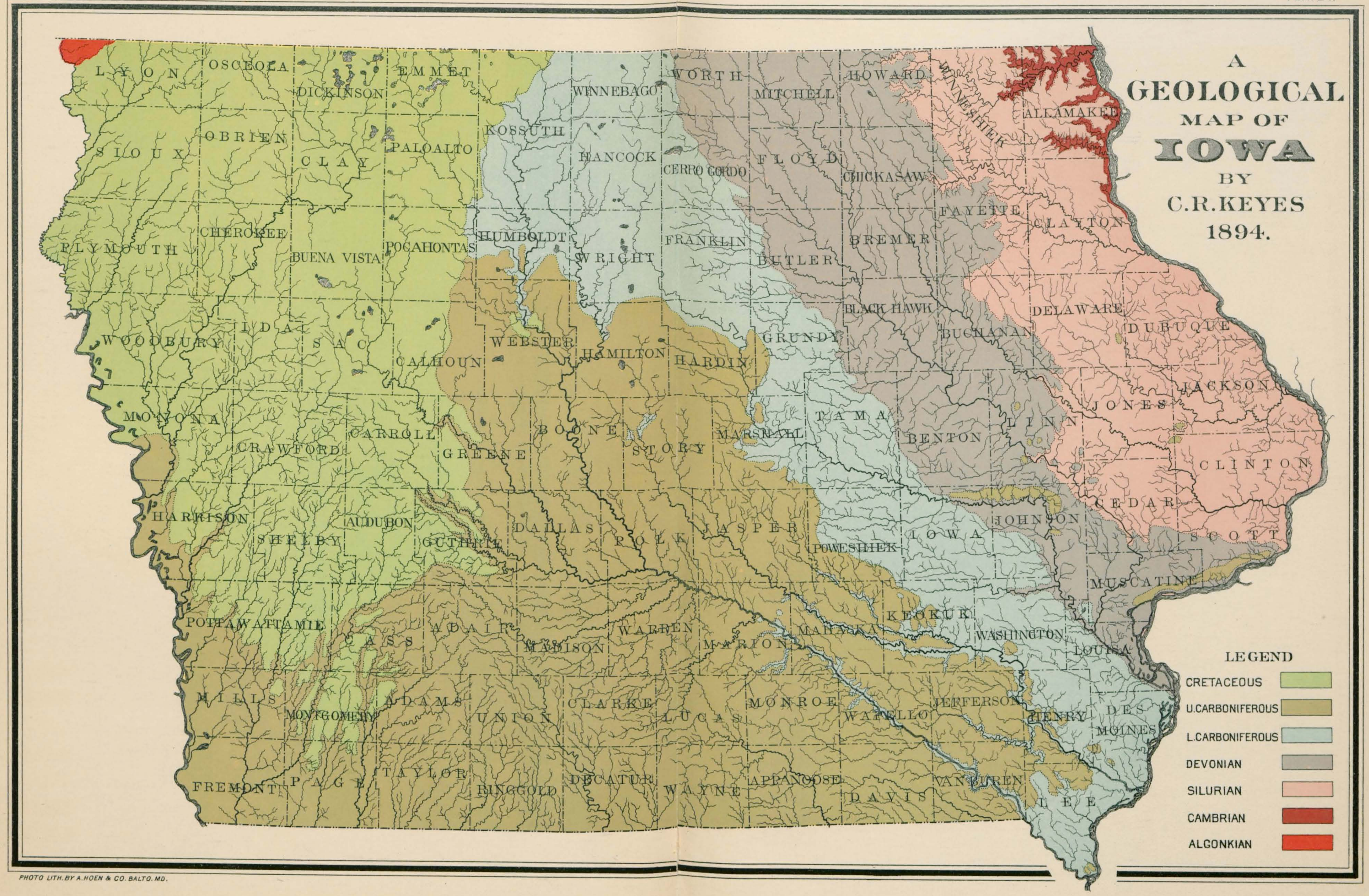


PHOTO LITH. BY A. HOEN & CO. BALTO. MD.

WORK AND SCOPE OF THE GEOLOGICAL SURVEY.

BY

CHARLES ROLLIN KEYES.

WORK AND SCOPE OF THE GEOLOGICAL SURVEY.

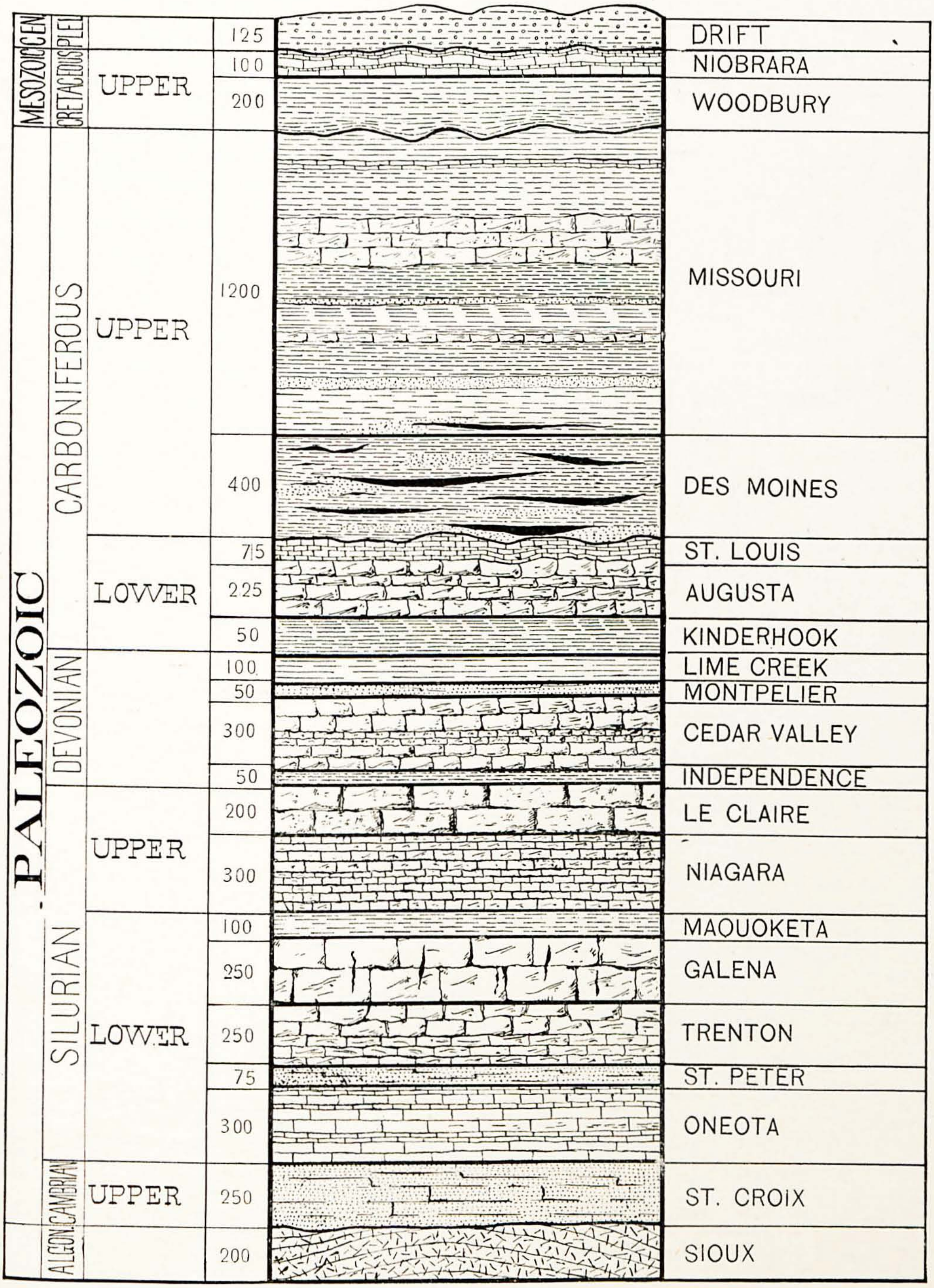
CHARLES ROLLIN KEYES.

CONTENTS.

ESTABLISHMENT OF THE GEOLOGICAL SURVEY OF IOWA.

The people of Iowa, through their representatives at the last session of the General Assembly, authorized a geological survey of the State. Probably at no period in Iowa's history had she felt more the need of a thorough economic investigation of her native wealth. The survey contemplated was not an investigation such as was vaguely conceived by many, but one broad in its scope and far-reaching in its workings, one whose primary aim was to bring before the public the State's natural products, to encourage its material development and to invite the investment of outside capital. Indeed, it had long been a matter of general regret that a commonwealth so happily supplied with boundless natural riches should have no official information concerning them to which either her citizens or the public at large could turn.

The law establishing the Geological Survey provides for "a complete survey of the natural resources of the State in all their economic and scientific aspects, including the determination of the order, arrangement, dip and comparative magnitude of the various formations; the discovery and examination of all useful deposits, their richness in mineral contents, and their fossils; and the investigation of the position, formation and arrangement of many different ores, coals, clays, building stones, glass sands, marls, peats, mineral oils, natural gas, mineral and artesian waters and such other mineral materials as may be useful, with particular regard to the value of said substances for commercial purposes and their accessibilities; also, the careful noting of the characters of the different soils and their capacities for agricultural purposes; the growth of timber and other scientific or natural history matters that



GENERAL GEOLOGICAL SECTION OF IOWA.

may be of practical importance and interest." The law is liberal in its application, comprehensive in its requirements, practical in its bearings. Not the least valuable of its measures is the provision for the diffusion of useful knowledge among the citizens of the State. The demand for authoritative information of this kind has long been so urgent that it is a matter of much surprise that steps in the proper direction were not taken years ago. To be sure, such a movement has been twice started and twice rendered inactive, first in the fifties and again more than a quarter of a century ago. Both attempts were hurried reconnaissances — one of the eastern half of the State, and the other of the western portion. Being thus merely preliminary, the results were necessarily very incomplete. Moreover, during the past two decades much information concerning the mineral wealth of Iowa has accumulated, and when brought together in a connected way with the results of other investigations it will be of the greatest value. In the same period geology itself has made gigantic strides, not only scientifically but economically.

The great interest now shown in the examination of the natural resources of Iowa is not confined wholly to the people of the State. There are probably as many persons living without the borders of Iowa as there are within them who are keeping themselves informed as to what is being done by the Survey. Indeed, the work has met with as universal favor and appreciation abroad as at home. As was well stated not long ago in one of the leading newspapers, Iowans are, as a rule, too busily occupied with their own affairs to go much out of their way to get information in regard to that which does not connect itself directly with the advancement of their own material interests. The benefits of the Survey appear to some people to be only indirect; hence, there is often by these persons a lack of proper appreciation of the aims and ends of the work. As the real facts become known and the citizens become more and more acquainted with the doings of the Survey it is extremely rare that a warm interest is not manifested. This solicitude for the carrying out and completion of the investigations begun is not shown in Iowa alone. As the published reports are made accessible they are reviewed and talked about, more or less, in almost every country of the globe.

In connection with the report on the progress of the Iowa Geological Survey, it has been thought desirable to present in some detail the general scheme of operation. As will be readily seen, the entire plan of the Survey is practical in its aim. While thoroughly economic in all its aspects the work is so arranged that it may be carried on in a manner perfectly systematic and scientific. At all times the investigations are conducted in a way which, it is thought, will best serve the interests involved.

OBJECT OF THE GEOLOGICAL SURVEY.

When a merchant wishes to know exactly how his business stands he takes an inventory of his possessions. A state in establishing a geological survey has also in mind an inventory of her possessions; that is, of her natural products, all those mineral substances which may be made to serve the purposes of man. But a geological survey is very much more than a simple inventory—a mere taking account of stock. It not only lists the various minerals, but locates them accurately, investigates their qualities, extent and accessibility, notes their particular uses and value, and suggests improvements in the methods of obtaining and treating them for commercial purposes. In order that the information may be readily and accurately interpreted the determinations and facts are recorded and explained on suitable maps or in the descriptive notes which accompany them.

In the establishment of the Geological Survey it was manifestly not the purpose of the legislators, as many people suppose, to replace by state work individual testing and investigating, but rather to encourage and supplement personal efforts and greatly lessen the chances of failure.

Among the general objects to be attained for the State through the work of a completed geological survey may be mentioned:

(1) The provision of a suitable foundation for detailed and intelligent search for mineral wealth. One of the chief benefits resulting from this work is the limitation of different mineral bearing areas in which prospecting may be profitably undertaken. The necessity of this course has appeared all the more urgent as the work of the Survey has progressed. It may be a matter of considerable surprise to learn that carefully made estimates show that more money has often been wasted in many counties in a single year in ill-advised and poorly conducted efforts to discover coal and other minerals than would annually support a systematic investigation of the entire State. Numberless abandoned diggings are met with, most of which mark fruitless efforts to obtain minerals in places where success is as utterly hopeless as could be imagined. All this useless expenditure of capital and labor might have been largely avoided had some authoritative information concerning the geological features of the particular localities been accessible.

(2) The assurance of permanency in the development of resources already known. Means will be provided

beforehand by which, without encountering repeated failures and inconveniences, each one may know how to turn his discoveries to best account, how to work the deposits to the best advantage and how to prepare the product in the most suitable manner for market. The properties of the different substances and the uses to which they may be put having been determined practically, the further advancement of the dependent industries is greatly simplified. On the completion of the work on any subject all information possible is brought together, so that when a person engages in any mining enterprise or business connected with the natural resources of the State he can hardly fail to find in the particular report something which will greatly assist him in his efforts and prevent useless waste of time and money.

(3) The establishment of an official guaranty respecting the natural wealth of the State. Information given by disinterested persons concerning the State's possessions is always regarded as more trustworthy than when imparted by private individuals. Citizens at home as well as abroad have confidence in making investments and feel that they are not entering into mere speculative fields.

(4) The formation, on a scientific basis, of a standard by which the geological features of the State may be compared with those of other districts. There is a wide demand for something of this kind for purposes of instruction in schools and colleges. Text books commonly used consider only the principles of science; the reports of the Survey supplement this outline by giving detailed information of local application.

(5) An advancement of the agricultural interests of the State. This is more fully considered elsewhere under the subject of soils.

WHAT IS TO BE EXPECTED OF THE SURVEY.

Popular opinion differs widely as to the proper functions of a geological survey. Just what should be expected of the organization, in accordance with the evident intent and expressed purpose of the law establishing the Survey is manifestly not fully understood by many persons. It, however, has been best stated perhaps by the editor of the Iowa State Register, in an editorial which appeared in the issue of January 31, 1892, when the bill for the Geological Survey of the State was pending before the General Assembly:

"A glance at what other states are doing to encourage the development of their mineral wealth forcibly impresses us that great advantages are to be derived from a thorough investigation of our own natural resources. Nature has given us one of the richest domains in the world. She has done much; as yet we have done but little. Fortunately, however, our farmers, mechanics, miners and legislators are beginning to see what geological surveys have done for other states and countries, and what a similar organization can do for our own. Geology comprehends all the facts ever known respecting the rocks and minerals of the earth, and all the uses to which they have been applied. It has treasured up the agricultural capacities of every soil and the best means of developing those capacities, yet many persons have doubted whether such a science can aid in developing the great resources of peerless Iowa.

"Now, how will a geological survey help in this matter? If properly conducted, it cannot fail to develop the mineral resources of the State, and place our mining interests on a more permanent basis, by inviting capital and securing systematic and profitable operations.

"It will increase our mechanical and manufacturing interests by pointing out the raw materials and the facilities for converting them into articles for domestic and foreign trade.

"Agriculture will be advanced by the investigation of the structure and the chemical properties of the soils; and the results will enable us to determine the modes of culture necessary to sustain and to increase their productive energies.

"Our artesian waters will be thoroughly understood, so that anyone in the State by simple calculations may determine within a few feet how far he will have to bore to obtain good water, and how much of a flow he will secure.

"The water powers of every stream will be definitely known, and the conversion of this energy into electricity will eventually give us light and heat for the whole State.

"New coal fields cannot fail to be developed, and the limits of the present ones will be definitely made out, so that the great sums of money now annually expended uselessly in vain searches for this mineral in portions of the State where it cannot possibly occur may be saved and turned into other channels.

"Our building stones will be thoroughly tested and carefully located, for without the slightest doubt Iowa has as good building stones as can be found in this country.

"The clay industry will receive a great impetus. Instead of importing large quantities of brick and other clay products from other states, we would be exporting to all the neighboring districts. The aluminum clays would also receive careful attention.

"Commerce will receive a new impulse from the increased products of the farm, the mine, and the workshop.

"Who can estimate the increased value of the land in the State when all the natural wealth has been pointed out. If we can judge at all from our neighboring states there is little doubt that a systematic investigation, such as is suggested, would greatly increase the value of the lands over large tracts, amounting to many times the expenditure."

It is not, therefore, to be anticipated that the work of the Survey is to be a continuous series of startling discoveries of precious metals, but rather a careful investigation of those things which, as in England, are infinitely more valuable and compel the world to pay tribute in gold and silver.

GENERAL PLAN.

The efforts of the Geological Survey are directed primarily to a consideration of the mineral resources of the State from the standpoint of the utilitarian. In the progress of the work there come to be recognized two classes of operations; the one somewhat general in its character; the other more specific. The first may be called the subject work and the second the areal work. In the former it is designed to take up each particular topic, as coal, clay, building stone, or soil and to consider the deposits as a whole for the entire State. In contradistinction, areal work has for its object the consideration of all useful mineral deposits of limited districts, as a county or other convenient area, particular attention being given to local details. There are, in addition to the two principal classes here mentioned, two other lines of investigation, which together might properly form a third class.

SUBJECT WORK.

Mineral deposits are not limited by modern political boundaries. Each kind of ore, clay or other natural product dug from the earth belongs to some particular geological formation; that is, it is found at some horizon or level more plentifully than at others. Thus, one formation is abundantly supplied with coal; another with ores of zinc or lead; a third with gypsum, or materials for the manufacture of cements; and others with still different substances of economic value. Each is found in a particular geological zone and rarely or very sparingly elsewhere. Only within certain districts would search for a given substance be successful; outside of these areas no amount of prospecting would ever disclose the material sought.

An investigation of any special mineral substance necessitates a careful consideration of the entire subject. At the outset a clear understanding of the geological structure of the rocks containing it is of prime importance. The localities where it occurs require description. The arrangement, relations and extent of the deposits must be defined; the origin and properties discussed; the accessibility and value determined. The uses of the substances, the nature and status, both present and probable future, of the industries connected should be fully considered. A report on each special subject must, therefore, be comprehensive in character and concise in statement. The work cannot be weighed down with all the details of only local interest, as this would extend the account far beyond the space that could be alloted to it. Information of an entirely local character may be recorded on maps or described in accounts of areas.

Subject work is thus quite prominent in dealing with all the useful mineral substances found in the State. It necessarily includes two classes: the principal topics, which are the larger subjects, each requiring a very considerable period to finish, and the subordinate subjects which comprise numerous minor points. The former of course are taken up first. While they are being investigated facts are continually accumulating in regard to the collateral subjects which, with a little special attention later, will ultimately be brought together, forming valuable additions to what is already known concerning the resources of the State.

The advantages of having the work done according to topics are numerous:

(1) Since different mineral substances, as already stated, are rarely confined to single counties, but usually extend over several and sometimes many such districts, it is necessary to investigate each kind of deposit in its entirety. It may then be told with certainty how and to what extent the several locations will be benefited by the development of such minerals.

(2) The general discussion of the properties, uses and magnitude of each deposit may be investigated and the results published long before all of the work in the counties containing the particular substance can be finished.

(3) If lasting results are to be obtained more or less work of general character is always necessary in order to interpret intelligibly the phenomena observed in any one county and to connect them with those seen in neighboring districts.

(4) It enables the investigations to be made by experts or specialists in different lines. The results accomplished are therefore much more satisfactory, more accurate and far more valuable than if obtained in any other way. Furthermore, much less time is required and the cost is consequently less.

(5) As the majority of people are interested in one industry only, the information they most desire is brought together. The miner wishes to be informed about coal, the quarryman, architect or engineer is interested in building stones; the brickmaker desires information regarding clays; each wants to know in regard to his special field and cares little or nothing about the others.

AREA WORK.

Area work has for its object the consideration of the economic resources of particular districts, as already explained. Its direct purpose is to satisfy constant and ever increasing demands for information in regard to given localities. The desire to know about the mineral products of each particular neighborhood is so general throughout the State that full details are required concerning every substance which is or is likely to be of value to the land owner or occupant of the territory. Probably one-half of the people of the State seek this local information.

PUBLICATION OF RESULTS.

One of the cardinal points in the investigation of the natural resources of the State is the placing of practical information in regard to the various deposits before the people as rapidly as possible and at the same time in a measurably complete form. Therefore in making public the results of the geological survey of the State the common practice of transcribing field notes and of making incoherent preliminary reports on different subjects has been discarded. The general plan of field work is of course arranged so as to accord with the ultimate presentation of the results in printed form. Hence, two general divisions are recognized in publication, as in the field work, though their distinctions may not be so obvious at first glance.

A single series of publications has been adopted. All the numbers of the series will be uniform in general style, in binding and in size. As nearly as possible each volume will contain about 500 pages. There will be, however, one exception, the final State atlas. Although numbered consecutively the separate volumes are in no way dependent upon any which have gone before or any which may follow. Each may therefore be regarded as complete in itself. This plan enables one volume to be devoted to one topic and another to another. It allows all information on one subject to be brought together. It permits the placing of results before the public as rapidly as the investigations are completed, without long and vexatious delays. A particular deposit extending into a number of districts may thus be studied thoroughly and a report made without waiting for the entire work in the several counties to be finished. Similarly, different counties or areas may be reported upon before any special deposit is examined over all the State. In some cases the work requires a very much longer time to complete than in others; and it is often very desirable, especially with the larger subjects, that some information be made accessible before the appearance of the final report. When the work on any particular topic has reached a more or less advanced stage of completion some special phase of the subject may be briefly discussed and emphasized in advance, but the article is always made complete in itself, depending neither upon anything which has been nor which is to be published.

The appearance of the results of investigations concerning different deposits and areas is further hastened by carefully prepared articles of general interest which are given to leading periodicals and to the newspapers of the State.

SCHEME OF WORK.

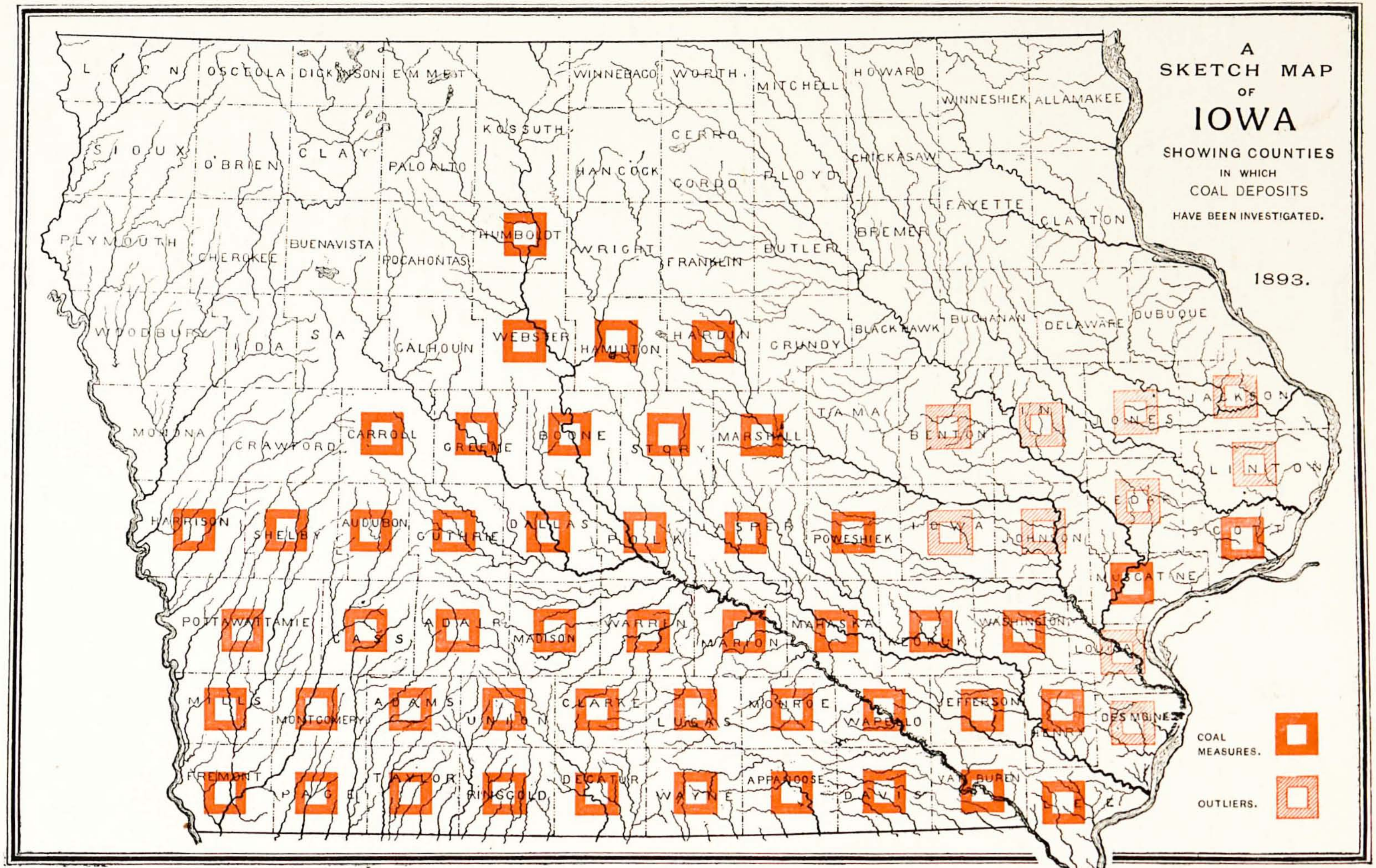
As the investigations of the Geological Survey go on the work resolves itself into three general categories: (1) the work in progress, (2) work taken up incidentally, and (3) work not yet begun. To these a fourth class may shortly be added, viz.: work completed.

Work in Progress.

As already explained the general investigations regarding the natural resources of the State run along parallel lines. To these the terms subject and areal work have been given. While covering the same ground in part they do not necessarily occasion duplication in either field work or publication. Of these two divisions the former, from its nature, must in the beginning receive greater attention. All the problems of economic importance and interest cannot be solved at once. Time is required to do the work carefully and thoroughly. Consequently it was necessary to make some selections before entering upon the work as a whole. Those subjects which were thought to most need immediate attention were taken up and the work pushed vigorously. At the same time a number of collateral subjects demanded prompt consideration and these were investigated as far as circumstances permitted.

WORK ON THE COAL DEPOSITS.

Although at the present time coal easily ranks first in importance among the mineral resources of Iowa, less has


A
SKETCH MAP
OF
IOWA
SHOWING COUNTIES
IN WHICH
COAL DEPOSITS
HAVE BEEN INVESTIGATED.
1893.
COAL MEASURES.
OUTLIERS.
LYON
OSCEOLA
DICKINSON
EMMET
WINNEBAGO
WORTH
MITCHELL
HOWARD
WINNESHIEK
ALLAMAKEE
SIOUX
O'BRIEN
CLAY
PALO ALTO
KOSSUTH
HANCOCK
CERRO GORDO
FLOYD
CHICKASAW
FAYETTE
CLAYTON
PLYMOUTH
CHEROKEE
BUENAVISTA
POCAHONTAS
HUMBOLDT
WRIGHT
FRANKLIN
BUTLER
BREMER
WOODBURY
IDA
SAC
CALHOUN
WEBSTER
HAMILTON
HARDIN
GRUNDY
BLACK HAWK
BUCHANAN
DELAWARE
DUBUQUE
MONONA
CRAWFORD
CARROLL
GREENE
BOONE
STORY
MARSHALL
TAMA
BENTON
LINN
JONES
JACKSON
CLINTON
CEDAR
HARRISON
SHELBY
AUDUBON
GUTHRIE
DALLAS
POLK
JASPER
POWESHIEK
IOWA
JOHNSON
SCOTT
MUSCATINE
POTTAWATTAMIE
CASS
ADAIR
MADISON
WARREN
MARION
MAHASKA
KEOKUK
WASHINGTON
LOUISA
MILLS
MONTGOMERY
ADAMS
UNION
CLARKE
LUCAS
MONROE
WAPELLO
JEFFERSON
HENRY
DES MOINES
FREMONT
PAGE
TAYLOR
RINGGOLD
DECATUR
WAYNE
APPANOOSE
DAVIS
VAN BUREN
LEE

been known in regard to its structure and distribution than perhaps any other mineral deposit of economic value in the State. The subject was therefore clearly among the first demanding attention. At the very beginning it was found that in order to make satisfactory progress it was necessary to carry on the investigations in a perfectly systematic way. Consequently localities were visited first which, it was thought, would furnish most readily a key to the structure, character and disposition of the coal beds over large areas. The leading geological features of these districts were carefully made out and the examination extended into neighboring regions. In this way the extent of territory covered and the amount of practical information secured was far greater than could have been obtained otherwise.

The area of the Coal Measures in Iowa embraces over twenty thousand square miles; besides, there are numerous Carboniferous outliers, or isolated areas, along and beyond the borders of the productive measures, which make up many additional square miles. The investigation of the coal deposits of the State is thus seen to be a work of no small magnitude. Detailed attention to the coal industry in all its phases involves labor which cannot be completed in a few months; it will require several years to make satisfactory observations, to accumulate the facts and carry on the proper tests.

In the presentation of the information there are contemplated:

(1) A report on the coal deposits, somewhat general in its character, perhaps, but supplying temporarily a great and ever increasing demand for information on the subject. This desire for authoritative accounts of different portions of the great coal field is shared not only

by the citizens of Iowa but by many persons with means who now reside in distant places, but who are desirous of making safe investments in the State, of starting new industries and possibly of soon becoming residents of the commonwealth.

(2) A detailed account of the geological features of the coal district. This should embrace a full description of the different kinds of beds and their associations, the minute structure of the coal bearing strata, the exact relations of the different seams, the distance from the surface that it is necessary to go in order to reach them, the pointing out of notable and easily recognized strata which may serve as guides in searching for particular veins, and all kindred information of practical import.

(3) A discussion of practical mining in the State, the methods employed and improvements which may be made, the kinds of machinery used and its advantages, the best plans and the most suitable machinery for prospecting.

(4) A description of the uses and properties of Iowa coals, with tables of chemical analyses of all the principal varieties from the different counties, the adaptabilities of the various kinds for steam, domestic and metallurgical purposes and for gas-making. In this connection will be considered all information tending toward a greater development of the industry, including the utilization of coal dust, slack and the lignites of northwestern Iowa.

The first portion of the work is now completed and the report ready for distribution. It forms a volume similar in size and style to the First Annual Report. The information contained, in respect to the arrangement of the coal bearing strata is of the greatest practical value, as well as of scientific interest.

The work on the coal is being continued. Special mapping of certain typical areas has been undertaken. Upon the maps will be based the construction of several relief models which will show clearly the details of structure, arrangement and present accessibility of the coal seams. The models will exhibit graphically all the facts pertaining to the disposition of the veins and will clearly illustrate the nature of coal occurrences over wide areas. A map of the State showing the location of all the mines and the natural outcrops is also in preparation.

EXAMINATION OF CLAYS.

The number, extent and importance of the industries based upon clays has been little appreciated. Still less has the existence, distribution and qualities of the available deposits been comprehended. Yet, to-day manufactured clay products constitute one of the leading features in the material welfare of the commonwealth.

It would be difficult at this time to place an exact valuation on the building materials, pottery and other products made of clay which are used yearly in the State; $20,000,000 would probably be a very conservative estimate. For many years large sums of money have annually left the State to purchase clay products from other districts. This, evidently, is not due to a lack of raw material, for recent investigations have amply shown that Iowa possesses vast and exhaustless deposits of the very best of clays, and that they are to be found in nearly every geological formation and in every county of the state.

Much information of great value has already accumulated in regard to the clays and the industries connected with them. Another field season will go far toward the completion of a report which will be comprehensive and practical. The investigations have already gone far enough to indicate the general character and scope of the final report on the subject. It will contain a full discussion of:

(1) The origin, composition and properties of the clays in Iowa.

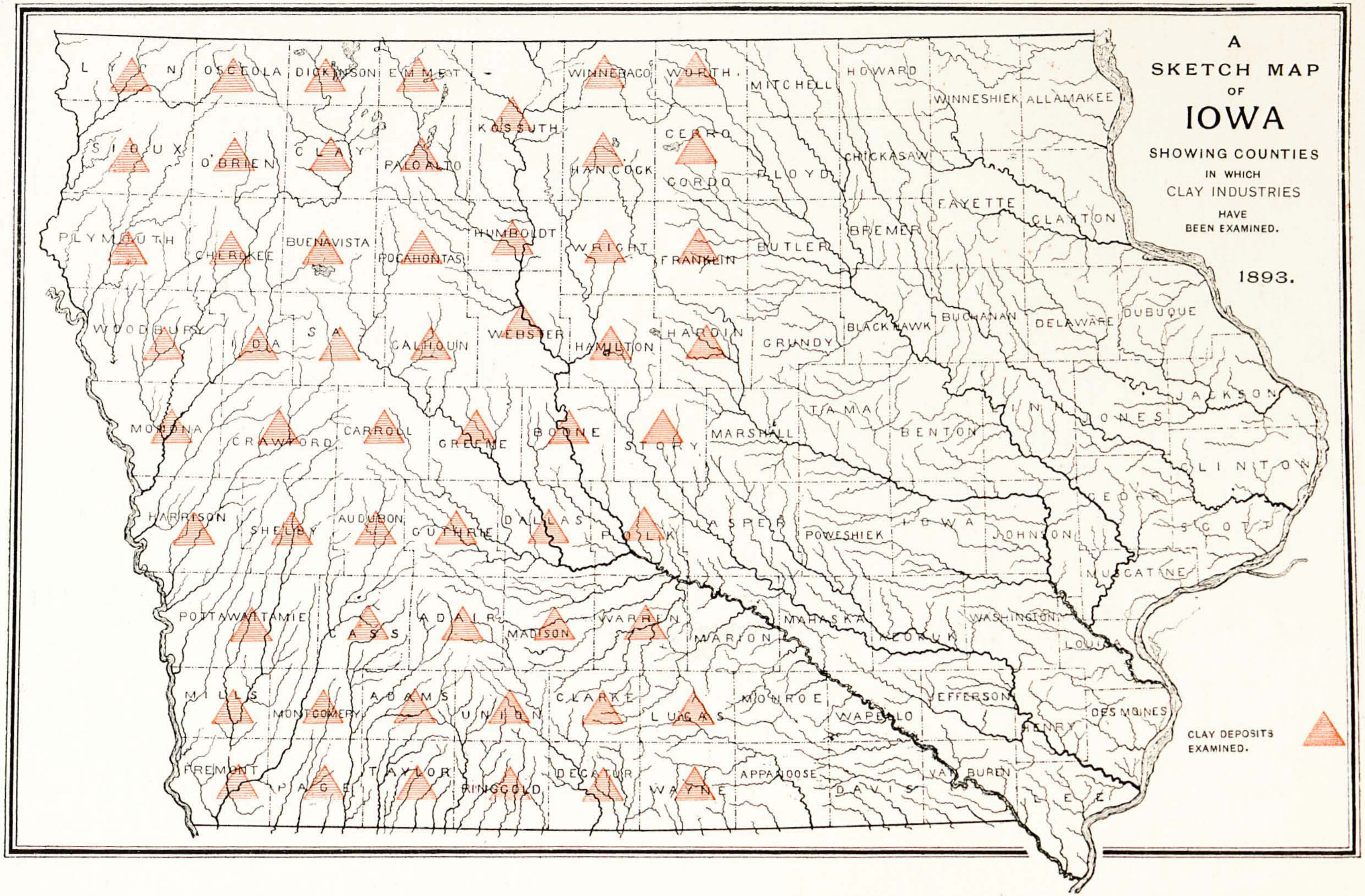
(2) The uses to which the various kinds of clay are, and may be put, and a consideration of the best varieties adapted to each specific purpose.

(3) The general geology of the State with special reference to clay deposits, their distribution and availability.

(4) The brick and draintile clays, the localities yielding the best qualities and the methods followed in rendering the poorer grades workable. There will also be embraced a special consideration of the clays used in making paving brick and sewer pipe. The recent extensive use of brick as a paving material and its superiority over many other substances has rendered the subject of brick for this purpose one of very great importance and one to which sufficient attention has not yet been paid. Paving streets with hard bricks is fast becoming popular in the larger towns and cities. Tests are continually being made which go to prove that the durability of a street paved with good, vitrified brick compares more than favorably with that of streets paved with other material.

(5) Pottery clays of the State, their properties, distribution and location; also the materials used for glazing and in mixtures.

(6) Fire clays and other deposits suitable for the manufacture of refractory products. There will be given in this connection extensive comparisons of the raw materials from the different localities in the State, and references to noted places beyond its limits.


A
SKETCH MAP
OF
IOWA
SHOWING COUNTIES
IN WHICH
CLAY INDUSTRIES
HAVE
BEEN EXAMINED.
1893.
CLAY DEPOSITS
EXAMINED.
LYON
OSCEOLA
DICKINSON
EMMET
WINNEBAGO
WORTH
MITCHELL
HOWARD
WINNESHIEK
ALLAMAKEE
KOSSUTH
SIOUX
O'BRIEN
CLAY
PALO ALTO
HANCOCK
CERRO GORDO
FLOYD
CHICKASAW
FAYETTE
CLAYTON
PLYMOUTH
CHEROKEE
BUENAVISTA
POCAHONTAS
HUMBOLDT
WRIGHT
FRANKLIN
BUTLER
BREMER
WOODBURY
IDA
SAC
CALHOUN
WEBSTER
HAMILTON
HARDIN
GRUNDY
BLACK HAWK
BUCHANAN
DELAWARE
DUBUQUE
MONONA
CRAWFORD
CARROLL
GREENE
BOONE
STORY
MARSHALL
TAMA
BENTON
LINN
JONES
JACKSON
CLINTON
HARRISON
SHELBY
AUDUBON
GUTHRIE
DALLAS
POLK
JASPER
POWESHIEK
IOWA
JOHNSON
CEDAR
SCOTT
MUSCATINE
POTTAWATTAMIE
CASS
ADAIR
MADISON
WARREN
MARION
MAHASKA
KEOKUK
WASHINGTON
LOUISA
MILLS
MONTGOMERY
ADAMS
UNION
CLARKE
LUCAS
MONROE
WAPELLO
JEFFERSON
HENRY
DES MOINES
FREMONT
PAGE
TAYLOR
RINGGOLD
DECATUR
WAYNE
APPANOOSE
DAVIS
VAN BUREN
LEE

(7) Kaolinic clays. This term applies to all the higher grades of clay which may be used for making the better classes of clay goods for domestic purposes.

(8) The principal industries based upon clay.

(9) Preparation of clay for manufacture into the different products and the methods used.

(10) Recommendations for better methods of manipulation. The importance of raising the standard of excellence of clay goods cannot be overestimated. It not only aids directly the manufacturer of the products but indirectly greatly benefits every citizen by providing him with a superior quality of material at a no higher price than he would otherwise give for the inferior article.

(11) Complete statistics in regard to the production of the various kinds of clay goods.

In this report it is proposed not only to test the chemical but also the physical properties of the clays. Through the latter especially the various comparisons may be more thoroughly appreciated, and the exact character of the different deposits more readily understood. The following outlines the method, taking for example a sample of typical fire clay:

A preliminary examination shows:

Coler varying from light ash to drab.
Texture nearly uniform, fine grained, compact.
Taste "lean," gritty.
Slacks slowly into irregular granules with little uniformity of size.
Accessories: pyrite not perceptible; sand as grains from one-tenth to one-thirtieth of an inch in size, freely disseminated.

A physical examination shows:

Specific gravity, 1.950.
Plasticity, as determined by working a clay paste is eminent; as determined by the tensile strength of air dried briquettes it has a maximum of 172, the average of ten samples being 155 pounds per square inch.
Water required to make a plastic, easily worked paste is 15.4 per cent.

Air shrinkage, in drying bricklets ranging from four inches by one-fourth inch to eight inches by four inches averaged 5.6 per cent in ten samples. It can be dried rapidly in a warm air bath at 125° to 200° F. without breaking.

Fire shrinkage, in burning air dried samples at a vitrifying heat averaged 2.3 per cent in three samples; requires care and slow heating to avoid cracking.

Total shrinkage, or the sum of the fire and the air contraction, averages 7.9 per cent, which is remarkably low.

Fusion takes place at about 2,400° F., or a white heat; incipient vitrification takes place at 2,100° F., or at a bright cherry red heat.

Color of burned clay is light gray.

Conclusions: This fire clay is a fairly good refractory material, as it may be used for temperatures as high as 2,300° F., or a very bright cherry heat. It admits of rapid air drying without cracking and does not fissure readily in firing. The total shrinkage being very low adds greatly to its value in any practicable application of the clay. Being highly plastic it moulds admirably. The burnt ware is quite strong. The clay when washed may be used successfully by potters. It is even possible that a white ware may be produced if the clay is properly washed and treated.

BUILDING STONES.

The resources of Iowa in building stone are unquestionably great. There is but little doubt that as good rock for structural and architectural purposes is obtainable within the limits of the State as anywhere in the neighboring districts. When, however, Iowa goes to New England, Ohio, and Lake Superior for stone with which to construct the better class of buildings the query at once arises as to the reasons. Furthermore, when inquiry is made concerning the sources of higher grades of stone used in the State, the proportion obtained from Iowa is found to be surprisingly small as compared with the quantity shipped in from other places, and the importance and absolute need of a systematic investigation of the State's domain is immediately made evident.

In order of their importance the chief factors determining the value of a building stone are: Accessibility, Durability, Strength, Structure and Reputation.

No matter how excellent a stone may be it is of course valueless for constructional purposes if it does not have good transportation facilities. Durability is a phase of the subject which cannot be determined readily from hand specimens and is usually brought out through experience. Stones which ordinarily withstand the influences of atmospheric agencies readily waste away when exposed to conditions quite different from those of their native places; and the acid-laden air of great cities is especially deleterious to rock. The resistance to weathering is ascertained best in the field by careful examination of the native ledges. These observations may be supplemented by tests in the laboratory. Strength, however, is usually the only factor tested in determining whether or not a given stone shall be used.

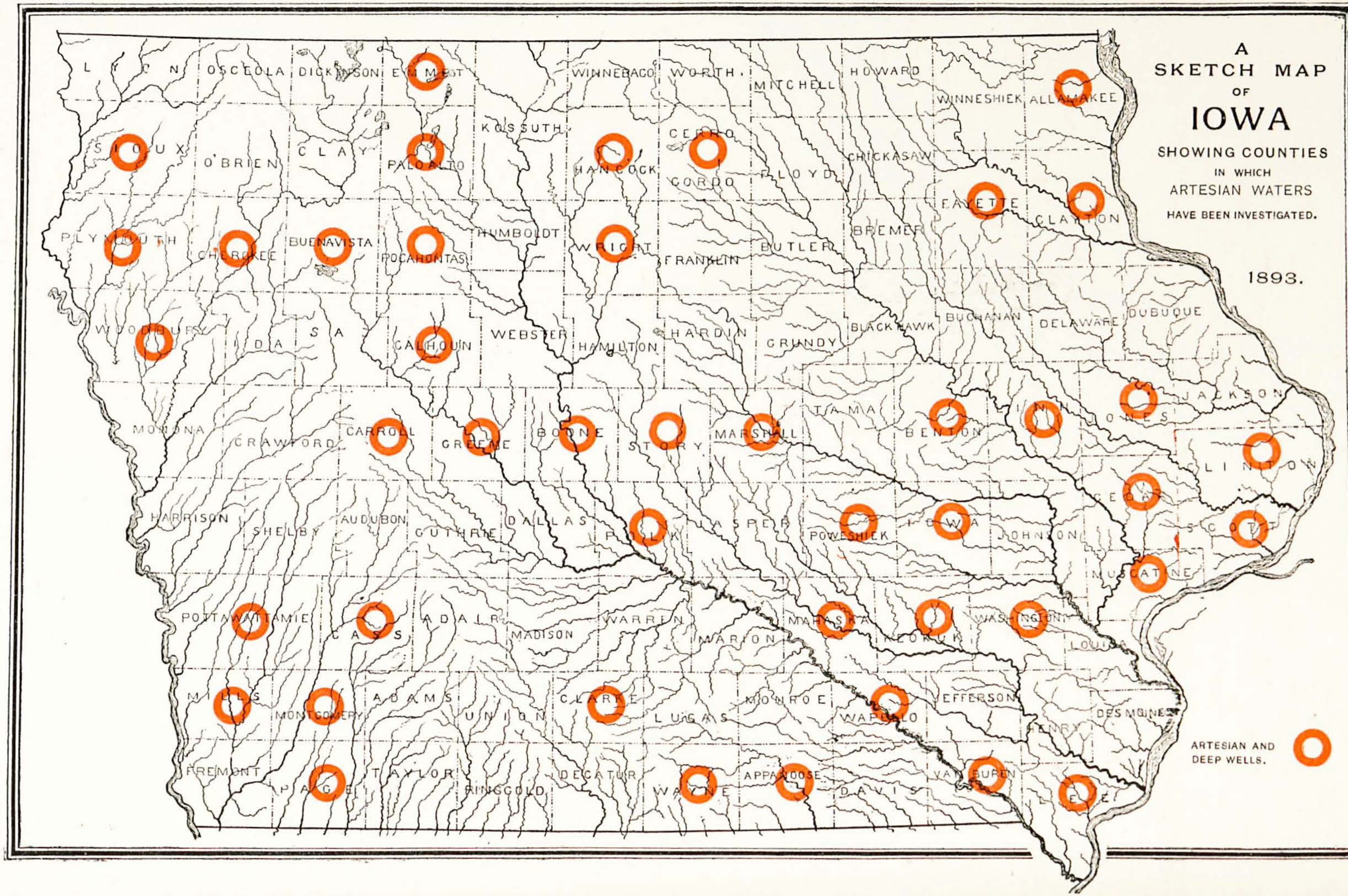
Architects and engineers commonly have neither the apparatus nor the inclination to make extensive tests in regard to local building materials. Consequently they employ stone which already has its reputation established. Thus the lack of authoritative information in regard to local resources causes the rocks of the State to be discarded and building stone to be transported half way across the continent and often placed upon ledges of rock in every way their equal or even their superior. The quarrying industry at home does not receive the support it should, while, foreign markets are entered and purchases made.

The remarks just made indicate the lines along which investigations concerning the Iowa building stones are being made. There is scarcely a county in the eastern half of the State which does not contain stone of good quality for all ordinary building purposes, some of very superior character. Thus Johnson county has a rock of which the basement of the new Capitol building has been constructed; the same stone was used in erecting the central building of the State University at Iowa City, and although put up more than half a century ago the tool marks are still fresh. Scott and Jones counties have long supplied a very superior stone which has been widely used; while Marshall has shipped a fine grade of ornamental rock to Boston and other large eastern cities. Lyon county has been found to possess exhaustless quantities of the most durable stone in the world, and one which will outlast granite ten times over. These isolated instances show clearly that Iowa does really possess building stone which has all the desirable qualities for becoming a widely known constructional material.

The work of making the observations and requisite tests on the Iowa building stone is already well under way. In collecting this information special attention has been given to the distribution of the ledges and layers best adapted for building purposes, the properties recommending the various kinds and the influences of weathering on the natural outcrops. In the report which will probably be completed next year it is intended to give full descriptions of the localities and of the quarries now opened, statistics as to production and the methods of getting out the stone. Illustrations of some of the finer grades of the ornamental varieties and of the larger buildings and constructions erected from Iowa stone will also be given.

INVESTIGATION OF ARTESIAN WATERS.

The desire for artesian water supplies is widespread among the people of Iowa. The demand for this source of water is not because the State is not well supplied with streams at the surface nor because of the unfavorable


A
SKETCH MAP
OF
IOWA
SHOWING COUNTIES
IN WHICH
ARTESIAN WATERS
HAVE BEEN INVESTIGATED.
1893.
ARTESIAN AND
DEEP WELLS.
LYON
OSCEOLA
DICKINSON
EMMET
WINNEBAGO
WORTH
MITCHELL
HOWARD
WINNESHIEK
ALLAMAKEE
SIOUX
O'BRIEN
CLAY
PALO ALTO
KOSSUTH
HANCOCK
CERRO GORDO
FLOYD
CHICKASAW
FAYETTE
CLAYTON
PLYMOUTH
CHEROKEE
BUENA VISTA
POCAHONTAS
HUMBOLDT
WRIGHT
FRANKLIN
BUTLER
BREMER
WOODBURY
IDA
SAC
CALHOUN
WEBSTER
HAMILTON
HARDIN
GRUNDY
BLACK HAWK
BUCHANAN
DELAWARE
DUBUQUE
MONONA
CRAWFORD
CARROLL
GREENE
BOONE
STORY
MARSHALL
TAMA
BENTON
LINN
JONES
JACKSON
CLINTON
CEDAR
HARRISON
SHELBY
AUDUBON
GUTHRIE
DALLAS
POLK
JASPER
POWESHIEK
IOWA
JOHNSON
SCOTT
MUSCATINE
POTTAWATTAMIE
CASS
ADAIR
MADISON
WARREN
MARION
MAHASKA
KEOKUK
WASHINGTON
LOUISA
MILLS
MONTGOMERY
ADAMS
UNION
CLARKE
LUCAS
MONROE
WAPELLO
JEFFERSON
HENRY
DES MOINES
FREMONT
PAGE
TAYLOR
RINGGOLD
DECATUR
WAYNE
APPANOOSE
DAVIS
VAN BUREN
LEE

climatic influences, but for reason of the great convenience in the use of flowing wells and on account of the common belief that such water is exceptionally pure. With the desire of securing flowing wells borings have been put down in all parts of the State. In a large number of the cases failure has resulted.

The principles involved in a successful artesian flow are so simple that it comes to be generally believed that the governing conditions are equally simple and all that is necessary is to put down a hole far enough and a flowing well will result. In reality the conditions of a successful flow are quite complex, and the practical determination of artesian areas involves a broad comprehension of the general geological features of the region, not of the State alone, but of the surrounding territory as well.

During the past year the work of collecting facts concerning the artesian probabilities of the State has been carried on vigorously. Records of a large number of borings and wells have been obtained and samples of the drillings secured whenever possible. By careful comparisons of the various data the water bearing strata have been traced over a considerable portion of northeastern Iowa. The investigation is now being extended into other parts of the State as rapidly as circumstances permit. Some of the results of this work are sufficiently complete to be made public, and an account of the investigations will shortly appear. The work also adds largely to a knowledge of the characters of the older and more deeply buried formations in Iowa and discloses much of value in regard to their texture and structural relations.

Not only the mapping of the different areas but also other considerations are taken into account. These may be noted separately:

(1) The essential conditions of flowing wells are discussed in connection with their special application to the State. The structure of the region, the geographical distribution of the formations, the texture of the rocks, the amount of rainfall and kindred topics require explanation and description.

(2) Under nature of artesian wells there is properly included all studies upon the flow, the force and the factors upon which it is dependent, the height to which the water rises, causes of decrease in flow and methods of increasing it.

(3) In discussing the uses of the waters there are considered the adaptabilities of artesian flows; their values as sources of power, as supplies for city waterworks and as medicinal remedies.

(4) Certain methods of boring and special forms of machinery have been found to be more economical in this work and a description of these are within the scope of the work.

(5) In connection with mapping come those topics which relate more especially to the conditions of individual areas.

Fundamental to this work is the careful collection and study of the records of all wells previously sunk in the State. These records become very largely the basis of subsequent work. In the determination of flow levels certain geological horizons have been found to be water bearing. For example the Dakota sandstone is in South Dakota the source of many wells; in northeastern Iowa the Saint Peter sandstone is the best known stratum performing a similar function. It becomes important to determine which among the many layers are most likely to prove valuable for this purpose. Next to the question of what horizon may be expected to furnish supplies of water comes that of the depth at which it will be encountered. This may be made out by a careful comparison of the levels of outcrops, surface waters, horizons in neighboring wells and similar data. The areas available for artesian wells can, therefore, only be determined by a detailed study of the structure and texture of the rocks as well as the other conditions mentioned.

GENERAL GEOLOGY.

In all geological work there are certain broad preliminary questions relating to the origin and succession of the formations which must be considered in order that the best results may be secured in regard to the more strictly economic work. Some of these are wide-reaching in their bearing. They are not confined to a single district nor a single county but may extend over a greater part of the State or through several states. Fortunately many of these problems had already been partially or wholly solved before the work of the Survey had begun. A general study of the rocks, their arrangement and relations in this and the adjoining states had been made. The results, to which the Iowa Survey fell heir at the very beginning of its career, greatly facilitated the preliminary investigations which invariably must precede all detailed examinations. With the broad general questions of inter-state importance already tolerably well understood, those which apply more particularly to the State alone are much more easily taken up and more readily solved than they could be otherwise. There is considerable work of this kind yet to be done. A discussion of it, which embraces a somewhat generalized and co-ordinated consideration of the lithological characters of the different formations, the structure and arrangement of the various beds and a classification of the formations in accordance with the latest criteria of geological science, is necessary. The direct bearing of the general geological problems upon the more strictly economic phases of the several topics is shown more in detail in connection with the remarks on the different subjects of which special mention has been made.

The general scheme of the final report is already foreshadowed. It includes a general description of the geological features and structure of the upper Mississippi valley, particularly as applying to Iowa. It takes up the separate geological formations and describes in detail the characters and distinguishing features of each. It considers the arrangement, succession and thicknesses of the formations, the variability of the different strata, the unconformities and deformations. It notes particularly the useful minerals and substances occurring in the different parts of each formation and points out how most readily to detect the deposits; it considers also other useful materials which are not as yet utilized. It discusses farther the origin, conditions of deposition and the associations of the various beds.

Among some of the problems which are of more particular interest may be mentioned the exact divisions and relations of the upper part of the Silurian, the subdivisions of the Devonian and the transitional beds between it and the overlying and underlying formations, the eastern limits of the Cretaceous and the correlation of these beds, and the age of the Sioux quartzite which is yet to be definitely settled.

MAPPING.

A modern geological map is a graphic summary of a vast mass of useful information. In addition to an accurate representation of the ordinary geographical features, as in the best atlases, a properly constructed geological map records much more. On it is indicated, within a few feet, the elevation above the sea level of every point within the compass of the area; the drainage basins and the water powers are noted; the distribution and limits of the different geological formations are plainly marked; the various kinds of ores, building stones, clays and all minerals of economic value contained in the several beds are located; the best places for obtaining all these substances are indicated. The map also forms a reliable soil index.

The construction of a full set of maps of this character is not the work of a few days or of a few weeks, but the labor of several years. In connection with the investigations of the economic resources of the State there is contemplated a series of maps which shall embrace for every part of the State all the information above mentioned. Some of them will be somewhat general in their nature and will accompany the different special reports. Others will be more detailed in their make-up and will cover given counties or such areas as may be thought desirable. In the construction of maps showing the distribution and occurrences of mineral substances it is of prime importance that the surface relief should be depicted in a readily intelligible manner. One which represents most closely a perfect miniature of the surface of the region is far superior to any ordinary atlas. It is invaluable not only to the trained geologist but it is about the only practical way by which the average citizen is able to comprehend at a glance the explanations. In proportion as the exactness with which the diminutive representation approaches the actual surface, in the same proportion does the usefulness of the work increase. The modern methods of making maps are so far advanced over those of a quarter of a century ago that there is now no excuse for a community to be without the best.

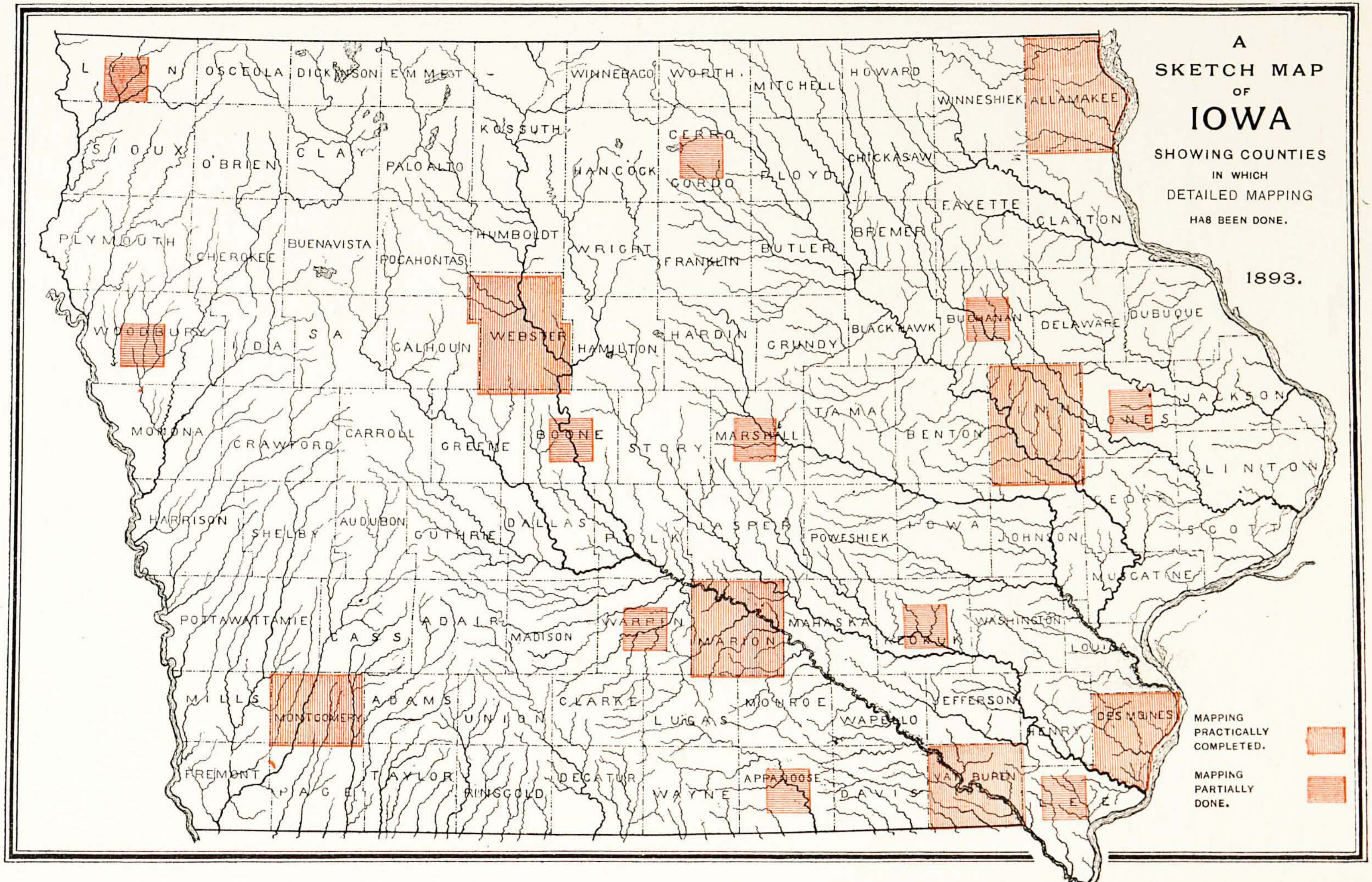
A properly constructed geological map of a district, therefore, not only locates the various mineral deposits but also represents the prominent landscape features by which the locations may be more readily recognized. A relief map also serves other purposes. Upon it is based the models of the more important districts which are to be taken as characteristic of much larger areas and which are to represent in a graphic manner the structure, arrangement and relations of deposits. Eventually a relief model of the entire State will be constructed on a suitable scale.

COUNTY RESOURCES.

As the state is the political unit of the nation, so the county is the political unit of the state. When, therefore, in either the larger or the smaller of the two provinces it is desirable to consider any subject with special reference to its areal distribution the units mentioned become the natural divisions into which a complex topic may be separated. The reasons for making the county the areal unit in the treatment of the natural resources of a region are many:

(1) It is the most widely known and familiar political division of local importance.

(2) It is the district concerning which nearly every person in the State who is interested in the natural products of his neighborhood inquires.


A SKETCH MAP OF IOWA SHOWING COUNTIES IN WHICH DETAILED MAPPING HAS BEEN DONE.
1893.
MAPPING PRACTICALLY COMPLETED.
MAPPING PARTIALLY DONE.
LYON
OSCEOLA
DICKINSON
EMMET
WINNEBAGO
WORTH
MITCHELL
HOWARD
WINNESHIEK
ALLAMAKEE
SIOUX
O'BRIEN
CLAY
PALO ALTO
KOSSUTH
HANCOCK
CERRO GORDO
FLOYD
CHICKASAW
FAYETTE
CLAYTON
PLYMOUTH
CHEROKEE
BUENAVISTA
POCAHONTAS
HUMBOLDT
WRIGHT
FRANKLIN
BUTLER
BREMER
WOODBURY
IDA
SAC
CALHOUN
WEBSTER
HAMILTON
HARDIN
GRUNDY
BLACKHAWK
BUCHANAN
DELAWARE
DUBUQUE
MONONA
CRAWFORD
CARROLL
GREENE
BOONE
STORY
MARSHALL
TAMA
BENTON
LINN
JONES
JACKSON
CLINTON
HARRISON
SHELBY
AUDUBON
GUTHRIE
DALLAS
POLK
JASPER
POWESHIEK
IOWA
JOHNSON
CEDAR
SCOTT
MUSCATINE
POTTAWATTAMIE
CASS
ADAIR
MADISON
WARREN
MARION
MAHASKA
KEOKUK
WASHINGTON
LOUISA
MILLS
MONTGOMERY
ADAMS
UNION
CLARKE
LUCAS
MONROE
WAPELLO
JEFFERSON
HENRY
DES MOINES
FREMONT
PAGE
TAYLOR
RINGGOLD
DECATUR
WAYNE
APPANOOSE
DAVIS
VAN BUREN
LEE

(3) It forms a convenient district for working out geological details.

(4) It is an area whose size is perhaps best suited to the purposes of instruction in the schools.

(5) It is especially suited to the encouragement of detailed work by local observers.

(6) It is the district most commonly inquired about by investigators living in other parts of the state or in different places beyond its limits.

(7) In Iowa it is an area well suited to the preparation of maps.

(8) It in no way interferes, with the adoption of other units of uniform size for a state atlas, should occasion demand.

As has been said, subject work must necessarily be pushed somewhat more vigorously than areal work in the beginning of the survey. Nevertheless, detailed investigation of a number of counties has already been undertaken where the conditions are especially favorable. Although every county in the State must be thoroughly studied before the completion of the survey, it is readily understood that all these districts cannot be taken up at once. Some must of necessity be studied before others. In making a beginning in this direction the work has been governed to a great extent by the investigation as a whole, those regions being taken up first which best furnish an index to the surrounding counties, thus enabling the work to be done over larger areas and in a much shorter time than would otherwise be possible. Another important factor in determining the priority of certain counties in which operations have been begun has been the presence of volunteer and local assistants. In this way some counties containing educational institutions have afforded special facilities. The instructors of geological classes in the several colleges have given, to a greater or less extent, attention to the natural features of the surrounding country and have often accumulated considerable information. By utilizing the facts previously obtained and by extending the observations so as to accord with the general plan of the survey the State comes into possession of material of great practical value at a small cost. The reports of these counties will thus serve not only for purposes of class instruction but will reach the public much sooner than they would under less favorable circumstances. In this way work has been undertaken in a number of counties and considerable progress has been made.

A volume of the regular size devoted to the description of the geological and economic resources of several of the counties is expected to be issued early during the coming summer. The general scheme followed in the discussion of each county includes a brief general account of the surface relief and drainage, a description of the lithological characters of the different rocks and the geological structure of the strata. The principal geological subdivisions are considered separately and the means of recognizing each pointed out. All the mineral deposits of a useful nature are described, the various localities taken up in detail, the extent and distribution defined and the present and future value noted. The soils and minerals are also discussed and the discriminations to be made are pointed out. Chemical analyses and practical tests of the various substances are also given. Illustrations are incorporated wherever required. A map on a suitable scale accompanies the report of each county.

CHEMICAL WORK.

In all geological investigations chemical work forms an important part. It is often desirable to know, aside from the occurrence of a particular deposit, its composition more specifically than can be judged from its general appearance. The methods followed are not the same in all cases. While some substances require a complete analysis, many samples need only a partial chemical examination, and with a still larger number it is only necessary to make special tests.

The chemical analyses made by the Survey, like the work in other branches, are not to be regarded as supplanting work of a similar nature which should be done by individuals. All the examinations undertaken are broad in their bearings and of special import as explanatory of work which is being systematically carried on. Every analysis made is, therefore, of much more than local importance. In order that any analysis may be of the widest significance and value the samples must be collected personally by the parties having the investigations of the particular district in charge, since in no other way can satisfactory and accurate conclusions be drawn.

COLLECTIONS.

In the course of the various investigations there accumulates a large quantity of material which illustrates the natural products of the State. The best of these specimens are brought together, carefully labeled and deposited in the rooms set aside for this purpose. As yet, of course, the collection is quite incomplete, but for the short time spent upon it the progress has been very satisfactory. It is expected ultimately that all the mineral materials found in each county will be fully represented and the collection will form a complete index of what may be obtained in the State. Being attractively displayed and conveniently placed, architects, engineers and others may readily and easily examine and compare the various samples, and learn what is best adapted for their respective purposes. As they are deposited in the Capitol, a place persons from all parts of the State and from every state in the Union are continually visiting, the cabinet serves to show in the best manner possible what Iowa possesses. There are represented the various ores, clays, building stones, soils, limes, coals, minerals, fuels and innumerable other things of interest, as well as the products made from various materials. A series of photographs is also being secured to illustrate the various geological phenomena and, incidentally, Iowa scenery. A set of charts is in preparation showing the distribution and structure of the various useful deposits. The models already referred to in connection with mapping are also designed to be made useful in this connection.

The material for the cabinet which has been obtained by different members of the Survey is added to by the co-operation of many individuals. Owners of various quarries have thus offered to furnish, suitably dressed, different samples of building and ornamental stones. Proprietors of clay industries have been liberal in supplying suites of their wares and the raw materials. Operators have endeavored to send in representative sets of their mine products. Others have likewise aided. Although this work has only been fairly started, the ensuing years will show great gains.

In connection with the material for the cabinet there necessarily accumulates many duplicates which are not needed by the Survey after they have been studied and reported upon. Most of this material is very valuable for class instruction at the various colleges and high schools throughout the State, and may be made available for this purpose with little or no additional expense. A number of educational institutions have already expressed their desire to obtain suites illustrative of the geology and economic resources of the State. A selected set of photographs pertaining to Iowa geology is also contemplated for class use and may probably be disposed of at the nominal cost of making the prints.

LIBRARY.

Through exchanges and gifts from scientific organizations and institutions a nucleus of a geological library has been established. It is essentially a working collection of books and is designed to serve as a reference library for those directly interested in the geology of the State. During the past year about one hundred and fifty books bearing directly upon geology have been received, besides many others incidentally referring to geological themes. In addition, a considerable number of pamphlets and unbound volumes have been acquired. At the present time these are in the geological rooms but eventually they will probably be deposited in the State library. Efforts are being made to make the collection as complete as possible in the literature pertaining directly to the local geology of the State and in the publications which, though relating to the geology of other states, throw light on the geological structure and resources of Iowa.

Work Taken Up.

In addition to the subjects which have been taken up as principal lines of investigation there have been a number of topics which have been regarded as collateral subjects, concerning which, though little independent work has yet been done, considerable valuable information has been obtained. In time some of the subjects which now hold a place of only subordinate importance will receive special attention and be elevated to the position of leading topics of investigation.

THE SOILS.

There is probably no phase of economic geology which at present attracts more attention than the study of soils. Owing to the great fertility of the virgin prairies of Iowa, artificial fertilizers have not as yet come into use as in the older states of the Union and in the densely populated countries of Europe. Nevertheless, it has begun to dawn upon many communities, as it must necessarily sooner or later everywhere, that the soils may not yield so abundantly as years go by. In different parts of the country the real conditions are rapidly being comprehended and efforts are being made to rejuvenate the failing soils. The awakening is now occurring in many places, particularly in the eastern and southern states. But the subject is not receiving attention only in those districts where the soils are partly or wholly "worn out." It is beginning to be found out that in many places, even where the soil is surpassingly fertile, proper treatment may greatly increase the yield.

During the past two decades there has occurred in Iowa and the neighboring states in successive years violent fluctuations in the yields of various crops and at least two or three times within the period the crops have narrowly escaped almost total failure owing to prolonged droughts. Human efforts are of little avail in attempting to change these varying climatic conditions, but it is quite possible for them to effect the same results by manipulating the soil so that it will retain sufficient moisture to carry all vegetation safely through the most protracted dry spells. The accomplishment of this is possible through the proper chemical and physical investigation of the different soils.

It is commonly considered that geology is merely the adjunct of mining, but it is equally the helpmate of agriculture. The interdependence of the science of geology and the science of agriculture is daily becoming more and more intimate. The relations between the primitive rock ledges and the soils resulting from their disintegration are ever becoming better understood. The principle lying at the base of the more recent soil investigations is that each geological formation gives rise to a more or less well marked soil type which is especially adapted to particular crops. The latest work in regard to this subject has been on the physical rather than on the chemical side and the results have been eminently satisfactory.

The results of the application of mechanical analysis to the study of soils may be here summarized.

Starting from the fact that the farmer, simply from the character and appearance of the soil, is better able than the chemist, with his most refined analyses, to tell what kind of grain it will produce, there is reason to believe that the differences in the value of the soils is due rather to their texture and the arrangement of grains than to their chemical composition; that all soils contain sufficient food material to support crops for years; and that their value is measured, not by chemical composition, but by their relations to moisture.

The matter of moisture in a soil, or the circulation of water in it, is very important and is believed to be one of the leading determining factors in the local distribution of plants. The circulation of water in the soil is brought about by two forces, gravity and surface tension. The first is constant and acts always in the one direction, so that it may be practically neglected. The second acts in any direction, either pulling the water up to the plant or away from it, according to circumstances.

It has been found that, upon an average, fifty per cent of the volume of the soil contains no solids, but is made up of only water and air, and may be regarded as empty space. If a soil is slightly moist the water will form films around the component grains. If there is an increase of water these films will thicken and, the amount of surface exposed being smaller in proportion to the weight of water, the surface tension will become low. If, however, the amount of water be decreased the surface tension increases, as the surface exposed is much greater in proportion to the less weight of water.

The total surface exposure of the particles in a cubic foot of soil is usually in the neighborhood of 50,000 square feet, or a little more than an acre; in some kinds of soil it is over two acres. This amount of space may be divided in different ways and the manner in which it is broken up controls largely the surface tension of the soil moisture. In turn, this determines the relation of the soil to the amount of water it will hold. Experiments have shown that different chemicals have two distinct effects upon the soils. One is to directly modify the surface tension of the soil moisture; and the other is to indirectly accomplish the same result by inducing changes in the texture. Since upon the surface tension existing in the soil depends its ability to absorb and to retain moisture, important changes in the capacities of land may be brought about through the application of proper chemicals and the power of a given soil to resist drought may be very greatly increased.

GYPSUM DEPOSITS.

Although this has not been regarded as a principal subject considerable progress has been made in the investigation of the deposits and the work will probably be finished shortly. Gypsum is widely distributed and occurs more or less abundantly in nearly every geological formation exposed within the limits of Iowa. The only deposits, however, of commercial value are in Webster county in the neighborhood of Fort Dodge. These beds may be regarded as among the most important deposits of the kind in the United States, while their geographical position makes them the most valuable known in the Mississippi valley.

In the manufacture of plaster of Paris and in general production of gypsum Iowa may now be considered as ranking second among the states of the Union. The productive area of the state approximates twenty-eight square miles. The deposits vary in thickness from two to thirty feet or more, with an average measurement of about sixteen feet. The great depth of the drift in many places throughout the gypsum area often makes it extremely difficult and quite expensive to quarry readily, and the cost of removing the soft covering with the means usually employed renders it impossible to utilize the thinner portions of the deposit. With the introduction of proper apparatus the stripping might readily be accomplished by hydraulic means, thus greatly reducing the cost and at the same time enabling all the material to be utilized at a very small expense. The production of gypsum in

Iowa has greatly increased during the past few years and now amounts to more than fifty thousand tons annually. Three or four mills are in operation, employing about one hundred and twenty-five men and a number of teams.

In considering the gypsum there are described the surface relief, the geological formations associated with the deposits, the relations of the beds to the various strata, the character, quality, extent and origin of the gypsum itself, the geological age of the deposits, and the availability. Suggestions are also made in regard to the general development of the industry.

LEAD AND ZINC.

The lead and zinc deposits of northeastern Iowa and states adjacent are well known the country over. Worked for over one hundred years they have continued to yield ore in greater or less amounts up to the present time and yet the industry has not reached its full development. The supply of zinc ore now in sight at the mines is sufficient to keep them in operation for many years.

Considerable work has already been done on the ore deposits of the state. They will receive further attention during the coming season. It is proposed to publish soon an extended account of the deposits. The report on the subject will consider:

(1) The history of the development of the mines, treating especially of the beginning and rapid growth of zinc mining in recent years, its present importance and future prospects.

(2) An account of the geology of the lead and zinc region, the formations in which the ores occur, and the beds to which the deposits are confined.

(3) A detailed description of the mode of occurrence of the Iowa ores, their location in crevices, their association and relation to each other and other facts important to a complete understanding of the subject.

(4) A description of the mines at present in operation. Many of these havealready been visited and much valuable information concerning them gathered. The location of the mines will be shown on a map of convenient size.

(5) A detailed review of the different opinions which are held as to the origin of the ores. This subject has recently come into renewed prominence and the discussions of those best informed have thrown new light on the genesis of these deposits.

MINERALS OF THE STATE (NOT MINED).

The mineral deposits which are at the present time of direct commercial importance are taken up as special problems. There are, however, many minerals of different kinds which are not mined and which are not as yet used commercially. Facts in regard to these are continually accumulating in all parts of the state. Some of these minerals are known to have a very considerable economic value and will necessarily soon be the subject of special inquiry. Others will be found to have only a scientific interest. Many having little or no value from an economic standpoint are now attracting popular attention and are causing a considerable expenditure of money, time and labor every year, with absolutely no possibility of any adequate returns. On the other hand a number of those having a great economic value are not being worked to the extent that they deserve or they have received no notice whatever. Even though many of the minerals in the state should prove to be of no commercial importance negative results are by no means without value. Proof that certain deposits are not extensive enough or are not of a sufficiently high grade for profitable working will be the means of preventing annually a great waste of money and energy.

In the consideration of these minerals there will be given a complete list of the various kinds, full descriptions of their different occurrences, a catalogue of the known localities of each and the possibilities of their extent and utilization.

ROAD MATERIALS.

The subject of good highways is attracting much attention at the present time. The value and desirability of good roads in the state need not, however, be considered here, for it is not the province of the survey to take up the subject in all its various bearings. There are, nevertheless, certain phases of the question which properly come within the range of the investigations for which the Survey was organized. Among the things which may be regarded as demanding attention are the localities and character of any superior stone suitable for improving the roads, the facilities for transportation and the approximate cost of quarrying and preparation. In addition, the qualities and properties of these rocks are to be considered. The location of good gravels, their areal extent and their quality will also receive attention. The subject of the utilization of burnt clays as a road material will be fully discussed. Some of the railroads are already using burnt clay for ballast in preference to rock, sand or gravel, with good results, so that the extension of the use of this material to highways is in reality beyond the experimental stage.

LIMES.

Iowa is well supplied with limestone suitable for the manufacture of a high grade of quicklime. Some localities are supplying a quality of lime which may be regarded as having no superior in the world. Recent inquiry has shown that the lime industry is not developed nearly to the extent that it might be, and that rocks well adapted to the manufacture of lime are more generally distributed than was supposed. In many places where lime was formerly burned the industry could now be readily and profitably revived, as the circumstances which interfered with its continuance are now largely removed. The subject of lime is one of the first which was taken up by the Survey for investigation, but owing to circumstances which could not be foreseen the examination was delayed after the work had fairly begun. Among the topics to be considered in this connection are the properties and qualities of the various limes made in the different localities, the superiority of certain grades, and the chemical and physical characters of the rocks especially adapted to lime manufacture. The components which give value to lime and those which have a deleterious effect are much better understood at the present time than they were formerly; and the grade of lime that can be produced from given limerocks may now be predicted with considerable accuracy. The methods adopted and the improvements which may be made in the lime industry will receive full consideration.

CEMENTS.

This subject yearly becomes more and more important. The term itself has recently come to be used in a much broader sense than formerly and now applies to all those calcined lime products which will set or harden under water. Those grades which are capable of a more or less complete hardening are commonly called hydraulic limes and are generally considered better than the ordinary varieties. Their hydraulic properties are said to be enhanced by the presence of magnesia, and consequently certain dolomites are well adapted to their manufacture. Aside from certain so-called hydraulic limestones which occur in various parts of the state there are other materials which are capable of being made into a high grade of Portland or hydraulic cement. The recent investigations in the northwestern part of the state have shown that there are vast deposits of an excellent quality of chalk and clay especially adapted to the production of a very excellent quality of Portland cement. Experiments on these deposits are now being carried on in a practical way and something in regard to their success will be ready to be made public soon. The extent of the deposits, their composition and the methods of preparation will be taken up in detail.

NATURAL GAS AND OIL.

During the past decade no geological question has awakened more popular interest than that of the possibility of finding natural gas and petroleum within the limits of Iowa. In a number of places shallow borings have yielded from time to time sufficient quantities of natural gas for local use. The success of these small wells has led to the putting down of much deeper ones and the expenditure of considerable amounts of money in all parts of the state. The excitement awakened by the discovery of oil and gas in Pennsylvania, Ohio and Indiana has stimulated still farther the efforts to secure them in Iowa. The general opinion has been, not only in this state, but others as well, that the only prerequisite necessary to the securing of a successful flow of natural gas and oil is the sinking of a deep well. In reality the subject is much more complex than is commonly supposed. There are certain natural conditions all of which must be fully considered before a successful flow of either substance can be obtained. The absence of any one of these can only result in failure. These conditions may be reduced to four categories. There must be, (1) a suitable receptacle or reservoir in which the oil and gas may accumulate; (2) a non-porous cover to retain them; (3) a particular geological structure or arrangement of strata; (4) a pressure sufficient to push the oil and gas to the surface.

The presence in the Iowa rocks of considerable quantities of petroleum is well known. The occurence of extensive coarse sandstones, conglomerates and porous limestones which act as reservoirs is also known. The existence of compact, impervious shales which serve as covers for the more porous beds is well understood. Artesian or hydraulic pressure sufficient to bring to the surface oil or gas, should either exist, is present throughout most of the state. The remaining condition — that of geological structure — is the chief one which requires investigation in Iowa. Considerable effort has been made towards solving the problem during the past year. The work cannot be finished in a single season, and until more information is acquired on the subject it is not advisable to sink wells for this purpose in the haphazard way which has been followed in the past. The particular phase of geological structure in question is that the rocks must be tilted. This causes in the porous rocks a movement of the water, oil and gas particles, a simple mechanical rearrangement. They accumulate in order of their specific gravities, the water at the bottom, then the oil, and finally the gas at the top. The special structure of the strata which will accomplish the desired effect is ordinarily known as the arch, fold or anticline. When the top of a fold is pierced gas escapes, when the arch is penetrated a little farther down oil flows out, and when the base of the bow is drilled into only water appears. The most essential line of investigation that is connected with the inquiry into the probabilities of the occurrence of oil and gas in the state is the determination of the location, extent and trend of the folds. Towards this end much valuable information has been obtained.

FOSSILS.

For many years there has been a widespread desire among certain classes of citizens for a more accurate account of the organic remains found in the rocks of the state. This demand is becoming more and more urgent in the light of the fact that fossils have such a distinct economic importance in the determination of the age of useful mineral deposits and hence serve as the most trustworthy guides known in the further development of the natural wealth of a region. In the attempt to satisfy properly the demands arising in connection with the work of this character it is at present contemplated to present as briefly as possible, (1) an index to the fossils of the state, through means of which forms now known to occur within the limits of the region under consideration may be recognized readily without recourse to great libraries; (2) a list of the works pertaining to Iowa fossils, in which is brought together all that has been written on the subject and which is now widely scattered and practically inaccessible; (3) a concise summary of all that has been done up to the present time in this branch of science so far as it pertains to the state of Iowa; and (4) an index to a more comprehensive study in the solution of problems now more or less obscure concerning the arrangement and relations of the various strata.

The economic value of fossils is commonly overlooked. Ordinarily these remains of ancient life are regarded merely as curious; to the specialist the interest in the old organisms is wholly scientific; but by him who is fairly well acquainted with their character the rocks are read as a printed page. One of the best established facts of modern geological science is that there is an intimate relation between all mineral deposits and the surrounding rocks; hence the age of particular beds becomes an important factor in the early attempts to develop new mineral districts. These inferences rest upon one of the cardinal principles of geology, that the geological sequence of strata is determined most readily by the remains of life contained. Thus in reality fossils are labels on the rocks, telling one at a glance the age of the beds being worked and providing the most reliable guides that could possibly be secured in directing the miner and prospector to the layers most likely to contain the mineral sought.

In connection with the work recently done and which is being continued, a typical series of the most characteristic fossils of each geological formation will be collected and arranged in the cabinet for ready reference. Eventually a report on the subject will be prepared in accordance with the lines already marked out.

STATISTICS.

In order to compare the yearly progress of the different industries dependent on the geological resources of the state, it is desirable to collect annual statistics in regard to the work and output. The information obtained is regarded as strictly confidential in every way, and the tables of comparison are arranged by counties in such a manner as not to disclose the details of any individual business.

Work Yet to be Taken Up.

It perhaps is hardly necessary to state that it is a physical impossibility with the present resources of the Survey to consider all subjects in the beginning. Some must wait until others have been disposed of. With the means at command at present the different topics must be taken up and investigated in the order of their importance. Among the subjects which have not as yet been taken up in connection with the other work are a number of very considerable import.

The *lignites*, or brown coals, of the Cretaceous deposits of northwestern Iowa are now known to be of considerable importance; and their extent is much greater than heretofore suspected. Different localities are reported in which the veins of brown coal are upwards of four feet in thickness. By comparatively inexpensive methods of cleaning and grinding it may be made into briquettes which have the properties and qualities approaching the harder coals. Should the deposits be found as extensive as they now seem, the whole northwestern part of the state and the adjoining portions of Nebraska, South Dakota and Minnesota could be supplied with a very desirable fuel, which would compete with the eastern coals now largely used in these districts.

The *peats* of the state are known to be quite extensive, and with proper treatment can doubtless be utilized to advantage as fuel in those localities where other kinds are difficult to obtain. In this connection their distribution and availability become important subjects for future consideration.

The *iron ores* of the state have never received any attention, and their occurrences should probably form a theme for early investigation. The various kinds which occur throughout the Coal Measures and in the different regions of northeastern Iowa as well as elsewhere require careful consideration. The extent, distribution and utilization of the several kinds of ore and the methods best suited to their development should receive the attention they deserve.

The deposits suitable for the manufacture of *mineral pigments* is an important subject. In Jasper county an industry has been started for manufacturing metallic paint. Though only recently begun the output is already over 2,000,000 pounds a year. There are many other localities which doubtless furnish materials which are equally well adapted to such uses. There are, besides, ocher and other substances which might also be utilized to a great advantage.

Many *sands* of the state might be readily used not only for building but for other purposes. At numerous points these sands are sufficiently pure to admit of the manufacture of a good grade of glass. In the northeastern part of Iowa, in Clayton county, siliceous materials of this description have been shipped for a number of years to Chicago and Milwaukee for glassmaking purposes. There is no reason, however, why these industries should not be started up within the limits of the state.

The *crystalline rocks* of Iowa, though small in extent, demand investigation. The principal area is in the northwestern part of the state and the stone occurring there forms the most durable building rock known. The origin, relations and accessibility of this rock require attention. Large boulders of granite and other crystalline rocks, forty to fifty feet in diameter, occur widely scattered over the northern part of the state. Many of these have been quarried for building purposes and the extent to which they are utilized should be understood.

The so-called *marls* of Iowa, though not yet used for fertilizing purposes, may give rise before many years to a new industry. It is desirable to know the localities and extent of these deposits.

The *mineral waters* of the state are many. A description of the different kinds, their origin, composition and medicinal properties, as well as the extent to which they are at present used, should be considered.

The *water powers* deserve more attention than they now receive. The recent great development in the use of electricity furnishes a ready means for utilizing the waste power of streams by converting it into a form of energy of the highest practical utility. The amount of power that may be developed in the streams of Iowa is a question of great importance to every community.

PUBLICATIONS OF THE SURVEY.

The general plan of publication of the reports of the Survey has already been explained. It remains to state in this place what has been done toward placing the results of the work before the public. Two volumes of about 500 pages each have been made ready and a third is now in press. The contents of the three are appended.

VOLUME I. FIRST ANNUAL REPORT, FOR 1892.

480 Pages, 10 Plates, 26 Figures.

CONTENTS:

Administrative Report of the State Geologist.
Administrative Report of the Assistant State Geologist.
Geological Formations of Iowa; by Charles Rollin Keyes.
Cretaceous Deposits of Woodbury and Plymouth Counties, with Observations on their Economic Uses; by Samuel Calvin.
Ancient Lava Flows in Northwestern Iowa; by Samuel W. Beyer.
Distribution and Relations of the Saint Louis Limestone in Mahaska County, Iowa; by Harry Foster Bain.
Annotated Catalogue of Minerals; by Charles Rollin Keyes.
Some Niagara Lime Burning Dolomites and Dolomitic Building Stones of Iowa; by Gilbert L. Houser.
Bibliography of Iowa Geology; by Charles Rollin Keyes.

Price, in cloth, 85 cents; postage, 31 cents.
In paper, 70 cents; postage, 26 cents.

VOLUME II. COAL DEPOSITS.

536 Pages, 18 Plates, 221 Figures.

CONTENTS:

Chapter I.	Introduction.
Chapter II.	Origin of Coal.
Chapter III.	Carboniferous Basin of the Mississippi Valley.
Chapter IV.	General Geology of the Coal Region.
Chapter V.	Lithology of the Coal Measures.
Chapter VI.	Stratigraphy of the Coal Measures.
Chapter VII.	The Coal Beds.
Chapter VIII.	Description of the Coal Beds now operated in Northcentral Iowa.
Chapter IX.	Description of the Coal Beds in Central Iowa.
Chapter X.	Description of the Coal Beds of Southeastern Iowa.
Chapter XI.	Description of the Coal Beds of Southwestern Iowa.
Chapter XII.	Description of the Coal Beds of the Outliers in Eastern Iowa.
Chapter XIII.	Composition of Iowa Coals.
Chapter XIV.	Waste in Coal Mining.
Chapter XV.	The Coal Industry.

VOLUME III. ANNUAL REPORT (IN PRESS).

CONTENTS:

Administrative Report of the State Geologist.
Administrative Report of the Assistant State Geologist.
Administrative Report of the Chemist.
Work and Scope of the Geological Survey.

Gypsum Deposits of Iowa; by Charles Rollin Keyes.
Clay Industries of Western (half of) Iowa; by E. H. Lonsdale.
Certain Building Stones; by S. W. Beyer.
Thickness of the Paleozoic Formations in Northeastern Iowa; by W. H. Norton.
Carboniferous and Devonian Outliers in Northeastern Iowa; by W. H. Norton.
Glacial Markings in Southeastern Iowa; by F. M. Fultz.
Cretaceous Rocks of the Sioux River; by H. F. Bain.
Zinc Industry; by A. G. Leonard.

In addition to the reports mentioned a number of papers announcing results worthy of special notice have appeared in some of the principal scientific journals. During the year articles of a popular character have been given to leading newspapers of the state. Besides bringing out facts of both permanent and temporary value and supplying in a measure an ever increasing demand for information in advance of the completed lines of investigation, these articles keep the public in close touch with the progress of the work in the different parts of the state. The usefulness of this feature and the deep and widespread popular interest taken in it has been very much greater than was at first anticipated. During the past year upwards of fifty articles of this kind have been sent to various newspapers. The urgent demands for information concerning the different lines of work have been so numerous that even greater efforts in the same direction will be made during the coming season.

FUTURE OF THE GEOLOGICAL SURVEY.

The foregoing is a brief statement showing the scope of the survey and the methods followed in investigating the natural resources of the state. A summary is also given of what has already been accomplished during a period of but a little over one year, of the work which is in progress and of the work which is yet to be taken up. It may be readily inferred that a geological survey of a region, a thorough investigation of the useful deposits of a given district, is not a luxury which a state may well be without; but it is one of the fundamental factors of all industrial activities. In the words of one who has been, and is yet, prominent in the affairs of State, a properly conducted geological survey "is an investment which will yield good returns to the poor as well as to the rich; it is a work of improvement which will enhance the value of property; a work in harmony with the peace-loving spirit of the age, in accordance with which the energies of the state are being directed more and more toward industrial development."

The demands which are continually being made upon the survey from nearly every part of the state show clearly the widespread interest taken in the different lines of investigation with which it has to deal. As the work continues the fact is coming to be more and more appreciated by the people in general that the class of investigations now being done is what should have been undertaken a generation ago.

The work of the geological survey is now fairly begun. The plans of operation along different lines are fully laid out. The investigations undertaken are progressing systematically. The results are rapidly accumulating. In order that the work may be carried on to completion time is required. A fitful existence can only give rise to a depreciation, in a great measure, of the results already attained. That the attainments may last for all time to the benefit of the state liberal provision is necessary to carry the work to completion.

For reasons fully stated elsewhere practically only one field season has been allowed for work. The first appropriation has thus been made to cover a little more than a year and a half. In order that the work may be continued with the same vigor during the next two years the annual appropriation should not be less than that in the past. There is, however, a desire to have the investigations go on more rapidly, the reasons for which have already been stated. If the work is to be extended in the manner expected an enlargement of the means for the next one, two or more biennial periods, as the case may be, is necessary, after which a diminished amount would suffice until the completion of the survey. The advantages recommending this plan rather than that of smaller expenditures extending over a long period of years, are greater economy, more definite limitation to the completion of the work, quicker attainment of results, and earlier presentation of the information to the public.

CRETACEOUS DEPOSITS OF THE SIOUX VALLEY.

BY

HARRY FOSTER BAIN.

CRETACEOUS DEPOSITS OF THE SIOUX VALLEY.

BY HARRY FOSTER BAIN.

The Cretaceous formations of the upper Missouri region have long attracted attention. As early as 1839 the rocks at the mouth of the Sioux river, near the site of the city of the same name, were examined by the French explorer Nicollet. Since that time the locality has been visited by a number of workers and by them has been made the starting point for all geological investigations in the region. While the knowledge regarding the beds along the Missouri river has become quite complete, information pertaining to exposures along the various tributaries has been almost wholly neglected. Along the Sioux river, which forms the northern third of the western boundary of Iowa, the formations have received no notice except that which has been merely incidental to the examinations of more western districts.

In prosecuting the recent work it was found advantageous to begin with the well-known outcrops at Sargeant bluff and Sioux City. The Cretaceous exposures, however, begin some distance further down the Missouri river, so that the section of the Cretaceous made is not complete for the entire western border of the state. There are at least 100 to 200 feet of strata referable to this age which are below the horizon taken as the base line in the present connection.

The difficulties attending the study of the rocks of northwestern Iowa arise from two sources. In the first place the various members of the Cretaceous of this region are very slightly indurated. The second difficulty is caused by the great thickness of the drift throughout the region. On account of the softness of all the materials, exposures made by streams are more rapidly obscured than ordinarily and the stratigraphical details are not easily made out after a short period. On the other hand there has been produced topographical effects of wonderful beauty and variety.

From Sargeant bluff to a considerable distance beyond Sioux City the hills are made up almost entirely of loess, the Cretaceous beds being exposed only a few feet above the river level. The loess of this region is the typical, fine, homogeneous material retaining its usual characteristic topography. It is marked by picturesque bluffs from which single points stand out as isolated peaks 150 to 300 feet above the water level. North of Sioux City the bluffs on the east side of the Sioux river rise from the water's edge. On the opposite side of the stream as far up as Westfield there is a broad level plain which stretches away westward to the Missouri. The level bottom land in Dakota spreads out between the two rivers for a distance of twelve to fourteen miles. Beyond is the low fringe of green timber marking the course of the Missouri and back of this again rise the high bluffs on the Nebraska side of the stream, too far away to be distinguished except in the clearest weather.

About two miles below Westfield low rounded drift hills appear on the west border of the Sioux and it is here that the Sioux valley proper opens into that of the Missouri. From this point down to its mouth the former stream flows across the flood plain of the latter, the one keeping close to the eastern edge, while the channel of the other is well towards the opposite side. In this portion of its course the Pleistocene deposits along the Sioux river are very largely loess. North of Westfield the latter becomes less conspicuous.

The drift hills of the Sioux valley proper, from Westfield to Hawarden, have low rounded outlines. From the latter point to Granite station gravel beds become more prominent, forming a series of terraces which are usually well marked and extend along the river for miles. The basal beds of the drift at this place are made up almost entirely of large rough boulders of considerable variety, yet in the main derived from the Sioux quartzite. In size they range from ten feet in diameter down to the smallest pebbles. There is a more or less complete stratification noticeable in their arrangement. At Granite, the first exposure of Sioux quartzite is encountered in place. Two miles to the north the river cuts through ledges of this rock forming the most southerly of the gorges which mark a considerable portion of its course.

The large number of excellent exposures in this region allows the order and general succession of the rocks to be made out with considerable detail. The structure is at no point very complex. The beds have

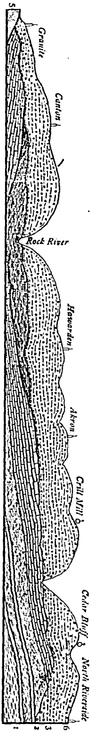


Figure 1. Geological Section along the Sioux River.

been practically undisturbed and apparently have now nearly the same inclination as when originally deposited, with a gentle slope seaward, in this case to the northwest. In a few places low anticlines and broad, shallow synclinal troughs are noticed.

It has recently been shown by Calvin* that the Cretaceous beds of northwestern Iowa contain the record of continuous subsidence; that the different formations were in fact laid down, in part at least, contemporaneously, the more open sea depositions gradually encroaching farther and farther inland and overlapping the more strictly littoral deposits as the shore sank beneath the invading waters.

In working up the Sioux river from its mouth, the rocks are seen to have a slight dip to the north. From Sioux City to Hawarden the different beds pass successively below the water level. From Hawarden to Canton only a few outcrops are seen, and the interval seems to represent a low syncline. At the latter point the Niobrara again appears, followed soon by the Sioux quartzite, the beds which further southward lie immediately below the chalks being here apparently absent. The general relations of the formations are represented in Figure 1, which is a section along the Sioux river from Sioux City northward to the state line. Number 1 is the Dakota, with two sandstone bands at the top; 2 is the Benton shale; 3, the Niobrara chalks; 4, the Pierre shale in the trough with Rock river in the middle; 5 is the Sioux quartzite; 6 is the drift and loess mantle.

At North Riverside the section exposed is as follows:

* Cretaceous Deposits of Woodbury and Plymouth Counties: Iowa Geol. Sur., vol. I, First Ann. Rep., pp. 147-161. Des Moines, 1893.

DAKOTA AND BENTON FORMATIONS ON THE SIOUX RIVER. WESTFIELD.

		FEET.
7.	Loess	30
6.	Sandstone, calcareous, white, fine-grained, shaly in part, with abundant characteristic plants	15
5.	Shale, variegated in color, with streaks of sand	28
4.	Lignite, impure	½
3.	Shale, clayey, variable, with bands of ferruginous nodules	10
2.	Sandstone, coarse-grained, orange to red in color, containing quartzitic concretions	10
1.	Shale, clayey, dark gray to drab in color	12

Further north these strata pass successively beneath the river until at the Crill mill only the upper sandstone (number 6) is seen. The section at this point, which is one of the most instructive now exposed above the water level, is as follows:

		FEET.
5.	Drift	50
4.	Limestone, chalky	12
3.	Shale, dark blue to drab, sandy in places	50
2.	Sandstone, fine-grained, calcareous, light buff to white	20
1.	Lignite (exposed)	1½

A short distance above the point mentioned the sandstone (number 2) passes beneath the level of the river. The drab shales persist with frequent outcrops some twelve miles farther. The chalky limestone (number 4) continues to be exposed at intervals to the north.

Within three miles of Hawarden the chalk rock becomes covered at one point by a later deposit. The section exposed is:

		FEET.
3	Drift	35
2.	Shale, drab to blue, argillaceous, sandy in part, containing selenite crystals	25
1.	Limestone, fossiliferous, thin-bedded, with chalky partings	20

In the extreme northwestern corner of Iowa the Sioux quartzite rises above the water level of the river. While no actual juncture between any of the Cretaceous beds and this rock have been observed within the limits of Iowa, a number of exposures in adjoining portions of South Dakota show that it is covered in part, at least, by the chalk rock of the preceding section.

Meek and Hayden, in their studies of the Cretaceous in the upper Missouri region, differentiated five formations*:

5. Fox Hills, sandstones and arenaceous shales.
4. Fort Pierre, blue, argillaceous shales.
3. Niobrara, chalks and limestones.
2. Fort Benton, variegated shales.
1. Dakota, sandstones.

The lowest member, the Dakota, has been recognized over a wide extent of territory, and is commonly regarded as the basal member of the Cretaceous in the upper Missouri region. To it the rocks in the neighborhood of Sioux City were early referred. While in the main the differences between the Dakota and Fort Benton are well marked, a gradation between them has been frequently noted, especially in the more eastern portions of its limits. This transition is so notable in Iowa that White grouped the two together under the name Woodbury shales and sandstones. The difficulties encountered in separating the formations were also clearly recognized by Hayden. The general utility, however, of the division has not been doubted. While there is no well marked physical break between the Dakota and Fort Benton formations, they are as a rule sharply contrasted, and at numerous points a well defined line of separation may be recognized. In Iowa the relative thinness of the beds make the separation

* U. S. Geol. Sur. Terr., vol. IX, pp. xxiv–xxv. Washington, 1876.

of less value stratigraphically than elsewhere, though it may still be recognized.

The Dakota, as developed in Iowa, consists of sandstones, clayey and sandy shales and may on the whole be characterized as prevailingly arenaceous as contrasted with the overlying argillaceous beds. Described more particularly the Dakota contains certain well marked sandstones, in part calcareous, fine-grained, white or buff in color, and in part drab, coarse-grained, ferruginous, assuming in places quartzitic facies, complex beds of clay and clay shales of variable color and texture, sandy shales and thin beds of lignite and coal of different degrees of purity.

At the well-known outcrop at Sargeant bluff, seven miles below Sioux City, there is exposed:

	FEET.
5. Loess, thickening back from the river and forming bold bluffs 100 to 150 feet high	40
4. Sandstone, fine-grained, light buff to white above, coarse, orange-yellow below	25
3. Lignite, more or less earthy, usually of a dark purplish hue	1½
2. Shale, variegated, brilliant orange to dark olive green, with interstratified beds of fine white sand and thin bands of ferruginous concretions containing plant remains	18
1. Shale, sandy, reddish, becoming drab to orange below; and containing large ferruginous sandy masses with plant remains	25

At the foot of Prospect hill in Sioux City is another exposure of Dakota, where two sandstones are seen separated by shale:

	FEET.
4. Loess	60
3. Sandstone, dark yellow, coarse-grained, with ferruginous concretions	10
2. Shale, clayey, dark blue to drab	12
1. Sandstone, fine-grained, homogeneous, white	20

Probably the best of the exposures examined in this vicinity is the one at Riverside already given. North of this point the lower sandstone (number 2) splits up and becomes shaly. It also thickens considerably and merges more or less with the underlying shales. At the Reese "granite" quarry it exhibits an interesting quartzitic facies. A portion of the sandstone has become indurated and forms a hard, steelgray layer with a thickness of four feet.

At Cedar bluff is a good exposure which has been frequently described. The beds seen here are as follows:

		FEET.
9.	Loess	50
8.	Limestone, thinly bedded, exposed in slope above	20
7.	Shale, buff, sandy, with layers of sandstone one to two inches thick, and ferruginous concretions	25
6.	Shale, drab to dark blue, fine-grained, argillaceous.	28
5.	Sand and lignite mixed	1½
4.	Sandstone, white, calcareous, loosely consolidated	8
3.	Shale, argillaceous, sandy in part, drab to blue	12
2.	Sandstone, white to orange, coarse-grained, with ferruginous concretions	10
1.	Shale, variable, largely arenaceous, imperfectly, (exposed)	35

Numbers 1 to 5 inclusive may be referred to the Dakota, 6 and 7 being Benton and 8 Niobrara. North of this place the Dakota is found at successively lower levels until at the old site of the Crill mill only a thin band of lignite and the upper sandstone members are visible. A short distance beyond, the lower member of the Cretaceous passes beneath the level of the river and does not reappear again in Iowa.

The following may be given as a general section of the Dakota as found in the vicinity of Sioux City:

	FEET.
5. Sandstone, fine-grained, calcareous, light buff to white, well characterized by an abundance of plant remains	20
4. Shales, argillaceous, arenaceous in part, very variable in color and texture, containing thin beds of impure lignite and bands of ferruginous nodules	50
3. Sandstone, coarse-grained, shaly in part, with a quartzitic facies; variable in thickness	10 to 30
2. Shale, argillaceous, dark gray to drab	12
1. Sandstone, fine, white, homogeneous	20

Sandstone number 1 is seen at the foot of Prospect hill, and above it at this same place is shale number 2, believed to be the same as the one seen at the base of the pit of the Northwestern Pipe and Tile Works at Riverside. Number 3, appearing first at Prospect hill, is well characterized at North Riverside, and becomes quite prominent from there to Cedar bluff, at which place it has become divided and assumed a shaly character. Beyond, it thins out considerably and soon passes below the water level. Number 4 is the most prominent bed of the entire formation. It is exposed at Sargeant bluff, is prominent at North Riverside, and the lignite at the base of the Crill mill section is believed to belong to it. Number 5 is considered the uppermost member of the Dakota group. It is seen caping the section at Sargeant bluff, is at the top of the Riverside section, appears at Cedar bluff and at the base of the Crill mill exposure.

The relations between the Dakota and Benton are, perhaps, most sharply defined at the Crill mill. Here the upper sandstone of the Dakota is a massive, quite homogeneous bed, twenty feet thick. Immediately overlying it are strata of undoubted Benton age.

The Benton formation, as defined by Hayden, is a dark gray, laminated, plastic clay containing abundant pyrite concretions and numerous selenite crystals. It is extensively developed along the upper Missouri and in the Black Hills. Its estimated total thickness is 800 feet. In passing down the Missouri river from Pierre it gets successively thinner and thinner, until in Iowa it is represented by a comparatively unimportant bed of shale scarcely fifty feet in thickness. The southern limit of the formation is not well defined. At Cedar bluff, beds 6 and 7 may be referred to it. Calvin gives its most southerly exposure at about four miles below the mouth of Broken Kettle creek. There are numerous minor exposures near the mouth of that stream. In the Crill mill section the Benton forms the median portion and is quite well exposed. The most northerly exposure known is on the Dakota side about eight miles north of Akron, at the site of the old Otis mill. It is also more or less completely exposed at a number of intermediate points.

The formation is represented by a dark blue to drab shale, slightly arenaceous in places, and somewhat calcareous near the top. Selenite is frequently abundant. The thickness of the beds is about forty feet, though at Crill mill a slightly greater vertical extent seems to be indicated. A number of vertebrate fossils have been found in the shales, and molluscan remains are not uncommon. *Inoceramus problematicus*, Schlotheim, is especially common; though this fossil is found occasionally in all the members of the Cretaceous of this region, being most abundant in the Niobrara.

The close relations existing between the Benton and the Niobrara are everywhere noticeable. The upper portion of the former becomes gradually more calcareous, thin bands of limestone divide the shale, and the fossils of the superior member appear. These facts, which have

CHALK CLIFF ON THE SIOUX RIVER. WESTFIELD.

been widely noticed, has led to the grouping of the two formations under the name Colorado, as proposed by King.

The Niobrara division has probably a wider geographic distribution in Iowa than any other of the Cretaceous deposits. It is also the most constant in lithological features and is characterized by numerous species of fossils, so that its recognition is easy and secure. A general section of this member is:

	FEET.
3. Chalk	4 to 6
2. Limestone, soft, splitting into thin slabs and crowded with shells of Inoceramus	12
1. Chalk	12

On the west side of the Missouri these beds extend for a distance of nearly thirty miles below Sioux City, though in Iowa they have not been recognized much below the northern boundary of Woodbury county. They are known to extend as far east as Sac county. They are exposed in the slope above the top of Cedar bluff and in the section at Crill mill. In the neighborhood of Westfield the Niobrara forms the major portion of the hills. An exposure immediately beyond Akron shows a thickness of twenty feet or more, and three miles below Hawarden it is again seen. Beyond the last named point the beds apparently pass below the river level and are not seen again until Canton, South Dakota, is reached. At this point the chalk rock was formerly quarried and used for building purposes. The superposition of the Niobrara on the Sioux quartzite is shown at a number of places near Carson, South Dakota, about five miles north of the Iowa line, where a thickness of fifteen feet of Niobrara strata is seen overlying the quartzite.

At all the exposures just mentioned, as well as a large number of others in adjoining regions, the Niobrara presents similar lithological characters. It is composed of varying proportions of chalk and limestone. The former is soft, white to buff in color, more or less fossiliferous, and while in places quite free from limestone for several feet, in others it is interbedded with it. The limestone is also soft, very fossiliferous, and quite thinly bedded. The different layers of limestone are separated by thin beds of chalk usually from one and one-half to ten inches in thickness.

Beds referable to the Pierre are exposed about three miles south of Hawarden, in Sioux county (Tp. 94 N., R. XLVIII W., Sec. 15). At this place the river makes a sharp bend and washes the face of a high bluff. The Chicago, Milwaukee and St. Paul railway has been built along the base of this bluff, which is at one place cut by a small ravine. The following section is exposed:

		FEET.
3.	Drift	30
2.	Shale, drab to blue, argillaceous, sandy in part, with numerous selenite crystals	25
1.	Limestone, fossiliferous, thinly bedded, with chalky layers	20

The lower portion (number 1) is manifestly Niobrara. It exhibits all the lithological characters which distinguish that formation in this region, and contains many of its most characteristic fossils. The shale which lies above the chalk is fine, drab, argillaceous, rather unctuous, contains some carbonaceous matter, balls of pyrite, thin veins of gypsum and much selenite. The latter usually occurs as small rosettes in the clay, though well formed crystals are not uncommon. The deposit is quite homogeneous, being to all appearances of the same character throughout its entire thickness. It is finely fissile, splitting easily though not sharply along the bedding planes. It is firm at first but crumbles under weathering influences, though maintaining an abrupt face in exposures. Along planes of division sand is not uncommon, though always in small quantities.

In all its lithological characters the Hawarden beds agree closely with the description given by Meek of the lower member of the Pierre formation as occurring throughout the upper Missouri region. There is little upon which to base a paleontological correlation. The fossils occurring in the Hawarden beds are rare and very imperfectly preserved. No species can be recognized. This is, however, itself evidence of the correctness of the correlation as the lowermost portion of the Pierre is characteristically non-fossiliferous. The general geological relations of the region bear out the probability of the Pierre age for the Hawarden beds. The same shales have recently been opened up at Caliope, and are there used in the manufacture of brick. The beds are exposed near the mouth of Rock river and extend up that stream some distance. Clays and shales, probably belonging to the same series, are also exposed near Canton, South Dakota.

The earliest indication of the presence of Cretaceous in the upper Missouri region is found in the account of the Lewis and Clarke expedition to the northwest. Both Nuttal and Long also collected fossils from this region; and in 1832 the Prince Neuwied obtained Cretaceous types from below Fort Pierre. Nicollet,* in 1839, noticed the presence of Cretaceous in Iowa, and seems to have recognized the Pierre beds farther up the Missouri, though apparently confusing some of the other members of the series. In 1849, Evans,† one of Owen's assistants, visited the region and collected *Inoceramus crispi* and other forms from the Pierre beds. No attempt, however, seems to have been made to construct a section of the rocks showing

* Sen. Doc., 26 Cong., 2nd Sess., vol. II, No. 237. 1841.
† Geol. Sur. Wis., Iowa, Minn., p. 195. 1852.

the relations of the different strata in the various localities. The first published section of the Cretaceous beds of the upper Missouri appears to have been that given by Meek,* in 1856. In this section five members of the Cretaceous were recognized and numbered. Though number 4 of this series corresponds essentially to the Pierre, it was not given this name until 1861.† It was then recognized as being developed principally in the Bad Lands, at the Great Bend of the Missouri, and extending down that river to near Bijou hill ten miles below the mouth of White river, where the lowest member was exposed. Hayden‡ mentioned its occurrence in the hills near the mouth of the Niobrara, and Calvin ‖ refers the dark beds of shale capping the Niobrara bluffs at Yankton to this age. This has been regarded as the eastern limit of the Pierre, and is forty-five miles southwest of Hawarden. It is significant that Meek, in describing the lower portion of the Pierre, uses these words: "This bed usually occupies depressions in the previously eroded upper surface of the formations beneath."§ This observation, taken in connection with the distance from the other outcrops and certain indications of unconformity seen at Hawarden, lead to the conclusion that the Hawarden beds may constitute an outlier. It seems probable that it covers but a comparatively small area and constitutes a remnant of a larger body now removed through erosion. The extension eastward of the Pierre limits, the recent discovery of Niobrara in Sac county, Iowa, the marked Fox Hills aspect of certain fossils discovered by White ¶ in 1873 renders it very probable that the Mesozoic seas spread much farther eastward than has hitherto been commonly recognized.

* Mem. Am. Acad. Arts and Sci., vol. V, 405. 1856.
† Proc. Acad. Nat. Sci., Phila., vol. XIII, p. 419. 1861.
‡ U. S Geol. and Geog. Sur. Terr., First Ann. Rep., pp. 54-55. 1873.
‖ Proc. Iowa Acad. Sci., vol. I, pt. iii, p. 12. 1893.
§ Proc. Acad. Nat. Sci., Phila., vol. XIII, p. 424. 1861.
¶ Am. Ad. As. Sci., vol. XXI, pp. 187-192. Cambridge, 1873.

CERTAIN DEVONIAN AND CARBONIFEROUS OUTLIERS IN EASTERN IOWA.

BY

WILLIAM HARMON NORTON.

CERTAIN DEVONIAN AND CARBONIFEROUS OUTLIERS IN EASTERN IOWA.

BY WILLIAM HARMON NORTON.

The isolated areas of rocks which occur in eastern Iowa in districts occupied by strata much older, have centered around them problems of great interest.

In modern geological work the aim is to picture as completely as may be the actual conditions prevalent over given areas during successive periods of time. In attaining this object, few determinations avail more or give a better key to the minutiæ of conditions existing at any time, than the correct determination of the land and water areas. Thus, stratigraphical work often has for one of its leading objects the tracing of ancient shore lines, in which connection the study of outliers becomes especially important.

The greater part of the area under consideration is made up chiefly of Silurian strata. In Linn, perhaps two-thirds, and in Cedar one-third of the county is covered by Devonian. Its eastern margin as now mapped runs in a more or less irregular line from the northwest corner of Buchanan to the middle of the southern boundary of Cedar county. The eastern border of the Carboniferous is some thirty miles to the west and approximately parallel to it. Neither of these lines are regular, but are curved and bent through erosion of the strata.

Between the Mississippi and the known Devonian areas of northeastern Iowa is a broad belt of Silurian rocks. Within this area several outliers of Devonian age have recently been discovered.

Lying between the eastern border of the Coal Measure deposits of Iowa and the corresponding beds in Illinois is a district varying considerably in width, in which no Coal Measures are now known except such as are found in isolated and limited areas. Whether these form part of a once continuous deposit connecting the two great coal fields, or whether they are the original depositions of a series of small unconnected or partially connected lagoons, are questions of interest which still remain open. As a contribution to their final solution the results of a detailed examination of several of these outliers are presented in the following pages.

An element which complicates the task involved in the interpretation of these outliers is the close lithological similarity of certain sandstones, one being Devonian and the other Carboniferous in age. This emphasizes the fact that the determinations to be of value, must be based upon the evidence of the fossils found.

DEVONIAN OUTLIERS.

Bertram. At Bertram, Linn county, Iowa, the Chicago and Northwestern railway has cut through the side of a low hill some fifteen or twenty rods east of the bridge over Big creek, displaying the following section at the west end of the exposure:

		FEET.
3.	Soil and drift	2
2.	Limestone, (Bertram beds)	15
1.	Sandstone, yellowish, shaly in part	½

The sandstone is thinly laminated and contains many minute fragments of brachiopods and traces of vegetal remains. It is overlain and interstratified with a clay, evidently weathered from a fine-grained argillaceous shale, fragments of which it contains. The clay is usually light gray in color, but in places becomes dark and carbonaceous. This thin layer of sandstone and shale continues to the east some nineteen feet, where it dips beneath the surface. One hundred feet to the east the sandstone reappears, filling a chimney thirteen feet wide, extending from the summit to the base of the rock section. On the western side of this chimney the line of juncture with the limestone is well defined and nearly vertical. Indeed, at the top a thin layer of limestone projects beyond the edge of the sandstone. On the eastern side the line of junction is abrupt at the base, but above curves gently upward and becomes horizontal as the sandstone opens beyond the chimney to the end of the cut. The upper layer of sandstone is here two feet four inches thick and is considerably indurated. The layers beneath are thinner, for the most part fragmental, or completely disintegrated. At the base, underlying the sandstone, the same shale occurs as at the west end of the cut. Although the limestone is largely weathered into "chipstone," after the habit of the Bertram beds, the unconformity is very marked. The "burrowing" of the sandstone and shale between the layers of the limestone to some distance from the chimney seems to prove that the deposit is not a channel filling, but rather a pocket of a later deposit than the limestone. Minute fragments of fossils are not uncommon in the sandstone, but any of sufficient size to admit of identification are extremely rare. Specimens of the following genera and species were collected, showing the age of the outlier to be Devonian :

Atrypa occidentalis, Hall.
Atrypa reticularis, Linn.
Cyrtina hamiltonensis, Hall.
Orthis, near, if not identical with, *O. iowensis*, Hall, fragments.
Spirifera, fragments of three species including a dorsal valve, one near *S. subattenuatus*, but more nearly semicircular in form and with fewer plications.
Tentaculites, indistinguishable from *T. spiculus*.
Acervularia davidsoni E. & H., fragments of coralla, each with several cells.

Lisbon. A sandstone apparently the same as the one just described occurs one-third of a mile southeast of Lisbon, in Linn county (Tp. 82 N., R. V W., Sec. 12, SW. qr., SE. ¼). Here on the side of a hill there is a small outcrop of a soft, light colored or white sandstone weathering to yellowish or brown. It contains a few small nodules of greenish clay and in places is so friable that it has been used in the neighborhood for scouring. It contains a few silicified fragments of brachiopods, none large enough to identify except one which seems to be a fragment of *Atrypa reticularis*, Linn., but bearing a general resemblance to those from the Bertram outlier. The base of this sandstone lies thirteen feet above the water of the adjacent creek. It is about ten feet thick, abutting directly against the LeClaire limestone which here rises ten feet above it and in adjacent hills considerably higher still. Across the creek the LeClaire outcrops a few rods to the east; also to the north, and to the south, so that this body of sandstone must be limited to the present valley of the creek and does not extend a distance of more than eighty rods.

About two miles south of Lisbon a similar sandstone occurs in the northwest corner of section 35 (Tp. 82 N., R. V W.). Some twenty years ago it was quarried for cellar walls, but the excavation has been filled long since, and now the site is marked only by a few small fragments of a reddish yellow, rather soft sandstone, scattered over a few square rods in a cultivated field.

Clear Creek. Along the banks of this creek, near the northwestern corner of Cedar county (Tp. 82 N., R. IV W., Secs. 28 and 29), sandstone outcrops along a line measuring from east to west nearly two miles. In only one place, on the farm of Peter Bore, is it exposed in the ledge. This is three feet thick, thirty-five feet long, and rests directly and unconformably on the LeClaire dolomite. The sandstone here is massive and indurated. Blocks have been quarried eight to twelve inches thick and two to three feet long. It is thirty-five feet above the flood plain of the creek, and, as indicated by fragments of sandstone, may extend thirty rods to the north.

Elsewhere along Clear creek the sandstone is in the form of weathered, rudely hemispherical boulders of disintegration, partially embedded in the soil of the steeply sloping hillsides. The largest of these is fifteen feet long and five feet high, but the most of them are much smaller. The shallow depression in the LeClaire, once no doubt occupied by a continuous body of sandstone, must be narrow, since, except at the place just mentioned, it does not appear on the south branch of the creek, where the LeClaire stands out in bold, massive ledges fifteen to sixty feet high, and is not found in the valley of a small stream running parallel to Clear creek a few rods to the north. No fossils have been found in this bed and it is placed with the Devonian outliers only because of general lithological similarity and because it is but two miles distant from the Lisbon outlier which lies directly west.

Lithologically little or no difference exists in the sandstones of the outliers described. All are fine-grained, normally friable and light colored, but weathering into firmer rock, of reddish and yellow hues and gray or brown surfaces. While at Lisbon and Bertram part of the rock is friable, other portions are as indurated as elsewhere.

Canton. A yellowish gray sandstone, similar to those described above, outcrops about half a mile north of Canton in Jackson county (Tp. 85 N., R. I E., Sec. 18, SW. qr., NE. ¼). It occupies a narrow shelf in the Upper Silurian limestone, sixty feet above the present flood plain of the Maquoketa river, and extends east and west along the south slope of the hill a distance of about eighteen rods. The total thickness as defined by outcrops of the Upper Silurian both above and below it, cannot be over twelve feet. As shown in a well on the crest of the hill the limestone there rises between twenty and thirty feet higher than the sandstone. The latter, which occurs in a field in scattered boulders and with one or two ledges a foot or more high, presents nothing to differentiate it from perhaps a dozen or more other outliers of sandstone in northeastern Iowa. Fortunately, however, at the western end of the outcrop on the brow of a hill, a road crosses it, displaying a very interesting section. On the west side of the road there are noticeable some small, badly weathered boulders of brecciated limestone, which in the structural and lithological characteristics of its fragments and matrix are indistinguishable from the lower portions of the Fayette breccia of the Devonian. Three of these boulders were found and half a dozen rudely oval nodules of quartz with pitted surfaces, the latter peculiarly characteristic of the Kenwood shale, which in Linn county lies beneath the Fayette breccia. On the same side of the road the sandstone is exposed in a small gully for a distance of nearly two rods. Above this lies a stiff, gray or greenish unctuous clay, in places highly arenaceous, in others nearly free from sand. It extends five rods up the hill. This clay had been scraped clean in working the road and the surface was substantially free from foreign material. On the weathered surface of the clay, fragments of silicified Devonian fossils are quite plentiful. They comprise *Acervularia davidsoni*, *Atrypa reticularis*, *Orthis iovensis*, a *Strophodonta*, several species of *Spirifera*, one indistinguishable from fragments of a *Spirifera* at Bertram. Specially numerous were the rostral portions of the ventral valve of *Cyrtina umbonata*, Hall, their preservation being due to the fact that this portion of the shell is strengthened by the cardinal area and mesial septum. Still more abundant were fragments of simple rugose corals, and of favositids.

The occurrence of these remnants of Devonian beds of considerable thickness thirty miles east of their nearest outcrops was entirely unexpected. With the exception of the outliers above described, no Devonian outliers had previously been known in the state and none had been found in this region resting on the rocks of an earlier geological age. It therefore becomes necessary to consider, and if possible disprove every other working hypothesis of the presence of these Devonian fossils and boulders at Canton. Any suggestion of a fortuitous mingling of Devonian drift from northwestern outcrops with the sandstone and clay of a Carboniferous outlier was seen to be quite untenable. The fragments of fossils were silicious, specifically identical with forms from the Devonian sandstone at Bertram. The distribution of Devonian rocks and fossils was exactly conterminous with the outcrop of sandstone and clay on the west side of the road, being found along its entire extent and entirely absent both above and below. Further, this outlier is situated near the margin of the driftless area. The drift here is thin and inconstant, forming a thin, pebbly layer resting on geest or intermingling with it. No drift appears along the outcrop of the sandstone and clay, but seven rods farther up the hill the rotten Upper Silurian limestone is overlaid by a foot of residuary chert and clay mixed with pebbles of the northern drift. The boulders of Devonian limestone and breccia show no indication of transportation by water or ice. Fossils and breccia fragments are in relief. The surfaces are irregular and pitted. The quartz nodules retain their original form and their surfaces are vesicular from dissolution of associated calcite.

To be doubly sure of the relation of the fossils, breccia boulders and quartz nodules, to the clay and sandstone, a hole was dug in the undisturbed bank by the roadside, giving the following section:

		FEET.
3.	Soil, passing below into clay	½
2.	Clay, stiff, reddish brown, free from pebbles (passing below into number 1)	1
1.	Clay, stiff, greenish-gray, sandy, non-calcareous, containing silicified fragments of Devonian fossils	1½

The fossiliferous clay overlies a sandstone, which in turn rests upon a clay, as shown by the fact that a few years since an excavation was made in the middle of the road, and fire-clay was found to extend to a depth of six feet. The intimate association of clay and sandstone is shown by the following section on the east side of the road, where the bank is six feet higher than on the western:

	FEET.	INCHES.
6. Soil, passing into loess	1	
5. Loess, fine buff loam, rather stiff, with the lower inch a transition in color and texture into number 4	3	
4. Clay, fine, white, unctuous, with rounded fragments of sandstone		4
3. Clay, light brown, resembling fire-clay		2
2. Clay, light red, as above, with fragments of reddish sandstone	1	4
1. Clay, white, as above	1	

On the same side of the road no Devonian limestone or fossils were found. The width of the outcrop is the same on both sides.

One mile northeast of this outcrop there occurs at the head of a gully on the northeast $\frac{1}{4}$ of the northeast quarter, of section 18 (Tp. 81 N., R. I E.) a bed of the same clay six feet thick, intermixed with sand and becoming more sandy toward the base. The clay in this gully and that on the roadside have been used for making fire brick for a furnace used in distilling wood-alcohol at Canton and found to be admirably adapted for that purpose.

This clay is said also to outcrop some five miles to the southwest of the above exposure. Though at this point the clay contains fragments of sandstone, no blocks of it appear on the surface.

The little deposit of foreign rock on the brow of the Canton hill is full of meaning. Hitherto there has been no evidence that the Devonian sea ever transgressed the present western boundary of the Upper Silurian in Iowa. This outcrop affords proof that the ancient shore line must have extended at least as far east as Canton. It hardly can represent rocks deposited in some shallow estuary, connected with the Devonian ocean to the west.

More probably it represents one or more distinct beds of the Devonian series elsewhere of considerable thickness and deposited under oceanic conditions. Quartz nodules are common only in the Kenwood shales, though one is sometimes found in the Fayette breccia. The hard drab limestone with conchoidal fracture which forms the fragments of the Canton breccia characterizes a definite horizon of the Lower Devonian from Davenport to Fayette. It lies above the Kenwood shales of Linn county and where its beds are disturbed forms the lower portion of the Fayette breccia. It demands oceanic conditions for deposition and probably for brecciation. The fossils, if unassociated with sandstone and clay, would be referred to no horizon lower than the coralline beds above the breccia. The sandstone and clay are of doubtful position. They may be the Montpelier, or they may be related to the arenaceous material sometimes found associated with the matrix of the Fayette breccia.

It seems, therefore, highly probable that the strata of the Lower Devonian and, perhaps, some of the Upper Devonian, were laid down as far east as the western part of Jackson county and have since been removed by secular decay and erosion. It is a mere accident that in one place, at least, their remains were preserved from the ice invasions on the lee of a hill of obdurate Upper Silurian dolomite, at the margin of the driftless area.

Another outcrop of similar sandstone associated with similar clay was found two and one-half miles northeast of Canton (Tp. 85 N., R. I E., Sec. 9, SE. qr., SE. $\frac{1}{4}$). The outcrop extends a few hundred yards along the upper slope of a hill as scattered boulders. The clay is disclosed in a road thirty or forty feet below. No fossils were found.

CARBONIFEROUS OUTLIERS.

Marion. At several points between Marion and Cedar Rapids, as in the cuts of the Chicago, Milwaukee and St. Paul railroad, and on the old county road, sandstone has been found resting unconformably upon limestone of Devonian age. The sandstone is gray, yellowish, or brown in color, of medium grain, and sometimes contains fragments of woody tissue highly ferruginated. At Kenwood there is a drab, non-calcareous shale about three feet thick. A well twenty-three feet deep, recently dug one and one-half miles south of Marion (Tp. 83 N., R. VII W., Sec. 12, SE. qr.), penetrated, immediately below the drift, a bed of dark shale which, at the depth of twenty-one feet from the surface carried characteristic remains of Coal Measure plants. The species identified were: *Neuropteris rarinervis* Bunb., *N. flexuósa* Sternb., *N. loschii* Brgt., *Alethopteris serlii* Brgt., *Annularia longifolia* Brgt., *Sphenophyllum schlotheimii* Brgt. and, doubtfully, *Rachophyllum corallinum* Lesqrx. A number of fragments were in a condition which prevented only a more or less probable reference to the following: *Megalopteris sp.; Cyclopteris sp.; Pseudopecopteris sp.; Neuropteris clarksoni* Lesqrx, *N. acuminata* Brgt., *N. plicata* Sternb., and *Sphenopteris trifoliata* Brgt. Uncertain as the identification of several of these fragments must remain, it is well to notice that all the species in the above lists are found in localities in Illinois, referred by Lesquereaux to Coal B with the exception of *Neuropteris acuminata* and *Sphenopteris trifoliata.* The former is of uncertain horizon and the latter is found at Clinton, Missouri. Associated with the vegetal remains is a Spirorbis marked by microscopic, transverse, converging striæ of varying thickness and referred provisionally to *Spirorbis* *anthracosia* Whitfield. In the same well, probably above the plant remains, was found a fine *Soleniscus newberryi* Hall. About forty rods south of the well just mentioned, a shaft fourteen feet deep located on a hillside at a station perhaps twenty feet lower than the well, passed through light gray and yellowish, argillaceous, fissile shale, micaceous and containing brownish vestiges of vegetal matter. This overlaid four feet of friable sandstone, yellowish, fine-grained and micaceous.

Monmouth. This outlier was first reported by Osborn. It lies about three miles south of Monmouth, on Bear creek, in Jackson county. The main body of sandstone lies in Tp. 84 N., R. I E., Sec. 32, SW. qr., S. ½, and the SW. qr., SE. ¼, and in Sec. 31, SW. qr., SE. ¼. It occupies a shallow erosional trough in the Upper Silurian limestone, twenty rods wide and nearly a mile long, extending nearly due east and west parallel to the valley of Bear creek, and a short distance from the northern line of Clinton county.

Three quarters of a mile to the northeast, from the eastern end of the main body of sandstone, on a line parallel to the general course of Bear creek, there is another outcrop (Tp. 84 N., R. I E., Sec. 33, NW. qr., NE. ¼) and about a mile west of the western edge of the main body of sandstone there is a third isolated remnant of the same formation (Tp. 84 N., R. I W., Sec. 36) in Jones county. The total length of this outlier from east to west is about three miles.

The eastern outcrop is about twenty rods long and fifteen rods wide. No distinct ledge appears, but boulders of sandstone are numerous, often contiguous, and are evidently fragments of disintegration from a parent mass immediately subjacent. The thickness of the sandstone here is estimated at about forty-five feet, though sandstone boulders strew the steep hillside to the creek bed seventy feet below the supposed bottom of the sandstone. The base is marked by the presence of a coarse sandstone with sparse pebbles and the near presence of an outcrop of the limestone. Between the outcrop first described and the main body of sandstone the valley of Bear creek intervenes, here making a sharp bend to the southeast and returning again to the northwest inclosing a "hogsback" about sixty feet high of Silurian limestone.

The eastern outcrop of the main body of sandstone is in a little gully recently washed out high up on the side of the bluff. In places it is some twenty-two feet thick. From this point the sandstone stretches westward for a distance of a mile, outcropping at the head of a ravine and on the bluff sides in long ledges from two or three to twenty-five feet high. It is evidently one continuous body except where a narrow deep ravine passing north into Bear creek severs it, affording on either side an excellent section of the trough in which it lies. The maximum width of the trough is about twenty-five rods. The depth of the trough is defined by underlying limestone. Its base is about fifty-eight feet above the creek. The limestone rises on each side to a height of twenty-eight feet above the base of the trough, whose depth, as measured from the highest limestone in the hills, is upwards of sixty feet. Here, as at the eastern outcrop, the basal member is a pebble-bearing layer two to three feet thick. It reaches to within a few inches of the limestone beneath. In its lower portion it becomes a true conglomerate. Its pebbles attain the diameter of three and one-half inches, and consist mostly of clear quartz, and chert indistinguishable from the chert of the Upper Silurian. Occasional pebbles of red jasper and pink quartz occur. It is hardly in place at present to separate this conglomeratic mass from the Rockville conglomerate, which is only twenty-six miles away, merely by the absence here so far as observed of the pebbles of granitoid rocks which are sparingly found at Rockville. The total thickness of sandstone here exposed is some thirty feet.

On the west side of the ravine immense boulders, one thirty feet long and fifteen feet high, lie prone on the upper portion of the slope which reaches at this point to the base of the present escarpment. These once formed the face of the sandstone cliff, and have been detached by the secular decay of the calcareous floor beneath, or possibly by the removal of shales or friable sandstones subjacent.

Throughout this outlier, the rock is practically homogeneous, with the exception of the basal member containing pebbles. It is a moderately hard sandstone of quite fine and uniform grain, becoming harder on weathering. Its normal color seems to be a gray, but it is usually colored various tints of buff or light reddish, by the presence of iron peroxide and darkens on weathering. In the natural ledges quite regular and constant bedding planes appear and blocks from eight inches to two feet thick have been quarried for local use, such as foundations and the abutments of bridges. After an exposure of twenty years in an abutment the freshness of tool marks show that the stone has suffered no superficial disintegration. In places the rock is more massive, no clear and constant bedding planes appearing for a distance of from six to fifteen feet. These massive layers, as well as the thinner ones in many places are shown by weathering to be effected with oblique laminations, inclined at various angles, usually low and sometimes quaquaversal, the laminae being from a fraction of an inch to a few inches in thickness. Fossils are extremely rare, none being found except a Lepidodendron log four feet long, a fragment of a calamite and a flattened trigonocarp-like nut. Nodules of green or grayish clay an inch or less in diameter are also rarely seen. Beautiful ripple marks remain on some of the blocks, as evidence of the pulse of the waves of the ancient sea along whose margin these sands were laid.

OUTLIERS OF INDETERMINATE AGE.

Andrew. The sandstone of this locality lies three miles north of Andrew, in Jackson county. The outcrop occurs along or at the base of three ravines which slope westward into Farmer creek and are ranged along a line extending north-northeast some fifty rods. The sandstone rests on the Upper Silurian limestone about thirty-five feet above the creek and protrudes from the soil in rough boulders to a vertical distance of forty-five feet above its base. This is said to be the only sandstone found in the neighborhood. The stone is of moderately fine grain, indurated superficially, reddish yellow, or gray within, but deeply stained a dark purplish red or an iron black on the exterior.

Charlotte. The chief outcrop of this sandstone is a mile north of Charlotte, in Clinton county, on the north side of Willow creek (Tp. 83 N., R. IV W., Sec. 22, SE. qr., NW. ¼). The ledge is eleven feet high, with a probable extension below of five feet. It is ten rods long and twenty feet above the water in the creek. Eighty rods to the north the Pentamerus beds of the Niagara, containing *Cerionites dactyloides*, overlook the sandstone. The ledge resembles those at Monmouth showing layers a foot or more thick with discordant oblique lamination. In small pieces it is quite friable and on fresh surfaces shows various shades of gray, yellow and brown.

The same sandstone occurs at several other places in the vicinity; one mile east of Quigley and also one mile southeast of the ledge described. This and the Andrew outlier are probably Carboniferous.

The following estimates of the heights above sea level of the outliers mentioned are based upon measurements taken with an Abney hand level "tied" to the contour lines of the atlas sheets of the United States Geological Survey. They are, therefore, only approximations:

	FEET.
Bertram	720
Lisbon	833
Clear Creek	815
Canton	795
Marion	800
Monmouth	800
Andrew	890
Charlotte	760

It seems probable that the Carboniferous outliers of eastern Iowa have relations both to the Coal Measures of Illinois and to those of Iowa. The connection is close between the sandstones of Jones, Jackson and Clinton counties, and the outposts of the Illinois coal field in Scott and Muscatine counties. Still nearer to these outposts are the outliers along the Iowa river above Iowa City. From the latter it is but little over ten miles to the outlier at Marion. On the other hand the Iowa river outlier extends to the Lower Carboniferous above Marengo, and is even nearer to the Iowa coal field to the southwest than to the Illinois coal field to the southeast. Toward the north the Iowa coal field has several eastern outliers; and toward the south in Washington county such outliers bridge nearly half the width of the Lower Carboniferous. The hypothetical eastward extension of the Iowa coal field into Jackson county to join the Carboniferous outliers there receives, perhaps, some support from the previous eastward extension of the Iowa Devonian into the same county as already noted. The views of Hall and White that the scattered sandstones were once laid down in isolated basins becomes less probable with each outlier discovered. Those now known are so numerous and widely distributed that they seem rather to support the view, that over the depressed area of eastern Iowa the central and western coal fields were broadly joined, or united along a somewhat intricately dissected coast, the most northern known limit of shore or estuarian extension being in Jackson and Linn counties.

GEOLOGICAL SECTION ALONG MIDDLE RIVER IN CENTRAL IOWA.

BY

J. L. TILTON.

GEOLOGICAL SECTION ALONG MIDDLE RIVER IN CENTRAL IOWA.

BY J. L. TILTON.

The "Three Rivers Country" comprises the greater portion of Warren and Madison counties in central Iowa. It is drained by the streams respectively known as the North, Middle and South rivers, which flow in courses nearly parallel to one another, and empty into the Des Moines river near the northeastern corner of the first named county. Along the median of these water courses the geological section herein described was constructed. It extends from Ford, on the Des Moines, in a slightly south of west direction to Winterset, the county seat of Madison.

Of the geological problems presented by the region, none is of greater practical import than the determination of the thickness of the Lower or productive Coal Measures. Middle river affords especially favorable opportunities for solving the problem. The stream now flows in a direction approximately normal to the old Carboniferous shore line. The section connects the Ford bluff outcrops, whose relations to the Lower Carboniferous limestones have been definitely determined, and the Winterset exposure which has been regarded as a typical development of the base of the Upper Coal Measures in Iowa. In its general features it also serves as a check on a similarly constructed section parallel to it but some twenty miles to the north. It further answers as a base to which all detailed stratigraphical work in Warren and Madison counties may be referred. Lastly, one of the principal objects has been to determine the position and extent of folds or undulations in the strata which might serve as guides to intelligent prospecting for natural gas and oil.

If along the line of the general section there is encountered a heavy limestone formation whose outcrop can be readily traced northwestward into Guthrie county and southward into Missouri, connecting with a very similar limestone which has been recognized near the northern boundary of that state, a clear and natural line of demarkation is obtained for separating the Iowa Coal Measure area into two distinct districts, one, made up mostly of shore and swamp deposits, in which coal was abundantly formed (Des Moines terrane), and the other composed chiefly of more strictly maritime beds (Missouri terrane). This is the first important limestone above those of the great Carboniferous basement.

A knowledge of the position of this off-shore line has an important theoretical and practical bearing. Theoretically it tells of the physical conditions under which a part of the Iowa land surface was formed and the relations of sea and land during Carboniferous times; practically, it gives an exact and rational division between the Lower and Upper Coal Measures, above which conditions favorable to the formation of thick coal seams cease to exist. Also, new data are furnished by which to judge the depth of the Lower Coal Measures with their rich contents.

At the eastern end of the general section the surface is quite rugged on the south, while on the north the broad flood plain of the Des Moines stretches out for a distance of several miles. From the mouth of Middle river valley to the west county line of Warren the surface slopes quite gradually on both sides, though the river generally hugs the southern margin of its valley, thus bringing it closer to the high, rolling uplands on the south, while to the north the surface rises in more gradual undulations. Near the western boundary of Warren county the hills become more rugged and precipitous. In the eastern part of Madison county, where the limestone deposits of the Upper Coal Measure strata begin, the valley is contracted to a gorge, the high limestone bluffs rising quite abruptly on either side of the river to a height of fully two hundred feet.

The first outcrop to be considered is one mile east of Ford (Tp. 77 N., R. XXII W., Sec. 10). It is as follows (number 1 in figure 2):

		FEET.
9.	Drift and loess	20
8.	Shale	4
7.	Sandstone, soft, yellow	35
6.	Shale, bituminous	2
5.	Clay-shale, dark, sandy above	12
4.	Clay, white	3
3.	Sandstone, soft, heavily bedded	4
2.	Clay, white	4
1.	Shale, sandy and clayey (exposed to water)	25

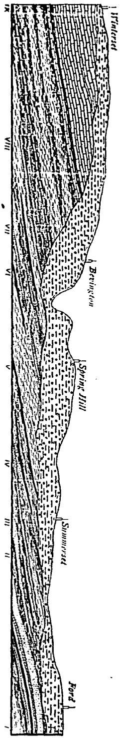


Figure 2. Geological Cross Section on Middle River in Central Iowa.

The section is located at the crest of a low anticline. From this place to a point a mile west of Ford the strata can be traced in the bluff which forms the south bank of the Des Moines and Middle rivers. Beyond this point the exposures are not so continuous, but there seems to be little room for doubt that the principal seam of coal, which appears just above the railroad track at the station, thins out somewhat before it reaches the water level of Middle river about one-fourth of a mile east of the bridge at Clarkson. At this point the upper part of the vein is well exposed. The overlying sandstone is present, but is not so thick as at Ford, and the dark shale and soft sandstone crop out in the bluff. At this place another vein begins that may be traced three miles up the river, the bituminous shales which overlie it being especially noticeable near the bridge on the road to Carlisle. A third seam, a few feet above, appears best developed two miles to the southwest and at Summerset, at both of which places shafts are located. The coal is said to thin out between the two points. Seventy-five feet above the last mentioned seam is another which is mined at Summerset and also a few miles eastward as a surface seam. This is the vein which outcrops in the bluff at Summerset station.

A short distance east of Summerset, at the mouth of a ravine in which are situated the Jones and Benham coal mines (Tp. 77 N., R. XXIII W., Sec. 22, NE. qr., SE. $\frac{1}{4}$) the outcrop shows (number 2):

	FEET.	INCHES.
8. Clay, bluish	1	1
7. Coal		6
6. Fire clay		1
5. Shale	6	7
4. Sandstone, coarse, reddish	1	8
3. Shale, sandy	2	6
2. Shale	3	8
1. Shale, clayey (exposed to river)	1	

The sandstone above the seam of coal is a continuation of that which is so prominent in the cliff at Ford. It disappears beneath the bed of the river just west of Summerset. The coal seam overlying the sandstone in the bluff at Summerset outcrops repeatedly in the hillsides for a distance of several miles to the east where it is "drifted." It thins out rapidly west of the town. The Summerset section (Tp. 77 N., R. XXIII W., Sec. 31, NE. qr.) is as follows (number 3):

	FEET.	INCHES.
9. Loess	13	9
8. Sandstone		9
7. Shale	6	8
6. Coal	1	2
5. Fire clay	4	6
4. Shale, sandy	3	6
3. Sandstone	1	6
2. Shale	1	
1. Sandstone, heavily bedded	2	

From Summerset to Spring Hill, the outcrops in the immediate vicinity of the river are not very numerous. Several thin veins of coal are found, the best natural exposure occurring about half way between the towns mentioned. A little to the south of the river the seams supply a limited quantity of coal for local consumption. The most instructive section is a short distance west of the first-named town (Tp. 76 N., R. XXIV W., Sec. 2, NW. qr., SE. ¼), where is exposed (number 4):

	FEET.	INCHES.
9. Shale, bituminous		3
8. Shale	6	9
7. Sandstone	3	
6. (Concealed)	7	8
5. Shale, black (exposed)	1	
4. Shale		9
3. Coal		6
2. Fire clay	1	9
1. Shale	1	2

Immediately west of Spring Hill an excellent section has been disclosed in opening a seam of coal. Northward in the ravines sloping into North river valley, and in a bluff by the stream itself, are exposures revealing shale and sandstone both above and below a narrow pocket of coal, whose main axis is directed north and south, the stratum thinning out very rapidly east and west.

A mile and a quarter west of the town (Tp. 76 N., R. XXV W., Sec. 12, NE. qr., SW. ¼) is the following section (number 5):

		FEET.	INCHES.
10.	Loess	2	
9.	Coal, badly weathered		½
8.	Shale, gray, with thin seams of sandstone.	9	7
7.	Shale, blue above, black below	4	4
6.	Sandstone, nodular, calcareous		6
5.	Shale, black	2	
4.	Coal	1	1
3.	Fire clay	4	4
2.	Sandstone, heavily bedded, gray	1	4
1.	Shale, irregular (exposed)	4	6

Between Lothrop and Bevington, an interval of three miles, few outcrops occur. The scarcity of exposures and the general relations of the strata argue for the absence of any layer that by resisting weathering would protude through the overlying loess or become exposed in the ravines. This, together with the fact that the lowermost stratum found above is argillaceous shale and the uppermost found below is a sandstone passing in places into a sandy shale, give evidence that the strata thus concealed are largely shales.

Two miles west of Greenbush is a section in a ravine where coal is at present obtained by "stripping" (Tp. 76 N., R. XXV W., Sec. 1, NW. qr., NE. ¼). The upper half of the section is obtained about fifty yards west of the point where the lower half is found (number 6):

		FEET.	INCHES.
12.	Sandstone, shaly	2	2
11.	Shale, gray	1	3
10.	Shale, reddish	2	3
9.	Sandstone, gray, shaly		5
8.	Shale, blue		9
7.	Sandstone, fossiliferous	1	3
6.	Shale, blue (exposed)		7
5.	Shale	4	
4.	Limestone, arenaceous, fossiliferous		6
3.	Shale, black		7
2.	Coal		6
1.	Fire clay (exposed)		4

A short distance southwest of Bevington, in the ravines and in the bluff near the river (Tp. 76 N., R. XXVI W., Sec. 36, SW. qr., NW. ¼) one of the best exposures (number 7) shows:

		FEET.	INCHES.
8.	Drift		
7.	Sandstone	1	3
6.	Sandstone, massive	1	2
5.	(Unexposed)	3	8
4.	Shale, black below	2	6
3.	Coal		3
2.	Fire clay and light colored shale	7	
1.	Shale, (exposed)	40	

Between Bevington and Patterson heavy sandstones are quite prominent, shale lying both above and below. But one coal horizon is exposed.

The massive sandstones which lie near the railroad track from one to two miles west of Patterson are undoubtedly represented a mile and a half southwest by a corresponding stratum a few feet above the water. Large blocks of a heavily bedded sandstone were found on the hillside at a level where such a stratum should be, but no exposure of undisturbed layers appeared. Above this stratum shale is exposed though not to its full extent.

Two miles southwest of Patterson (Tp. 76 N., R. XXVII W., Sec. 35, SW. qr. NE. ¼) there is a good exposure (number 8) in the bluffs bordering the river on the south:

	FEET.	INCHES.
8. Not exposed	64	
7. Limestone, thin-bedded, white	1	4
6. Shale, clayey	60	
5. Sandstone, reddish	1	5
4. Shale, bluish above, sandy and grayish below	37	
3. Sandstone, shaly below	2	6
2. Shale, bituminous	2	
1. Shale, mostly exposed	52	

From the last section, southwest of Patterson, to Winterset the limestone (Upper Coal formation) capping the hills has so protected the underlying softer strata from erosion that the bluffs rise high and steep in the immediate vicinity of the river. There are three rock layers of special prominence: the first a sandstone fifty-two feet above the river at Patterson, the second a sandstone thirty-eight feet above the first, the third, the limestone cliff, sixty to ninety feet above the last. Even where there are no good exposures, these strata have so resisted erosion that the sides of the hills south of the river are terraced. These characteristic ledges with their associated strata are perhaps best shown across the river from Tileville. The only good indications of coal immediately underlying the lowest stratum of limestone disappear beneath the river bed a mile east of Buffalo bridge.

West of the locality last mentioned the highlands approach very near the river, which has formed a gorge perhaps half a mile wide. The upper portion of the section (Tp. 75 N., R. XXVII W., Sec. 6, NW. qr.) is easily traced in the upper part of the ravine along the road south of Winterset; the lower half is exposed in this and other ravines near the river, but the lowest stratum of limestone outcrops in the bed of the river a mile to the east. The observations made here correspond essentially with those made by White, whose section (number 9) is here given:

		FEET.	INCHES.
16.	Limestone, yellowish, thin-bedded	1	
15.	Clay, marly	4	
14.	Limestone, massive	6	
13.	Limestone, regularly bedded, with marly partings	12	
12.	Shale, carbonaceous	2	
11.	Limestone, regularly bedded, with marly partings	34	
10.	Shale, carbonaceous	2	6
9.	Limestone, thin-bedded	15	
8.	Limestone, compact	2	
7.	Limestone, thin-bedded	16	6
6.	Coal, impure		6
5.	Marlite, light bluish	2	
4.	Limestone, bluish	5	
3.	Shale, blue and red	6	
2.	Shale, with layers of thinly bedded sandstone	71	
1.	Limestone, bluish, shaly, impure	1	6

The Upper Coal Measures form an almost continuous limestone formation that may be readily distinguished from the clay and sandy formations occurring eastward. On the north bank of Middle river the Upper Coal Measure strata extend along the highlands between Cedar creek and Middle river from Winterset to just east of Tileville. At Winterset they form a stratum 110 feet thick, the base of the formation resting seventy-two feet above the river bed. At Tileville the capping limestone is about seventy feet thick; the base 128 feet above the river bed.

In conclusion it may be said that the section clearly agrees with the Raccoon river section twenty miles farther north, and in the same general direction. A further agreement is manifest in a very marked absence of folds or undulations in the layers, the only one of importance being the Ford anticline, at the extreme eastern end of the section, which was made out some years ago. The third important consideration is that the shales and sandstones continue, to the exclusion of calcareous beds, from the Lower Carboniferous basement up to the very base of the great limestone of Winterset where they abruptly stop. A sharp line of demarkation is thus recognized between the coal bearing strata and the formations where fuel-furnishing layers are practically absent.

GLACIAL SCORINGS IN IOWA.

BY

CHARLES ROLLIN KEYES.

GLACIAL SCORINGS IN IOWA.

BY CHARLES ROLLIN KEYES.

Although evidences of glaciation abound on every side throughout the 55,000 square miles of Iowa's territory, there have been recorded but few instances of ice scorings and striations. Until very recently less than half a dozen localities were known within the limits of the state where glacial markings had been noted. All of these were discovered more than a quarter of a century ago. Concerning them little more than the mere mention had been made, though in some cases the directions of the scratches were given. The locations where glacial markings on the indurated rocks were observed were at Burlington, near Council Bluffs and in the extreme northwestern corner of the state.

During the past year a number of new localities have been disclosed, at all of which good evidences of ice planing are shown. Some of these surfaces are in such an excellent state of preservation that they seem worthy of special mention at this time. The apparent rareness heretofore of glacial striations in Iowa is manifestly due not so much to an absence of ice action as it is to a lack of careful observation and examination.

In considering the rock scorings of the great ice invasions of North America Chamberlain* has called

*U. S. Geol. Sur., 7th Ann. Rep., p. 158. Washington, 1888.

attention to the very marked disparity in the geographical distribution of the glacial striæ. In attempting to record the known scratches on a map of the United States, some localities, as for instance New Hampshire, disclosed the striæ so abundantly that it was almost impossible to plat them properly, while other localities showed only an occasional mark often far removed from any others. In the map of the United States just alluded to, Iowa is credited with four places where glacial striation has been observed. As in other portions of the glaciated region the unequal distribution may be regarded as partly only apparent and partly real. Under the first are enumerated: (1) the illusory effects due to lack of observation on account of the deep drift covering, (2) post-glacial obliteration of markings, (3) unequal search for evidences of scorings and (4) unequal detection of ice planings. Under the second, or original irregularity of distribution are: (1) the greater abundance of markings in the northern than the southern portion of the glaciated tract, (2) greater prevalence of scoring north of the limiting moraines than south of them, (3) greater frequency of markings in hilly than plain regions, (4) greater prominence of striations as exposed sides of elevations than on the leeward, and (5) surfaces that sloped away from the onset of the ice were less universally scored than those inclined towards it.

Phenomena illustrating all of the peculiarities mentioned by Chamberlin in the distribution of the ice scorings are not wanting in Iowa. With one or possibly two exceptions they are all clearly defined.

As already stated the great paucity of glacial markings in Iowa is doubtless owing in a great measure to a want of proper search, while the great irregularity in distribution

QUARRY IN DEVONIAN LIMESTONE, SHOWING SALIENTS ICE POLISHED AND GROOVED IOWA CITY.

is probably to be accounted for partly by the same cause and partly by other causes. The lack of favorable observational facilities is most noticeable in the northwestern part of the area under consideration.

The earlier drift mantles all the district, except a small area in the extreme northeastern corner of the state. The later drift is represented by a broad, rounded lobe, which extends over one-third the way across the state, where it enters from the north and reaches down as far as Des Moines. The drift accumulations of the glacial materials over the northcentral part of the state prevent almost entirely a direct examination of the indurated rock surfaces. Within the area enclosed by the Des Moines lobe of the terminal moraine, there is as yet little or no evidence of ice planing. It is quite possible, however, that at Fort Dodge, some of the peculiarities shown on the upper surface of the gypsum deposits may be due to glacial action. The gypsum beds are from two to thirty or more feet in thickness and occupy the tops of the bluffs and hills. They are covered by drift clay to a thickness of ten to sixty feet, containing some sand and pebbles. Usually the gypsum is thickest where it is protected by the greatest bodies of drift materials. The upper surface of the gypsum deposit is often rounded into small hillocks, between which are sometimes deep pot-holes, while in many places the gypsum shows the effects of the solvent action of percolating waters. There are certain points where the overlying drift is undisturbed and is apparently just as it was originally laid down. If the gypsum was ever subjected to the gouging effects of the ice sheets it would be extremely doubtful whether glacial striæ would be preserved for any great length of time even under the most favorable circumstances since the material is so soft and so soluble.

The lithological characters of the rocks in many other parts of the state also preclude the retention of ice markings.

Perhaps one of the principal reasons why glacial scorings have not been reported more frequently is on account of the almost total lack of study in the field which has been given to the glacial deposits in all but one quarter of Iowa.

NORTHEASTERN IOWA.

In his elaborate study of the Pleistocene accumulations of the northeastern part of the state McGee* has stated that the entire history of the formations was deciphered "without a single glacial striæ or an inch of ice polish, save in one small spot, in the whole tract of 16,500 square miles." The isolated glaciated surface here alluded to is that which was found by Webster several years ago near Iowa City. The Iowa river at this point has cut a deep, narrow gorge into the hard Devonian limestone. The bluffs on either side of the stream are steep-sided, often perpendicular, and rise to a height of sixty to one hundred and twenty-five feet. On the west side of the water-course almost directly opposite the State University the stone has been quarried in a number of places. The top ledge is about fifty feet above low-water level in the river and is covered by ten to thirty feet of drift material. The latter is removed for a considerable distance each time the quarry face is carried forward. In stripping, the upper surface of the limestone is often well exposed. Several years ago when the top of the ledge was examined immediately after the removal of a large amount of the drift capping the hard limestone was found to be beautifully

* U. S. Geol. Sur., 11th Ann. Rep., p. 200. Washington, 1893.

GLACIAL PLANING ON DEVONIAN LIMESTONE. CLEAR CREEK, WEST OF IOWA CITY.

polished by ice and covered by glacial striations. (Plate ix, salient at extreme left is covered by striæ.) Numerous characteristic pot-holes (center of same plate) and ice furrows were also disclosed. These have been described in some detail by Webster* and figures of the more important ones given. The striæ varied slightly in direction. The principal markings were south 52 to 62 degrees east, the magnetic deviation being about 7½ degrees east of north. Some of the best surfaces were disclosed at the south end of the quarry on one of the truncated salients (shown in the extreme left of the accompanying plate ix).

Still more recently, Professor Calvin has discovered additional surfaces showing glacial markings (plate x). The locality is a few miles west of Iowa City, on Clear creek, near the site of the old woolen mill. A short time ago the stream cut around the end of the mill dam, carrying away a portion of the bank, which was composed of loess to a depth of twenty or thirty feet, resting on a bed of sand, pebbles and small striated boulders. The material reclining directly on the planed surface of the limestone was a mixture of sand, clay, gravel and small boulders, having a maximum diameter of eight to ten inches. Many of the pebbles and boulders are smooth on one or two sides. The giving away of the dam exposed the Devonian rocks over considerable area. The planed surface at the old mill, like that of Iowa City, consists of very fine grained, compact, brittle limestone that resists the solvent action of percolating waters to an unusual degree. In general the indurated rocks of Iowa have the surface in contact with the superficial material eaten away or corroded to a depth of often several inches and thus the

*American Naturalist, XXII, pp. 408-409. Philadelphia, 1888.

effects of glacial action have been very generally obliterated. The striæ have a direction of south 62 degrees east, which is practically the same direction as the striations on the west bank of the Iowa river at Iowa City.

SOUTHEASTERN IOWA.

In Washington county, near Brighton, Mr. H. F. Bain has recently found glacial markings on the Saint Louis limestone. The location is at the Brighton quarries about a mile north of the town, on the southwestern branch of the Chicago, Rock Island and Pacific railroad. At the time of examination an area thirty by fifty feet had been stripped preparatory to quarrying. Some of the striations were fully half an inch deep and ten or more feet in length. The directions were south, south 4 degrees east, and south 6 degrees east (true meridian).

The first glacial markings which were reported to have been found in southeastern Iowa were those discovered by White in 1858 near Burlington. No account of them was published at the time, though afterwards, on several occasions, mention was made of the fact. The direction of these striations was approximately south 15 degrees east. Until very recently nothing additional has been recorded concerning the glacial striæ of this part of the state. On the west bank of the Mississippi river for the greater part of the distance between the mouths of the Iowa and Des Moines rivers a high escarpment capped by a massive limestone borders the stream. In many places the rocks stand out in bold cliff-like walls, one hundred to two hundred feet high, with a heavy talus at the base. Along much of this exposed scarp the conditions are exceptionally favorable to the recording of ice scorings.

GLACIAL STRIATIONS ON DEVONIAN LIMESTONE AT IOWA CITY.

Burlington has been the only place known heretofore in southeastern Iowa which has disclosed glacial striæ. There is no record of White's original location, but it is thought to be two or three miles north of the city. On North hill, at the brow of the Mississippi bluff, striated surfaces have been reported from time to time but only on one occasion were they examined carefully. The bearing of the striæ was south 63 degrees east, the magnetic deviation being about 7 degrees. Mr. Frank Leverett has stated more recently that he also has measured the direction of some glacial grooves in the same vicinity. He reported the bearings to be 65 degrees east. Observations made a few years ago show that the sharp salient at the Cascade two miles south of the city was manifestly a center of much ice-planing. Mention of this place will be made later.

Everywhere in the neighborhood of Burlington the Pleistocene deposits consist chiefly of loess and the lower till. These incoherent materials cap the high hills and cover the uplands to a depth of ten to sixty feet or more. The preglacial surface relief of the region under consideration has not been completely obscured by the covering of glacial debris. The present topographical features are therefore to a greater or less extent dependent upon the indurated rocks which make up the greater portion of the altitude of the bluffs. Over the more elevated areas the later deposits are relatively thin, but over many of the lower places there are deep accumulations of drift materials. The city of Burlington itself is built upon several hills, all of which rise to a height of nearly two hundred feet above the low water level of the Mississippi river. The drift has formed nearly insulated plateaux the sides of which are scalloped by steep-sided ravines, very deep toward the lower extremity but interiorly becoming rapidly shallow.

In protected places the surface deposits rest directly upon the Augusta limestone which is usually much decomposed and broken to a depth of two to six feet. The interstices and irregularities are filled with drift materials and red, residuary clays containing flint nodules in abundance. The drift itself is usually more or less modified superficially. It contains considerable gravel in places, but the boulders are for the most part small in size, being seldom more than four or five feet in diameter. There are, however, a few exceptions, one erratic being known which is more than fifteen feet across. Overlying the drift in most places is a mantle of loess carrying characteristic fossils. A road cutting upon the brow of North hill discloses the following section which may be taken as characteristic of a considerable area:

	FEET.
3. Clay, brownish-yellow, free from gravel and for the most part homogeneous; graduating into 2.........	5
2. Loess, typical, ashen, compact, containing numerous small, loess-kindchen and the following fossils: *Pupa muscorum* Linn., *Succinea obliqua* Say, *Patula striatella* Anth., *Limnophysa desidiosa* Say, *Patula perspectiva* Say, *Helicina occulata* Say.............	8
1. Till, with an abundance of gravel, and pebbles up to three feet in diameter (exposed)..................	20

Over much of this plateau the distribution of the Pleistocene deposits is essentially the same except that the lower member suffers considerable attenuation over the more elevated places, sometimes being reduced to only a few feet in thickness. Upon the removal of the drift materials in excavations it has been reported that polished and striated surfaces have been discovered at various points, but as yet none have been brought to view at times when they could be properly investigated.

Incidentally, reference has been made to the evidence of glacial scorings two miles south of the city of Burlington. At the present time no ice markings are visible at this place. A few years ago, however, large limestone slabs four to five feet long and two to three feet wide were removed in quarrying from the top of the salient above the present works of the Granite Brick Company. Some of these flat blocks were beautifully glaciated, deep flutings

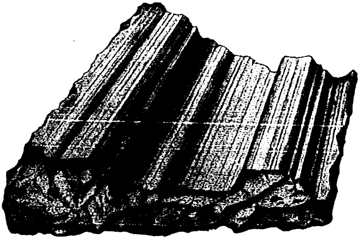
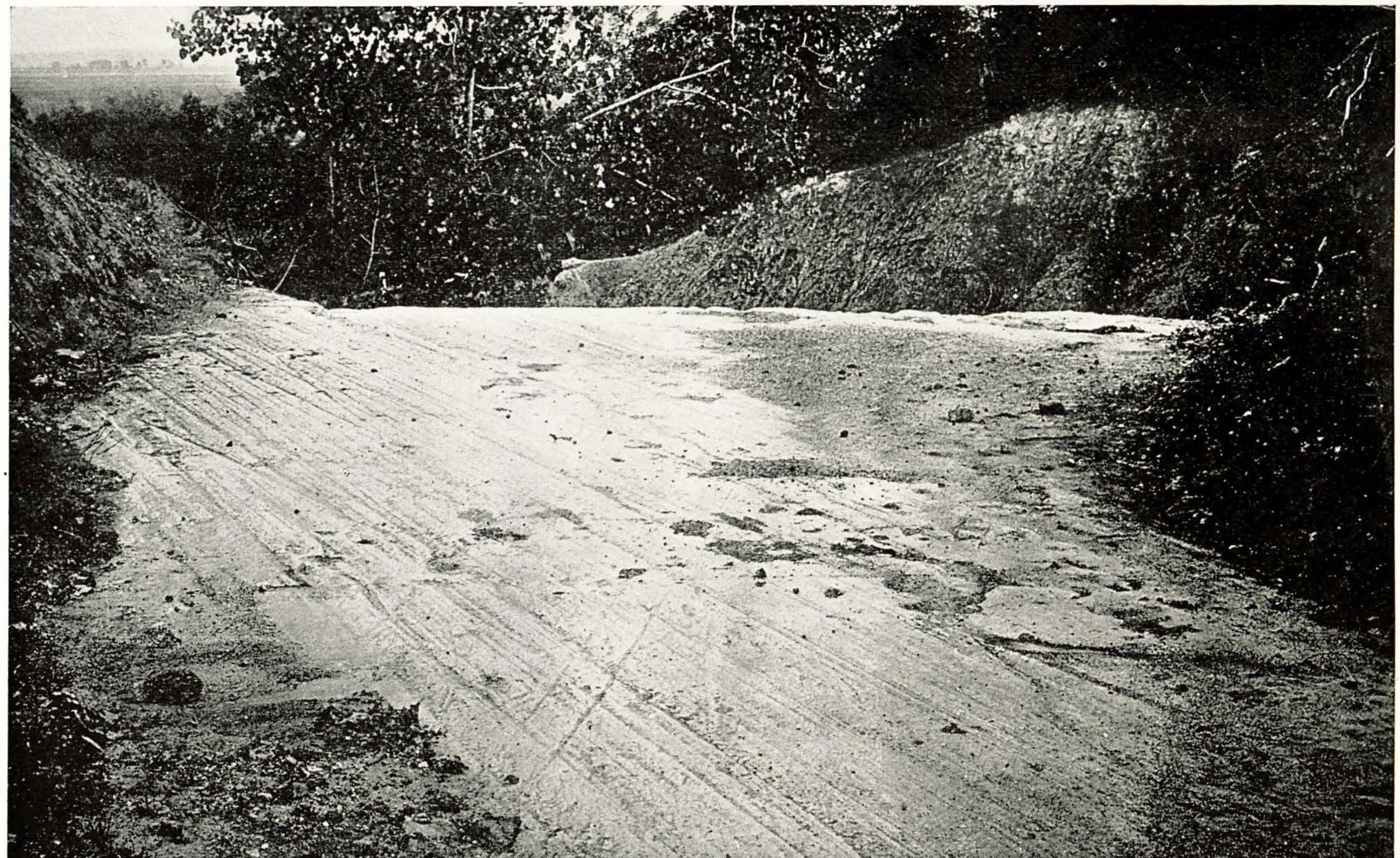


Figure 3. Ice Flutings. Burlington.

and moulding striated and polished to perfection. One of these surfaces is represented in the accompanying cut (figure 3). The broad median groove shown is about six inches deep and eighteen inches wide. The others, while not so deep, have sharper edges.

During the past summer, Mr. F. M. Fultz found two new localities in the neighborhood of Burlington showing exceptionally fine effects of glacial action. The one north of the city near Kingston was brought to light under very favorable circumstances and the general appearance of the



GLACIATED SURFACE ON BLUFF OVERLOOKING THE MISSISSIPPI. KINGSTON.

surface is well shown in the accompanying plate which is reproduced from a photograph taken by Mr. Fultz. (Plate xi.)

Mr. Fultz has made several special trips to this locality and also to the one west of Burlington, and his notes are so complete that they are given entire below.

Some Glaciated Surfaces near Burlington.

(By F. M. Fultz.)

Recently two new localities have been found near Burlington showing well preserved glacial scorings. One is near Kingston (Tp. 71 N., R. II W., Sec. 12, SW. qr.) in Des Moines county, about thirteen miles north of Burlington, on the top of the bluff which borders the Mississippi river. From Burlington northward this bluff takes a north-easterly course for several miles, thence changes to nearly due north and continues in this direction almost to the Louisa county line, where it assumes a westerly trend. In the county last mentioned it becomes for several miles the south border of the Iowa river valley. Throughout this whole extent the bluff is a prominent topographical feature. Although situated several miles from the river channel it rises abruptly, forming a high mural escarpment. At the top it is composed of the compact Upper and Lower Burlington limestones; at the base are the Kinderhook shales. The summit is capped with a very heavy covering of loess and drift. In places the limestones appear as bold salients; at others the rock front has broken down, and the whole face deeply covered by talus. While many of the smaller streams have cut through the limestone nearly to the base of the bluff, they offer no better exposures than the face of the bluff itself.

DIRECTIONS OF GLACIAL GROOVES AT KINGSTON.

The top platform of the indurated rocks remains hidden almost everywhere by glacial débris; and although it may, and undoubtedly does, exhibit abundant evidence of ancient glacier movements, it is so deeply buried that only by chance small surfaces are revealed. Occasionally a small block of limestone is found detached at the base of the bluff, or at a distance from the original ledge, which has one of its surfaces grooved and polished, showing unmistakably that it once was part of the rocky floor over which an ice stream moved.

The glaciated surface at the Kingston exposure is remarkably well preserved. It was originally covered with from ten to twenty-five feet of loess and drift, and was accidentally exposed to view in the following way. A water course coming down from the upland issues from the bluff at a very sharp angle. Although draining quite a large area the stream carries no water except during, and immediately after, heavy rains. Consequently the bed has been eroded only a few feet into the solid limestone. As the water issues from the bluff it breaks into a cascade about twenty feet in height, with rapids to the base. On account of the inconvenience caused by the great volume of water brought down during times of freshet the owner of the land decided to change the course of the rivulet. This was easily done by reason of its shallow bed and the sharp angle made with the general trend of the bluff. Going back from the crest of the escarpment a distance of about 150 yards, the old channel was dammed up and a trench excavated at right angles to the old course. This new channel is about forty yards long. Where it leaves the old bed the loess and drift are not more than three feet in depth but by the time the face of the bluff is reached the thickness has increased to fully twenty feet, and two hundred yards further south the covering reaches a thickness of at least sixty feet.

The drift is quite typical and lies undisturbed upon the rock floor. This surface, as exposed in the new channel for a distance of more than one hundred feet, is perfectly level and is thickly covered with glacial markings. At least four distinct sets of scratches have been determined. Each one of the series consists of perfectly straight, parallel grooves, the larger ones of the latest being about an inch in depth while those of the oldest are nearly obliterated. Plate xii gives a good idea of the character of the glaciated surface.

The direction of the different sets, as determined by the compass, making seven degrees allowance for the magnetic deviation, is as follows:

No. 1, south 30 degrees, 15 minutes east (line A-B, plate xii).
No. 2, south 64 degrees east (line C-D).
No. 3, south 60 degrees, 30 minutes east (E-E).
No. 4, south 72 degrees, 15 minutes east (G-H).

Set number 1 is nearly obliterated, but its traces are so numerous as to indicate that at one time it occupied the whole surface, and that it is the record of a long continued movement of the ice stream in one direction.

Number 2 is the most prominent, principally on account of the much greater number of the deeper grooves, on which the later cross movements have made but little impression.

Numbers 3 and 4 have comparatively few markings, but some of them are very deep and plainly show their later origin by cutting across those of number 2 and also reaching to a greater depth. The cutting of one groove directly across another is shown at x in plate xii. It will also be noticed that the later one shows the greater depth.

LATERAL ICE EROSION AND STRIATED SURFACES AT LOFTUS QUARRY. WEST BURLINGTON.

The second locality showing glacial markings is situated about four miles northwest of Burlington and about two miles from the nearest point of the Mississippi river bluff (Tp. 70 N., R. III W., Sec. 25, NW. qr., SW. ¼). The exposure was disclosed in stripping at the Loftus quarry. A section taken at this point gives:

		FEET.
6.	Loess	4
5.	Drift	10
4.	Limestone, thinly bedded, with flint bands	8
3.	Limestone, light colored, fine-grained, subcrystalline	6
2.	Limestone, heavily bedded, white	10
1.	Limestone, unevenly bedded, dark gray (exposed).	4

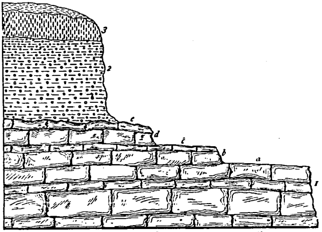


Figure 4. Cross-Section at Loftus Quarry. West Burlington.

The loess is very characteristic and compact. The drift is filled with striated stones which are smaller and much waterworn towards the top. Immediately beneath the loess it becomes quite gravelly.

The quarry has been opened along the face of the bluff which borders a small creek. The general trend of both the bluff and creek valley at this point is east and west. The bluff being on the south of the valley, faces the north. In working back into the hill the surface of the rock is found to rise quite rapidly, showing that the brow and face have suffered considerable erosion. The rise is not uniform, but in a series of steps, as indicated in the accompanying cross-section. It is on these benches that the glacial markings occur. In the figure *a* is a ledge eight to ten feet in width; the whole surface is striated, scored and grooved, most of the markings being very well preserved; *b* is the edge of the next bench, and is finely striated and polished; *c* is the surface of the second bench, and like *a* is covered with parallel grooves; *d* and *e* are respectively the edge and top of the next higher bench. They show no markings, the rock being too badly disintegrated to preserve them. The markings on *a* and *c* resemble very much those already described in the exposure near Kingston, but only one set of striations can be made out. The direction of the markings has not been taken with a compass, but it is approximately south 68 degrees east. The general character of the lateral erosion is shown in plate xiii. The direction of the striæ and position of the benches would seem to indicate that the movement of the ice stream was in the same general direction as the trend of the bluffs.

The most striking feature of this whole exposure is the great differences shown between the scoring of the floor and the sides. The former is the same as is usually seen elsewhere. It consists largely of straight, parallel grooves, to the depth of an inch or more, situated on an almost perfectly flat surface. There is little or no gouging out where the rock is softer and no blocks have been wrenched loose or carried away. On the other hand the lateral planing shows no grooves, but a multitude of fine striæ which, while trending longitudinally, are not parallel, but cross one another at small angles. The softer parts of the rock

GLACIAL GROOVES AT KINGSTON.

exhibit gouging, and pieces of rock have been torn loose and carried away.

The character of the brow of the escarpment which borders the west side of the Mississippi river between the mouths of the Iowa and the Des Moines rivers is perhaps best shown at Keokuk. At several points within the city limits there are great accumulations of large boulders which rest partly upon the crest of the bluff in beds fifteen to twenty feet in depth and partly at the base of the cliff over which they have been tumbled. These boulders are composed chiefly of granites, porphyries, diabases, and other crystalline rocks, ranging in size from a few inches to two or three feet. In a recent street cutting just west of the Union station at Keokuk, one of these beds is well exposed. It is shown in the accompanying plate xv, which is reproduced from a photograph taken by Mr. Fultz.

SOUTHWESTERN IOWA.

The glacial scratches of southwestern Iowa require but passing mention in this place in order to make complete the known records in Iowa. The first mention of the markings in this part of the state is by White, who found them in Mills county, at the Stout quarry, about five miles south of Pacific Junction (Tp. 71 N., R. XLIII W., Sec. 16, SE. qr). The location is on the abrupt eastern bluff of the Missouri river, about three miles from the stream. The marks are upon the Upper Coal Measure limestone which crops out a few feet above the broad flood plain.

According to White the scratches are of two sets, one a rather coarse, the other much finer and much more numerous than the former. The rock surface is beautifully planed. The direction of the striations of the first series was south 10 degrees east and of the second set south 1 degree east (magnetic deviation here about 10 degrees). Professor J. E. Todd has visited the same locality lately and found several series of striæ. The coarsest and best developed were found to be south 2 degrees west and 0 degrees, 3 degrees and 6 degrees east. Two finer series had bearings south 25 degrees east and south 31 to 34 degrees east, and still more delicate striæ were detected south 50 degrees east. About a rod to the eastward and on the same level, striæ equally distinct were noted with directions south 6 degrees west and south 12 degrees west. About a mile north of the Stout quarry, Todd also reports another place in which the striæ run south 3 to 5 degrees west. A quarter of a mile farther north and twenty or thirty feet above the flood plain he has observed a limestone surface on which the striations are mostly south 5 degrees west; a few, however, are south 30 degrees west.

NORTHWESTERN IOWA.

The glacial scratches observed in northwestern Iowa are all in the extreme corner of the state where the Sioux quartzite crops out. In many places the hard quartzite has been bared over considerable tracts. These surfaces frequently exhibit glacial scratches and grooves. Some of the latter observed a mile south of Rowena, just over the Iowa line in Minnesota, were thirty feet or more in length and several inches wide. The direction was south 53 degrees east. Fine scratches were also noticeable. Glacial striæ have been noticed in a number of places in the vicinity of the northwestern corner of Iowa. At Lawrence, a short distance to the northeast in Minnesota, the striæ have a direction south 15 to 25 degrees east.

BOWLDER BED ON CREST OF MISSISSIPPI BLUFF. KEOKUK.

At Sioux Falls, a few miles to the northwest, variable directions are shown, but some of the most pronounced scratches are south 40 degrees east.

Table of Observed Directions of Glacial Striæ in Iowa.

LOCALITY.	DIRECTION. (Corrected.)	AUTHORITY.
NORTHEASTERN IOWA—		
Iowa City	S. 52 E.	Webster.
Iowa City	62 E.	Webster.
Iowa City	54 E.	Keyes.
Iowa City (Clear creek)	62 E.	Calvin.
SOUTHEASTERN—		
Brighton	4 E.	Bain.
Brighton	6 E.	Bain.
Burlington, 2 miles north	15 E.	White.
Burlington, North Hill	63 E.	Keyes.
Burlington, North Hill	65 E.	Leverett.
Kingston	30 E.	Fultz.
Kingston	60 E.	Fultz.
Kingston	64 E.	Fultz.
Kingston	64 E.	Fultz.
Kingston	72 E.	Fultz.
West Burlington	68 E.	Fultz.
SOUTHWESTERN—		
Pacific Junction, 5 m. South	10 E.	White.
Pacific Junction, " "	41 E.	White.
Pacific Junction, " "	2 W.	Todd.
Pacific Junction, " "	due S.	Todd.
Pacific Junction, " "	3 E.	Todd.
Pacific Junction, " "	6 E.	Todd.
Pacific Junction, " "	25 E.	Todd.
Pacific Junction, " "	31 E.	Todd.
Pacific Junction, " "	34 E.	Todd.
Pacific Junction, " "	50 E.	Todd.
Pacific Junction, 4 " "	6 W.	Todd.
Pacific Junction, " "	12 W.	Todd.
Pacific Junction, " "	3 W.	Todd.
Pacific Junction, " "	5 W.	Todd.
Pacific Junction, 3¾ "	5 W.	Todd.
Pacific Junction, " "	30 W.	Todd.
NORTHWESTERN—		
Granite, 3 m. North	53 E.	Keyes.

THICKNESS OF THE PALEOZOIC STRATA OF NORTHEASTERN IOWA.

BY

WILLIAM HARMON NORTON.

THICKNESS OF THE PALEOZOIC STRATA OF NORTHEASTERN IOWA.

BY WILLIAM HARMON NORTON.

The data upon which the following report is based are driller's records of deep borings in northeastern Iowa and examinations of sample-drillings of the different strata penetrated.

It is well to mention here the presence of certain difficulties which have attended the investigation. These were chiefly in the character and extent of the data at hand. Some of these difficulties have been readily met. No observer, however inexperienced, could assign the cinders, slack and coal sometimes found in samples in considerable quantity to any other horizon than the ash heap of the engine house, nor the iron filaments which surround the magnet when plunged in the drillings and the rusty particles which often cemented a few grains together, to any other cause than the abrasion of drill and rods.

In the inspection of these drillings it must always be kept in mind that the vibration of ropes and rods and the lifting and lowering of the drill detach fragments of the rocks from far above the bottom of the boring. From shales and incoherent sandstones a large admixture of shale and sand is expected with the drillings of the rocks subjacent. When strata of sandstone or shale alternate rapidly with other rocks, the discrimination is one of peculiar difficulty and it is probable that the thickness of sandstone and shales has frequently been overestimated for this reason; drillings of the underlying rocks being masked in the samples by the material fallen from above. Drillings for example below the Saint Peter and from various horizons in the Cambrian often consist of finely comminuted arenaceous and dolomitic material intermixed. It then becomes a delicate question to decide whether the sand is entirely foreign, fallen from water-washed and incoherent sandstones above, and the drillings represent a pure dolomite, or whether the sand is partially extraneous and partly native, and the sample represents according to the proportion of silica, arenaceous dolomite or calciferous sandstone. The same doubt must frequently arise as to whether the silica in such drillings when native is disseminated or exists in thin layers of interbedded sandstones. The problem is made more intricate by the fact that, in artesian wells, drillings below the Saint Peter are often more or less sorted by the action of the water, being brought to the surface by the outflow of water, instead of by the sand-pump. When samples of each stratum are furnished, the errors resulting from these causes can be largely eliminated, but when only one sample is provided for scores or a hundred feet and the location of that sample within these limits is unknown, complete correction is impossible. The record of drillers, who in the "chuck" of the drill, the wear upon it and the length of the "runs" have other means of information, is often of assistance in interpreting the drillings. But experience very seriously invalidates determinations based upon records alone. Serious discrepancies exist between records of different wells in the same town, between the records of the boring and the reaming of the same well, and between the record and the series of sample drillings. Granular and arenaceous limestones are sometimes set down as sandstones and quartzites or dolomites as granites. Shales are made excessively thick, and scores or hundreds of feet of alternating heterogeneous strata are included under one designation. Drillings usually correct these errors; but when incomplete they may strengthen them. Thus, drillers' records failing to distinguish between limestone of different beds, as the Galena and Trenton, may include both under one head, "limestone so many feet thick," and leave the first sample drilling taken — or the last — to represent the entire group. It is believed that this will readily account for several cases in which formations appear to be wanting locally.

In the discrimination of the drillings which often came in the unpromising form of paste or powder, the rocks being completely pulverized by the drill, ordinary optical tests were supplemented by examinations with a petrographical microscope and by various chemical and mineralogical tests. Polarized light was used in discriminating for example between crystalline silica and non-crystalline and other minerals; while the relative proportion of different minerals in the drillings could often be decided by their relative proportions in the microscopic field. Limestones, dolomites and magnesian limestones were often treated with cold dilute hydrochloric acid, the residue observed, the solutions neutralized with ammonium carbonate and treated successively with ammonium oxalate and hydric disodic phosphate. The relative amounts of magnesia present in different limestones could thus be roughly estimated. Time permitted no exact quantitative tests.

In co-ordinating the strata of the well sections with the different geological formations, in rare instances a definite horizon may be recognized by the fortunate presence of some fossil fragment in the drillings. The means chiefly used, however, must be lithological similarity and order of superposition. So uniform, so well marked, and so widely diverse are the lithological characteristics of the rocks of the terranes outcropping in northeastern Iowa, and so constant also the order of their superposition, that when the drillings show unmistakably the mineralogical nature of any rock at any depth, little hesitancy need be felt in referring it to its appropriate place in the geological column. At the same time, due account must be taken of the true possible thinning out of any formation in passing westward and southward from its outcrop; of changes in its physical features, and of the intercalation of other terranes without superficial exposure within the limits of the state. In some instances also the structure of the rock, as for instance its porosity or incoherence making it a water-way, and the known thickness of a rock at its outcrop and its dip becomes facts of assistance in its correlation.

The frankest statement of the difficulties encountered in these investigations cannot, after all, destroy the substantial value of their results. Upon the results of such investigations only we can rely for all our knowledge of the vast underground extension of each geological formation; compared with which the area of its outcrop is insignificant. This knowledge is not only of high scientific interest and value but it is also of great practical worth. It bears directly upon the subject of artesian waters, the necessary conditions of the existence in Iowa of natural oil and gas in commercial quantities are matters of the altitude, and minerological and physical conditions of certain Paleozoic formations,— facts that can be determined only by exploitation of the drill.

It is a pleasure to acknowledge here the hearty co-operation of the many who have aided in collecting and preserving the data upon which this work is based. While the number of persons thus contributing to the work is large, grateful acknowledgement is due and is hereby rendered to all. So hearty indeed has been the co-operation of these persons that in no case has there been a failure to obtain drillings where they have been preserved. It is only to be regretted that in many cases deep wells have been bored at a considerable expense and yet no record of the strata is now extant.

It is to be hoped that in the future no deep borings will be made in the state without some trustworthy person obtaining a complete and accurate record and series of sample drillings. Such a record should contain all matters of observation and judgment of the drillers, and samples of the drillings should be taken whenever change in the rock occurs, and in any case, every ten or twenty feet. The drillings should be emptied directly into a box from the last of the sand pumpings of each "clearing out" and immediately labeled with depth from which they were obtained.

Certainly self interest should prompt employers to secure and preserve such data respecting their own property, and yet a considerable number of water works in the state depending upon artesian waters are without these facts so important in case of many possible contingencies to their wells and in case that additional wells are desired. In some instances even the depth of the water horizons are unknown, and yet many thousands of dollars have been fruitlessly spent in Iowa in deep borings below water horizons which the knowledge of such facts might have saved.

In the course of the investigation some twenty different well sections were examined, sixteen of which have been correlated. These allow themselves to be arranged in two lines, one running from Emmetsburg to Davenport and the other from McGregor to Centerville. Thus two sections of the underlying strata have been made. The first reaches from Davenport northwest and is based upon records of wells drilled at Davenport, Tipton, Cedar Rapids, Vinton, Ackley, Mason City and Emmetsburg. The second starting from above Dubuque includes the section on the Mississippi and the wells of Monticello, Cedar Rapids, Sigourney, Ottumwa and Centerville.

The correlation of the strata encountered in these wells is shown on the accompanying charts (plates xvii and xviii).

The Cretaceous and Upper Carboniferous appear so seldom in the well sections that they need not be here considered. Beginning, however, with the Lower Carboniferous the different formations down to Algonkian are widely recognized, frequently with considerable detail.

LOWER CARBONIFEROUS.

While a lack of certitude exists as to the precise limits of the series in several well sections, one impressive fact is clearly shown; that of the relative decrease of the limestone compared with its shales and their almost complete disappearance in its southwestern extension. At Centerville for example, from 500 to 1,240 feet—and surely within these wide limits the Lower Carboniferous must come—there are according to the record but two beds of limestone so much as twenty feet thick and beds of half this thickness are few. At Keokuk, shales comprise three-fifths of the Mississippian series. At Grinnell the proportion of limestone is but little greater than at Centerville. This change from limestone in the north to shales in the south has been noted by McGee who adduced the fact that the Kinderhook is almost wholly shales at Burlington and almost wholly limestone at Marshalltown, Iowa Falls and Humboldt. But the completeness of this change as shown by the Grinnell and Centerville sections is as new as it is significant.

DEVONIAN.

No well section presents the probable maximum thickness of the entire Devonian series. If the Devonian is divided by means of the brecciated beds which extend from Scott at least to Fayette county with singular uniformity of position and persistence of character, there would be an upper and a lower member which meet and merge in the disturbed or brecciated beds. The dividing line lithologically and paleontologically also to a certain extent passes through their midst. As thus defined the lower Devonian is penetrated by three wells: Davenport, Cedar Rapids and Vinton. At Davenport the summit of the section is somewhat above the base of the brecciated portion. The thickness of the section here is 115 feet. At Cedar Rapids the total thickness of the lower Devonian appears to be a little over 100 feet. At Vinton the well head is probably somewhat below the Spirifera pennata beds of Calvin and the thickness of the well section is 250 feet. At Ackley the entire Devonian series was pierced, its thickness being 365 feet. At Mason City the Devonian has thinned to from 100 to 200 feet. At Washington, also, it is but seventy-four feet thick. The greatest thickness of the Devonian therefore probably lies to the west of

Cedar Rapids and Vinton. The drillings from the lower Devonian at Davenport, Cedar Rapids and Vinton exhibit the same lithological peculiarities and are indistinguishable from the out-cropping rocks of the same horizon. A hard, drab, non-magnesian limestone with subconchoidal fracture compacted of the finest calcareous flour is highly characteristic of these beds. At Vinton and Cedar Rapids a buff magnesian limestone occurs which probably represents the lower buff magnesian limestone exposed at Otis. The non-magnesian beds have entirely passed out at Emmetsburg, if indeed any of the Devonian extends that far to the west.

SILURIAN.

Upper Division. Toward the north and west so far as determined the Upper Silurian preserves unchanged the characteristic qualities of its outcrop; remaining a hard, white gray, or buff, rough porous dolomite, often cherty and with obscure casts and moulds of fossils. At Vinton a thin vein or pocket or fine siliceous powder was struck but such residuary products are met in the country rock. The most interesting and important discovery made from well sections concerning the Upper Silurian is that of Calvin who found at Washington that it had lost its dolomitic character and had become a more or less calciferous sandstone. As such it continues to Keokuk and Centerville. To the west, as at Grinnell, it seems to retain its usual facies.

Special interest attaches to the thickness of the Upper Silurian in these sections on account of the estimates that have heretofore been made from its outcrop, these varying from 350 to 540 feet. At Davenport and Tipton the Upper Silurian section seems to reach its maximum thickness at 320 to 330 feet. At Tipton, perhaps the upper beds were not passed through, since at Mount Vernon, lying eighteen miles to the northwest, the same formation appears about 460 feet above the supposed base of the Upper Silurian at Tipton. But this may be due to an anticline, as sixteen miles further to the west at Cedar Rapids it has thinned to 285 feet. At Vinton, Ackley and Mason City it is about 100 feet.

Maquoketa Shales. This formation forms so constant and unequivocal a member of well sections at least in the eastern part of the state that it is quite indispensible in their interpretation. Softer and paler than the shales of the Cambrian and more free from sand and more largely calcareous than the shales of the Coal Measures it is readily differentiated from most of the lithologically similar beds above and below it. Though deeply buried over most of the area under consideration it may possibly have in some locality an economic value as a cover to some unknown reservoir of natural gas or oil. The name sometimes applied by drillers, "mud-rock shales," is forcible and appropriate. The calcareous element is large and in all samples tested is associated with more or less magnesia. Intercalated beds of limestone are rare, yet at Ackley two thin layers of magnesian limestone occur, and at Vinton there is a stratum of brown dolomite twenty-three feet thick, classed with the Maquoketa because of the fifty-four feet of shale that underlie it. Perhaps at both places these strata represent the Galena which is sometimes shaly and which is otherwise absent here. Near the base of the Maquoketa shale at Monticello highly bituminous layers occur. It often is in places highly pyritiferous, sometimes being colored black from this cause. At Tipton, its superior member is a gray argillaceous limestone. At Davenport, in the Kimball

House section, 125 feet of fossilferous argillaceous limestone underlie the Maquoketa and must be classed with it if its place in the record is correct.

The great thickness of these shales was quite unexpected, no previous estimate having exceeded 100 feet. But at Davenport, according to the Kimball House record, the shales are 242 feet thick. At Tipton they are at least 185 feet thick and may even reach 295. At Vinton they are 258 feet, according to drillings, and are reported in the record of the second well at 320 feet. At Monticello they may reach 285 feet. Toward the east and west of this central area they become thinner, although they are 160 feet thick at Clinton and Ackley. At Mason City they are reduced to fifty-seven feet and at Emmetsburg to fifteen feet if represented there at all.

To the southwest they also thin out, at Washington being not more than 101 feet; at Keokuk sixty-three feet, and at Centerville absent or so thin as to escape notice. At Grinnell eighty feet of shale may be referred to this formation.

Galena-Trenton Limestones. These formations which in well sections often cannot be differentiated are of special interest from their possibilities in economic geology. Wherever the drill passes within these rocks it is followed with an expectancy born of the disclosures it has made in other states. In Ohio and Indiana, the lower Trenton is the source and the porous, creviced Upper Trenton, or Galena, the reservoir of the stores of natural gas and oil, whose recent discovery has made an epoch in the industrial history of the nation. Cer-Certain conditions of attitude, structure and lithology are necessary for the accumulation in commercial quantities of these precious illuminates, but whether or not these conditions exist in eastern Iowa is a matter of further investigation.

The evidence for the existence of gas and oil in these rocks throughout the state is as yet largely negative. Thus far no facts have been discovered tending to prove that the Trenton in eastern Iowa embraces any thickness or extent of bituminous shale. At one place only, Washington, was such found in this formation, though elsewhere it may be present but unrepresented in the drillings. Argillaceo-calcareous shales indeed occur, and in greater volume than anywhere along the Trenton outcrop in Iowa. These are especially extensive to the north. At Emmetsburg they are ninety-five feet; at Mason City fifty-five feet, and at Ackley thirty-five feet thick. At the latter place, however, they are indurated and have the facies of the shaly layers of the Cambrian. These basal shales reappear only at Clinton and Centerville. Elsewhere the Trenton presents the lithological features which characterize it along its eastern outcrop. It is often fossiliferous, gray, bluish, or buff limestone, briskly effervescing with acid, never a dolomite, though usually containing more or less magnesia.

The Galena, the importance of which as a reservoir for oil and gas has been noticed, seems to preserve its identity and the structure which fits it for these uses, to long distances from its outcrop. As far south at least as Davenport and Tipton, and as far west as Cedar Rapids and Monticello, it remains unchanged. Further to the south and west, at Washington, and also at Ackley and at Vinton, no evidence of it appears. Yet, upon the western side of the Ackley-Vinton trough, the rising strata of this horizon again become magnesian limestones or dolomites, as seen at Mason City and Emmetsburg. At the extreme south, also at Centerville, the place of the Galena is occupied by a hard, buff, magnesian limestone or dolomite, which like the Upper Silurian becomes arenaceous.

Over the western part of the area under consideration the thickness of the Galena and Trenton is quite uniform, as from Mason City to Ackley it falls but little short of 400 feet, and exceeds this from Clinton to Davenport. Even as far west as Grinnell it is 420 feet. To the south it thins, together with the other members of the Devonian and Silurian, though much less than they; thus, at Washington it is 297 feet thick; at Sigourney and Keokuk less than 150 feet thick; and at Centerville 210 feet. At Monticello it is listed at but 225 feet. It probably extends, however, to the place of the last sample of the Maquoketa. This would add to it nearly 100 feet.

Saint Peter Sandstone. Whenever pierced by the drill the Saint Peter is found to remain the same bed of incoherent sand so often described in Iowa and adjacent states. Its grains are remarkably uniform in size in any locality and stratum, though they vary considerably in different places and sometimes in different strata in the same well section. At West Liberty, at a depth of 1,000 feet, the grains are .18 millimeters in diameter on the average. At Tipton most of the grains are included between .27 and .39 millimeters, the largest observed being 1 millimeter. At Cedar Rapids the larger number fall .37 and .55 millimeters; at Vinton and Ackley between .46 and .55 millimeters; and at Emmetsburg between .46 and .64 millimeters. At Centerville there is a remarkable nearness of the large majority of grains to .36 millimeters.

A sample taken at random from the sandstone of the Saint Peter at McGregor showed more diversity in size of grains than is usually obtained in the artesian washings.

In this sample most of the larger grains agree in size with those from Centerville, but there are many about .18 millimeters in diameter.

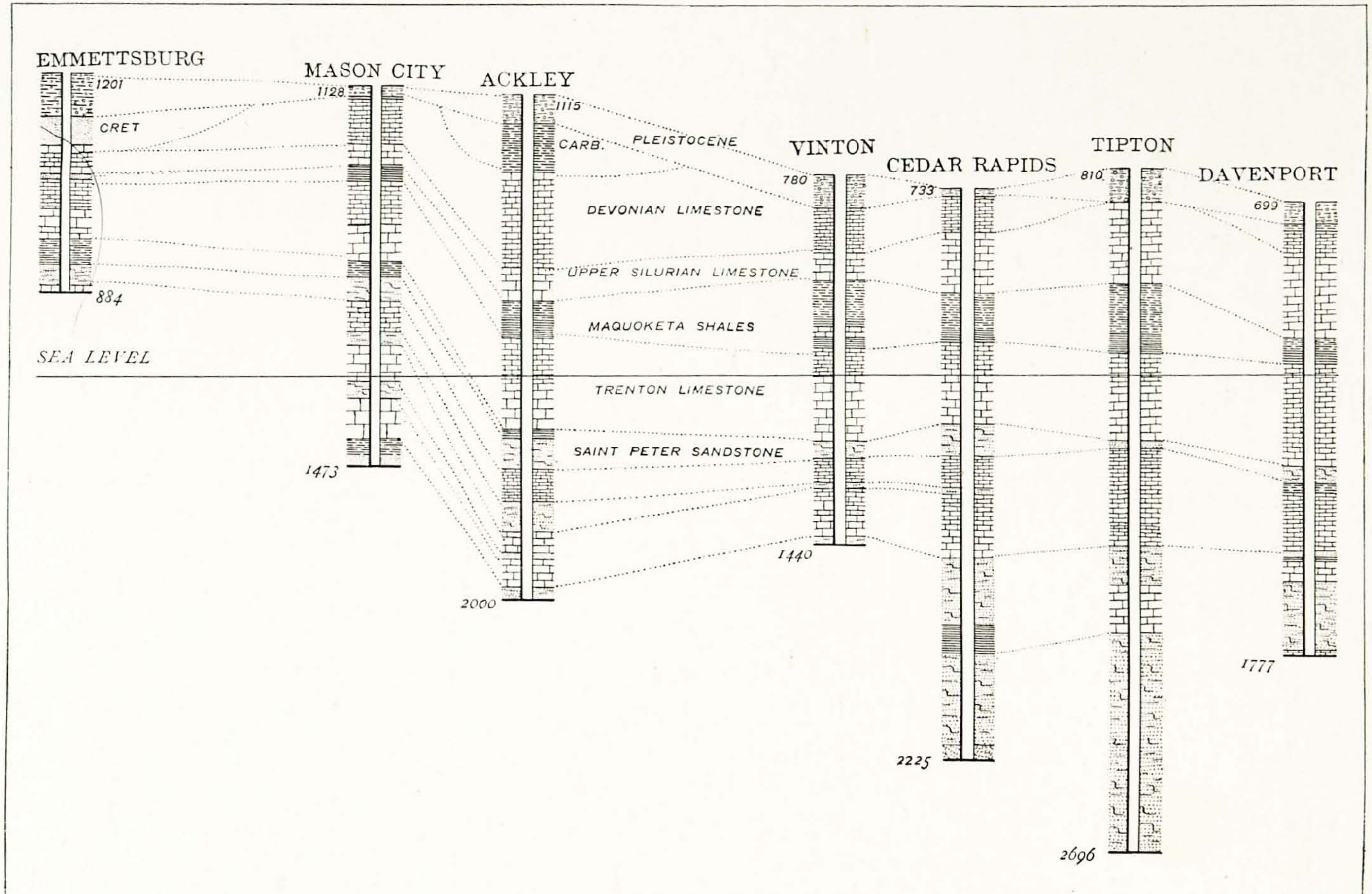
The grains from the drillings are of liquid quartz, well rounded through water movement and smoothed like ground-glass, so that under the microscope they have a certain superficial whiteness, though this is not opaque enough to conceal the brilliant colors which the abraded crystals display between crossed nicols. No silt or cement is present; nor do the grains show secondary enlargement.

The moist sand in bottles is sometimes seen to redden with time next the glass with dull ferruginous stains. The iron thus oxidizing is hardly native, but is probably either due to the slightly ferruginated water of the well or to minute filaments and scales of iron from the drill and rods. Such is certainly the origin of the rusty cement sometimes joining a few grains together.

In thickness, the Saint Peter varies from forty feet at Centerville to 116 feet at Cedar Rapids. No law is found governing this increase. A group of wells, where it is thinnest, as at Monticello, West Liberty, Vinton and at Tipton where it cannot be over fifty-five feet, are divided by the maximum thickness at Cedar Rapids. And though it reaches its minimum at Centerville it is remarkably uniform in the other wells of southeastern Iowa, not varying in them over ten feet from 100 feet. In the northwest the range of the Saint Peter is nearly the same as in the extreme southeast, it being eighty-five feet thick at Mason City and 110 feet at Emmetsburg. These variations are slight compared with those described in parts of Wisconsin, and where owing to the irregular surface of the Oneota on which the sands were spread the Saint Peter thins out completely on the folds of the inferior limestone, and thickens in its troughs to 212 feet.

The relation of the Saint Peter to sea level is seen in the accompanying diagrams (plates xvii and xviii) which illustrate some facts of interest. An eastward dip of the Paleozoic of northeastern Iowa is clearly seen in the section from Emmetsburg to Mason City. Where the section runs parallel to the strike of the geological formations, little change in level of the Saint Peter occurs; where it crosses the strike at an angle, the general southerly dip is usually noticed. Some significant exceptions occur; as for example, on the section from Tipton to Cedar Rapids (omitting intervening points). At the latter point the Saint Peter should be found at a lower level than at Tipton. But the Cedar River deformation, noticed by McGee, seems to have here lifted the sandstone to seventy-three feet above its level at Tipton. The dip is also anomalous on the entire section from Davenport to Ottumwa. In all this distance the Saint Peter seems to have declined but very little.

Oneota Limestone. Drillings from horizons beneath the Saint Peter have well-marked characteristics which readily distinguish them from drillings from any superior formation. But the difficulties already mentioned in passing from the finely comminuted and heterogeneous drillings to the rock of which they are in part composed apply here with peculiar force, when there is an attempt to discriminate the different formations of which this complex is composed. Even in the field, with plentiful outcrops and quarry sections, it sometimes is not very easy to delimit formations that graduate vertically into one another. How much harder then when the only data are artesian drillings! Other



DEEP WELL SECTIONS FROM EMMETTSBURG TO DAVENPORT.

difficulties arise when an attempt is made to correlate members of sections widely distant, belonging to a rock series whose members may be variable horizontally; arenaceous shales, for example, passing into sandstones on the one side and arenaceous limestones on the other. Add to this the fact that no limestone, shale, or sandstone of this series possesses any known features which in artesian drillings surely distinguish it from any other limestone, shale or sandstone of the same series, and it will be seen that no claim for inerrancy can be made for any conclusions that may reach any such methods.

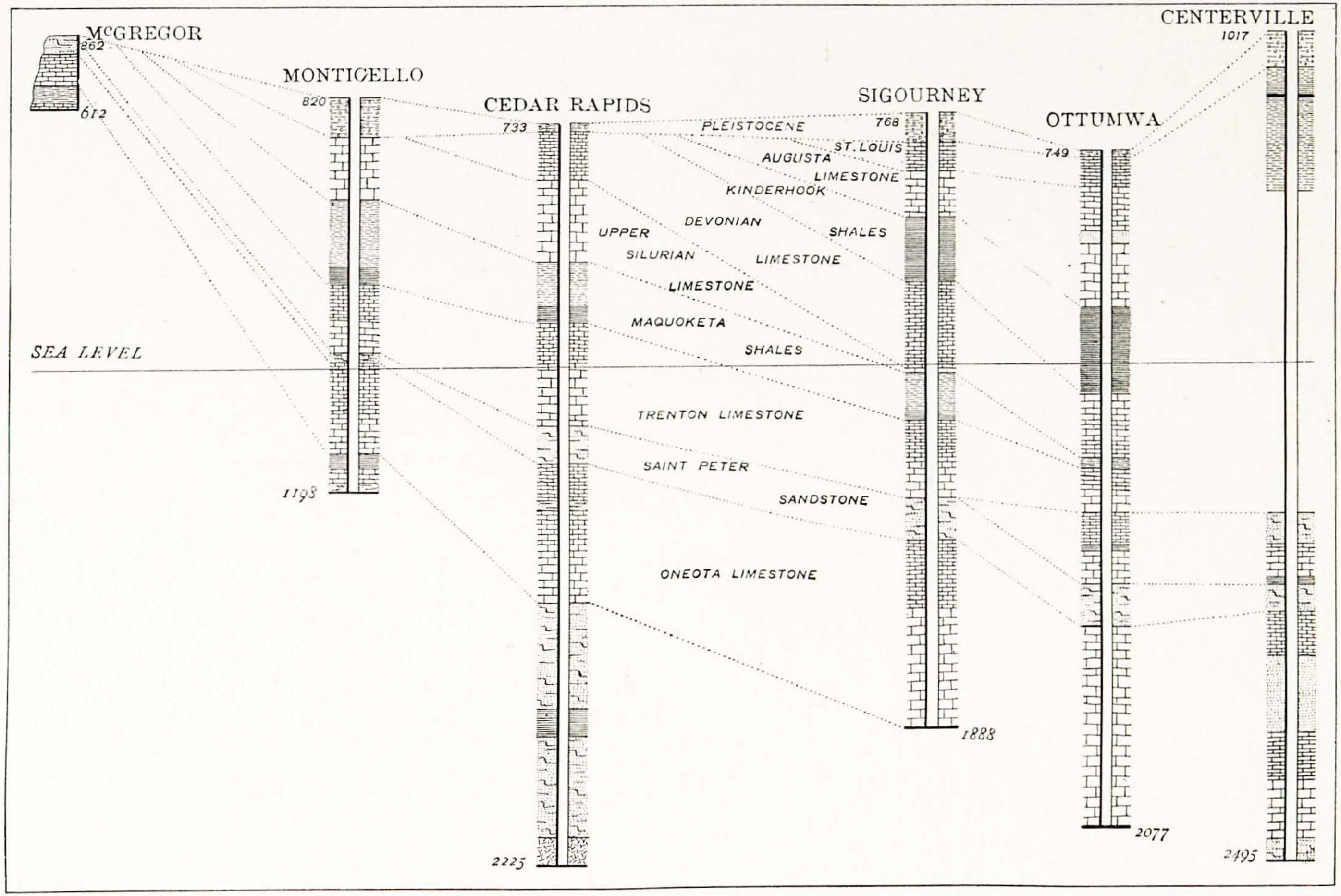
Nevertheless the various well sections set forth a few salient facts in which there can hardly be any large per cent of error. Immediately underlying the Saint Peter sandstone, though sometimes as at Ottumwa and Davenport, separated from it by a transition bed of arenaceous, slaty shale, there occur everywhere in eastern Iowa heavy beds of dolomite. These are in whole or in part the extension of dolomites of the Upper Mississippi, called the Lower Magnesian by Owen and the Oneota by McGee. In places, as at Tipton and Cedar Rapids, these dolomites are undivided so far as the incomplete records show, but elsewhere they are bipartite, being separated into two beds by a layer of sandstone. This intervening sandstone thins to the northeast and thickens to the west and south. At Monticello it may be no more than 15 feet thick and at Vinton it is 20 feet thick; at Cedar Rapids and Tipton it obtained no recognition from the drillers. At Ackley it is 80 feet thick; at Mason City 50 feet; at Grinnell 85 feet thick; at Ottumwa 122 feet; at Centerville 130 feet, and if calciferous passage beds with the upper dolomite be added, it is here 235 feet thick.

Meanwhile the dolomitic bed above this sandstone maintains a remarkable regularity in thickness from Mason City to Centerville. The lower dolomite is more variable, and to the south more massive. At Centerville it is at least 370 feet in thickness and it is reported to be 697 feet thick at Ottumwa. These dolomitic beds may be designated as the upper and lower Oneota and the intercalated sandstone as the New Richmond. The upper and lower Oneota are so alike in structural and lithological features, as appearing in drillings, that it is unnecessary to separate them in description further than to state that the lower division is on the whole more arenaceous. Each is a crystalline or subcrystalline dolomite, usually gray or white in color, but sometimes buff. So hard is the rock that chips large enough to indicate its structure are seldom procured. Occasionally it is seen to be porous or to carry minute imbedded grains of quartz. Much of the sand present in its drillings is no doubt from above, but much is also native, either disseminated or interstratified. The larger part of the silica of the Oneota is in the form of chert or flint, flakes of these minerals often forming a large part of the drillings and seldom or never wholly absent.

Drillings from the horizon referred to in New Richmond sandstone present no special diagnostic features to distinguish them from inferior sandstones. Usually in variation in size of grain and in proportion of fine quartzose matter, it resembles the sandstones beneath it. At the base of the Ackley section it strongly resembles the Saint Peter.

CAMBRIAN.

Saint Croix. Wherever, in eastern Iowa, the drill perforates the lower Oneota, it reaches a sandstone whose thickness varies considerably, from fifty-eight feet at



DEEP WELL SECTIONS FROM McGREGOR TO CENTERVILLE.

Monticello, where, however, the drill may not have reached its base, to perhaps 154 feet at Tipton, and 165 feet at West Liberty. Beneath this sandstone the deeper borings disclose dolomites, somewhat thin and inconstant compared with the Oneota, and heavy beds of shale. At Tipton this formation is composed of dolomites estimated a eighty-five feet thick, resting on 100 feet of arenaceous shale. At Cedar Rapids 100 feet of shale pass upward through calciferous sandrock into the sandstone just mentioned. At Mason City, 116 feet of limestone overlie fifty-eight feet of shale. The upper member, the sandstone, may be termed the upper Saint Croix and the lower member, the dolomites and shales, the lower Saint Croix.

The lithological affinities of the upper Saint Croix sandstone are with the Potsdam, as defined in this paper. As delimited in the sections, it is often more or less calciferous, and sometimes the dolomitic phases graduate upward into the lower Oneota and downward into the lower Saint Croix. At Ackley these transition beds are especially noteworthy. Perhaps here the main body of sandstone was not reached. Its colors are the lighter tints, gray, yellow and buff.

The dolomites of the lower Saint Croix do not differ lithologically from other dolomites of the magnesian series. They pass beneath into shales and sandy beds. At Cedar Rapids the argillaceous element prevails, the dolomites and silicous elements being insignificant. At Mason City and Tipton the latter elements are in excess of the former. The shales are of a decided green tint, usually bright and rather dark.

The sandstone below the lower Saint Croix differs from the Saint Peter in the wider diversity in size of grains, in fineness of grains of some of its beds and in its greater induration, as shown by faceted grains and the rarity of unfractured grains of any considerable size, the rule obtaining here, as elsewhere, that the harder the rock the smaller the fragments into which it is broken by the drill. In color it ranges from white to pale yellow, pink and buff, not reaching, where observed in Iowa, the darker shades of red and brown.

At only two points in eastern Iowa, at Cedar Rapids and Tipton, are there records of the strata beneath the basal shales of the lower Saint Croix; at Cedar Rapids 360 feet of sandstone which overlies the Algonkian floor, and at Tipton 443 feet of sandstone below the basal shales are referred to the horizon in question.

ALGONKIAN.

To the Sioux quartzite belongs the seventy-five feet of vitreous quartzite which forms the base of the Cedar Rapids section. On comparing the Tipton section it seems best to consider the 451 feet of its basal sandstones, all more or less indurated as indicated by their faceted grains and the fine, angular fragments into which the rock was broken by the drill, as the eastward extension of the same beds. The drillings examined furnished no proof that the Algonkian has been elsewhere reached.

DRILL RECORDS OF DEEP WELLS IN EMMETSBURG-DAVENPORT SECTION.

I. Emmetsburg Well.

(Elevation 1201 feet above sea level.)

	THICKNESS.	DEPTH.
18. Soil	5	5
17. Clay, bright yellow, calcareous with drift pebbles, Upper Till	16	21
16. Clay, blue, pebbly, more strongly calcareous than No. 17, Lower Till	204	225

		THICKNESS.	DEPTH.
15.	Sand, moderately coarse, gray, mostly clear quartz, but many grains of pink and dark gray quartz, jasper and flint	30	255
14.	Sand, very coarse, similar in composition to No. 15, fragments also of fine white kaolinic clay	79	334
13.	Clay, fine, bright red, a trifle sandy, non-calcareous	22	356
12.	Dolomite, hard, subcrystalline, fossiliferous, in gray and buff cubes	10	366
11.	Dolomite, or magnesian limestone, buff, hard, rough, sub-crystalline, with considerable sand	22	388
10.	Shale, blue	4	392
9.	Sandstone, coarse grained, with small pebbles identical in composition with Nos. 14 and 15	30	422
8.	Shale, light blue	15	437
7.	Limestone, magnesian, gray	50	487
6.	Dolomite, light buff, soft	90	577
5.	Magnesian limestone, hard, gray	84	661
4.	Shale, blue, argillaceous	65	726
3.	Shale, as above, dark blue	30	756
2.	Sandstone, presenting all the characteristics of the Saint Peter; grains mostly between .55 and .70 millimeters	110	866
1.	Dolomite, light gray, subcrystalline, termed in drillers' record "granite"	18	884

The total thickness of the Pleistocene (16 and 17) is 220 feet. Numbers 13, 14 and 15 are probably Cretaceous; 12 is a coarse, rough dolomite unlike, lithologically, any Cretaceous rocks in Iowa, and contains a fragment of an impression of one valve of a square-shouldered brachiopod unmistakably Paleozoic. The Chicago, Milwaukee and Saint Paul Railway Company contributed a tube of drillings which correspond exactly, in the drillings and in the accompanying record, so far as it is preserved, with the Emmetsburg section.

As 2 is plainly the Saint Peter, 3 and 4 may be referred to the Trenton and one to the upper Oneota.

II. Mason City Well.

(Elevation 1128 feet above sea level.)

		THICKNESS.	DEPTH.
19.	Black loam	2	2
18.	Clay	26	28
17.	Limestone, brown, soft, argillaceous	70	98
16.	Dolomite, hard, light bluish gray, granular, subcrystalline with some lighter and softer briskly effervescent limestone	119	217
15.	Dolomite, or magnesian limestone, hard, brown	87	304
14.	Shale, blue	57	361
13.	Limestone, magnesian, hard, pale buff	50	411
12.	Limestone, magnesian, flinty, impure, bluish gray with earthy lustre	300	711
11.	Shale, green, slightly gritty, with chert and particles of magnesian limestone	55	766
10.	Dolomite, highly arenaceous, yellow	20	786
9.	Sandstone, fine, white, grains rounded and ground	85	874
8.	Dolomite, white	113	984
7.	"Mixed lime and sandstone" (no sample)	50	1034
6.	Dolomite, light gray	147	1179
5.	Sandstone, buff and white	60	1249
4.	Dolomite, hard, gray, with flakes of rather hard, green shale	116	1365
3.	Shale, greenish, highly arenaceous, with fragments of dolomite	58	1423
2.	Sandstone, gray, larger grains, rounded, many smaller angular fragments, with some greenish shale	45	1468
1.	"Granite." The sample so labelled consists of sandstone similar to 2, rounded grains about .25-.35 millimeters in diameter, with some dolomite, chert and shale. None of the constituents of granite are present except quartz	5	1473

NUMBERS.		FEET.
17-19.	Humus and drift	28
15-17.	Devonian and Upper Silurian	276
14.	Maquoketa	57
11-13.	Galena-Trenton	405
9-10.	Saint Peter	105
6-8.	Upper Oneota	308
1.	Algonkian (penetrated)	5

The mixture of drillings in 16 and the absence of definite criteria make it impossible to delimit the Devonian and upper Silurian ; 12 shows drillings consisting mostly of flint, which cannot, of course, represent the true charter of rocks aggregating 300 feet. Though no "granite" occurs in 1, the driller's record may be relied upon that the Algonkian quartzite was reached at this point.

III. Ackley Well.

(Elevation 115 feet above tide.)	DEPTH.
87. Alluvium or drift	....
86. Shale, fine, blue	100
85. Shale, fine, blue	115
84. Sandstone, coarse, buff, vesicular	135
83. Shale, fine, blue	140
82. Shale, fine, blue	150
81. Sandstone, fine, bluish white	163
80. Shale, fine, blue	225
79. Shale, fine, blue	249
78. Shale, fine, blue	250
77. Sandstone, as No. 82	260
76. Shale, blue, white, ferruginous, with concretions	265
75. Shale, fine, blue	290
74. Limestone, magnesian, highly pyritiferous, containing a little chert	307
73. Shale, fine, blue	320
72. Limestone, dark gray, magnesian	335
71. Limestone, argillaceous, non-magnesian, with a fragment of *Atrypa reticularis*, Linn	400
70. Limestone, light yellowish gray, argillaceous, slightly magnesian, with some green shale	410
69. Limestone, light bluish gray, non-magnesian	460
68. Limestone, light yellowish gray, argillaceous and slightly siliceous	473
67. Limestone, blue, agillaceous, non-magnesian	500
66. Limestone, blue, argillaceous, slightly magnesian.	555
65. Limestone, brown, slightly magnesian	570
64. Limestone, brown, slightly magnesian	600
63. Limestone, brown, slightly magnesian	610
62. Limestone, light brown, magnesian	635
61. Dolomite	730
59. Dolomite, with much chert	735
58. Dolomite, with much chert	740

		DEPTH.
57.	Dolomite, with much chert	750
56.	Dolomite	751
55.	Dolomite	757
54.	Dolomite	759
53.	Dolomite	760
52.	Dolomite	764
51.	Dolomite, with chert	775
50.	Dolomite, with chert	787
49.	Dolomite, with green shale	797
48.	Dolomite, with green chert	800
47.	Dolomite, with green chert	803
46.	Shale, green, samples of this from 815 to 960 feet. A hard, brown dolomite, crystalline, cherty, occurs at 875 and 896 feet, thus being interbedded in the shale	960
45.	Limestone, light gray, cherty	975
44.	Limestone, light gray, cherty	995
43.	Limestone, light gray, soft	1015
42.	Limestone, light gray, darker	1040
41.	Limestone, light gray	1080
40.	Limestone, light gray, softer	1100
39.	Limestone, light gray, softer	1150
38.	Limestone, soft, light gray, with some darker bluish gray	1160
37.	Limestone, light gray	1180
36.	Limestone, light bluish gray, fossiliferous	1205
35.	Limestone, light bluish gray, fossiliferous	1230
34.	Limestone, light bluish gray, fossiliferous	1238
33.	Limestone, light buff	1250
32.	Limestone, dark gray	1257
31.	Limestone, light gray	1275
30.	Limestone, drillings are a fine, bluish black, calcareous sand mixed with some of lighter color, highly pyritiferous, considerable argillaceous material and many miscroscopic particles of quartz	1300
29.	Limestone, bluish gray, fossiliferous	1320
28.	Shale, green	1325
27.	Shale, bright green, indurated, slaty, highly pyritferous	1335
26.	Shale, bright green, slaty	1350
25.	Sand, white grains, rounded, somewhat uniform in size	1360
24.	Sand, white grains, rounded, somewhat uniform in size	1405

		DEPTH.
23.	Sand, white, grains rounded, somewhat uniform in size, finer	1415
22.	Limestone, white, subcrystalline	1445
21.	Dolomite, in fine, light yellow powder	1480
20.	Dolomite, with considerable light green shale	1490
19.	Dolomite, buff, with shale and ocherous grains	1500
18.	Dolomite, white, with some chert and quartz and green shale	1505
17.	Dolomite, white, with some chert, quartz and green shale	1515
16.	Dolomite, light yellow	1530
15.	Dolomite, hard, gray, subcrystalline, with grains of quartz	1540
14.	Dolomite, white	1548
13.	Dolomite, hard, rough, light buff, subcrystalline	1550
12.	Sandstone, white, rounded grains, with numerous minute chips of dolomite	1565
11.	Sandstone, as above	1580
10.	Sandstone, light, fine grained, friable, grains rounded, varying widely in size, the largest being about one millimeter in diameter	1595
9.	Sandstone, hard, light gray, moderately fine grained, with considerable green shale	1610
8.	Sandstone, white, grains rounded and resembling the Saint Peter in general uniformity in size; many from seven to nine millimeters, largest over one millimeter	1635
7.	Dolomite, buff	1645
6.	Dolomite, arenaceous or calciferous sandstone	1675
5.	Dolomite, hard, gray, subcrystalline, pyritiferous	1685
4.	Dolomite, light gray	1720
3.	Dolomite, siliceous, gray, with admixture of quartz grains, and some chert	1820
2.	Dolomite, like above, but with more chert	1950
1.	Sandstone, grains rounded, moderately large, with considerable gray dolomite	2000

NUMBERS.		FEET.
73-86.	Coal Measures	235
62-72.	Devonian	365
47-61.	Upper Silurian	115
46.	Maquoketa	160
26-45.	Upper and Lower Trenton	385
23-25.	Saint Peter	85
13.	Oneota	375
1- 3.	Upper Saint Croix (penetrated)	280

Numbers 73–86 are taken to represent a Carboniferous outlier rather than the Kinderhook. With the intercalated magnesian limestone in 46, there should be compared the similar bed interstratified with the Maquoketa shales at Vinton. In each instance it is possible that these beds represent the westward extension of the Galena. 26, 27 and 28 are transition beds from Trenton to Saint Peter, and into the latter 26 and 27 should perhaps be placed. Perhaps 22 represents a calcareous layer near the base of the Saint Peter. 1, 2 and 3 represents the passage beds from the lower Oneota to the upper Croix, growing more and more arenaceous downward, but remaining more or less calciferous to the bottom of the well. In this well, as in others, where the specific depth of each sample is stated, it is assumed as a general rule in reckoning the thickness of a stratum, that the drillings represent its summit and that it extends beneath to the portion of the next drillings.

IV. Vinton Well No. 1.

(Elevation 780 above tide.)

	THICKNESS.	DEPTH.
36. Alluvial and Drift deposits, in ancient river valley	115	115
35. Limestone, chips hard and compact, non-magnesian, light cream color, fracture sub-conchoidal	20	135
34. Limestone, chips magnesian, light buff, porous, subcrystalline	15	150
33. Limestone, powder pinkish, argillaceous, cherty, contains some magnesia; associated with some dark clay and light non-magnesian limestone	18	168
32. Limestone, powder white, non-magnesian, pyritiferous, with white chert and some rounded grains of quartz	82	250
31. Dolomite, hard, compact, sub-crystalline, yellowish in color, with white chert, inclosing centres of gray flint	15	265

		THICKNESS.	DEPTH.
30.	Dolomite, powder white	10	275
29.	Dolomite, bluish gray, subcrystalline, with gray flint	10	285
28.	Clay, light green	5	290
27.	Sandstone, very fine, white, grains angular	5	295
26.	Dolomite, chips soft, light gray, porous, subcrystalline, with a little dark gray flint.	55	350
25.	Shale, green, calcareous	25	375
24.	Shale, fine, bluish, calcareous, soluble portion magnesian	167	542
23.	Magnesian limestone or dolomite, chips hard, brown, subcrystalline, ferruginous	23	565
22.	Shale, light and dark gray	9	574
21.	Shale, light bluish, calcareous	45	619
20.	Limestone, powder light gray, argillaceous, contains some magnesia	111	730
19.	Limestone, powder cream colored, contains some magnesia	30	760
18.	Limestone, as above	20	780
17.	Limestone, as above	27	807
16.	No sample	13	820
15.	Limestone, like No. 19, gray in color	15	835
14.	Limestone, chips minute, soft gray	65	900
13.	Limestone, chips minute, bluish gray, non-magnesian	75	975
12.	Limestone, chips thin, flaky, rather soft, fine grained, compact, light gray, non-magnesian	45	1020
11.	Sandstone, with fragments of limestone	20	1040
10.	Sandstone, clean quartz, grains rounded, of moderate and nearly uniform size, vitreous, limpid, surface ground	35	1075
9.	Chert, white, with white dolomite, and greenish slate-like shale	5	1080
8.	Dolomite, chips subcrystalline, minutely porous, medium dark gray, with much chert	15	1095
7.	Dolomite, powder fine, white	5	1100
6.	Dolomite, chips white and light gray, fine grained, subcrystalline, with some chert	25	1125
5.	Dolomite, hard, medium dark gray, and softer white	50	1175

		THICKNESS.	DEPTH.
4.	Sandstone, with considerable dolomite, grains of silica light colored, varying widely in size, largest being about .9 millimeters in diameter	15	1190
3.	Dolomite, like No. 6	85	1275
2.	Chert, with minute calcareous fragments	10	1285
1.	Sandstone, grains mostly rounded varying considerable in size, largest about one milimeter, also considerable dolomite	2	1287

NUMBERS.		FEET.
32–36.	Devonian	250
26-31.	Upper Silurian	100
21–25.	Maquoketa	269
12–20.	Upper and Lower Trenton	401
10–11.	Saint Peter	55
2– 9.	Upper Oneota	210
1.	New Richmond (penetrated)	2

As the ancient river valley whose depth is represented in 38 is excavated in Devonian strata, the thickness of the Devonian penetrated is reckoned to the well-head. The following drillers' record is of a second well at Vinton bored to a depth of 1,440 feet or more:

		THICKNESS.	DEPTH.
10.	"To rock"	100	100
9.	"White limestone"	200	300
8.	"Tough, blue clay"	320	620
7.	"Brown limestone"	200	820
6.	"Light gray limestone"	150	970
5.	"Saint Peter sandstone"	50	1020
4.	"Brown sandstone"	200	1220
3.	"Light sandstone, water bearing"	20	1240
2.	"Coarse brown sandstone"	170	1410
1.	"White, coarse sandstone, water bearing".	30	1440

The agreement of the above record with the record and and drillings of well No. 1 is more noticeable than the disagreement between them. The discrepancies in the records of the two wells are as follows: In well No. 2 the

Upper Silurian is not discriminated, the top of the Maquoketa is fifty feet higher than in the record of well No. 1; the Maquoketa is fifty-two feet thicker and the Galena-Trenton as much thinner; the Upper Oneota is called "brown sandstone," the drillers not distinguishing the fine sand of angular drill-cut fragments of dolomite from true silicious sand, a common error. The thickness of the Saint Peter is the same in both sections, but it is placed fifty feet higher in well No. 2. The thin sandy layer at 1,175 in well No. 1 is overlooked in well No. 2. Sandstone 3 of well No. 2 is identical with the basal sandstone of well No. 1, and is referred to the New Richmond; 2 of well No. 2, 170 feet thick, is taken to be the lower Oneota dolomite and 1 to be the summit of the upper Saint Croix sandstone.

V. *Cedar Rapids Well, No. 1.*

(Elevation 733 feet above tide.)

		THICKNESS.	DEPTH.
26.	Alluvium	10	10
25.	Limestone, light buff, rather soft, magnesian; and gray, very hard, non-magnesian, compact, somewhat fragmental in structure	40	50
24.	Limestone, gray, sparry, subcrystalline	85	135
23.	Limestone, moderately hard, light buff, magnesian	40	175
22.	Dolomite, pink, minutely vesicular, subcrystalline	65	240
21.	Dolomite, bright buff, porous	60	300
20.	Dolomite, hard, light gray, porous	30	330
19.	Dolomite, coarser grained than above, light yellow in color	20	350
18.	Dolomite, hard, light gray, subcrystalline, with some white chert	25	375
17.	Dolomite, like above but softer and yellowish in color	45	420
16.	Shale, fine, bluish green, calcareous, magnesian	200	620
15.	Limestone, magnesian and non-magnesian.	295	915

	THICKNESS.	DEPTH.
14. Shale	5	920
13. Sandstone, slightly bluish or greenish gray, grains of quartz rounded, with considerable calcareous powder and some gray shale	65	985
12. Shale, dark colored	1	986
11. Sandstone, clean, white grains, rounded and somewhat uniform in size	50	1036
10. Dolomite, light gray, rather hard, arenaceous, of fine texture, and with much finely laminated green shale	74	1150
9. Dolomite, very hard, gray, subcrystalline.	..	....
8. Dolomite, gray, with chert, white and quartzose sand	270	1420
7. Sandstone, drillings consist of fine white rounded grains with much finely comminuted quartz and many small angular fragments of white dolomite	88	1508
6. Sandstone, fine, yellowish, water bearing	42	1550
5. Sandstone, with slight admixture of calcareous powder	140	1690
4. Shale, tough and hard, containing a small amount of very fine silicious particles and some dolomite	100	1790
3. Sandstone, light, reddish grains largely angular, some with crystalline facets	160	1950
2. Sandstone, cream colored, very fine grained	200	2150
1. Quartzite, reddish brown, grains angular, rock drilled with great difficulty	75	2225

Limestone of number 25 resembles the magnesian limestone outcropping beneath the Otis beds at water level along the Cedar river from Otis to Cedar Rapids. The well head lies somewhat above the Independence shales. Number 24 apparently occupies the place of the Bertram beds which they resemble lithologically; 23 is probably the Mount Vernon beds and the dolomites immediately subjacent, the Le Claire; 15 comprises the Galena and Trenton. In the drillers' record it appears as a "reddish brown sandstone." Three different sample drillings of this number each stated to represent the entire 295 feet, in the possession of different persons, illustrate the need of constant caution in dealing with such data. One sample is a gray dolomite, evidently from the Galena; one a light gray, non-magnesian limestone, as surely from the Trenton, and the third is a quartz sand whose true position is quite uncertain. From the reaming of the well authentic samples of the Trenton were obtained at 800 feet and 850 feet. These consisted of chips of light gray, fossiliferous limestone, briskly effervescent in cold dilute hydrochloric acid lustre earthy, relieved by a few crystalline facets. The Trenton must, therefore, extend upward at least to 800 feet and occupy 120 feet of the 295 feet referred conjointly to it and the Galena; 7 appears to be the transition beds between the Oneota dolomites and the upper Saint Croix sandstones, and is classed here with the latter.

SUMMARY.

NUMBERS.		FEET.
24–25.	Devonian	135
17–23.	Upper Silurian	285
16.	Maquoketa	200
14–15.	Galena-Trenton	300
11–13.	Saint Peter	116
8–10.	Oneota	384
2– 7.	Cambrian	570
1.	Algonkian? (Sioux Quartzite)	75

VI. Tipton Well.

(Elevation 810 feet above tide.)

		THICKNESS.	DEPTH OF SAMPLE.
54.	Drift	125	125
53.	Dolomite, hard, light gray, with white chert.	325	135
52.	Limestone, soft, medium dark gray, argillaceous, slightly magnesian		445
51.	Shale, greenish		520
50.	Shale, greenish		570
49.	Shale, greenish	295	640

		THICKNESS.	DEPTH.
48.	Dolomite, hard, gray	60	740
47.	Limestone, soft, light buff, magnesian		800
46.	Limestone, soft, light gray, somewhat argillaceous		850
45.	Limestone, white, slightly magnesian		885
44.	Limestone, soft, light gray, slightly magnesian		900
43.	Limestone, as above, but darker		950
42.	Limestone, dark bluish gray, fossiliferous, somewhat argillaceous, non-magnesian	150	990
41.	Shale, green	15	1000
40.	Limestone, soft, dark bluish gray, argillaceous		1015
39.	Limestone, as above	15	1030
38.	Sand, clean, white, grains rounded and ground	15–55	1070
37.	Dolomite, hard, gray, with green shale		1085
36.	Dolomite, white, in powder with considerable aluminous admixture and with minute grains of silicious sand		1100
35.	Dolomite, in minute angular fragments, subcrystalline, light buff		1140
34.	Dolomite, light gray		1150
33.	Dolomite, white, in powder		1155
32.	Dolomite, gray, in coarser powder		1180
31.	Dolomite, hard, gray		1195
30.	Dolomite, hard, lighter gray, with green shale		1220
29.	Dolomite, as above, cherty		1250
28.	Chert, white, with minute fragments of dolomite, hard, gray, porous	377	1362
27.	Sand, fine, light-colored grains of rounded quartz, many with fresh fractured surfaces, some displaying crystalline facets, also many grains of dolomite, white, subcrystalline		1462
26.	Sand, as above, but finer, with less dolomite	154	1502
25.	Dolomite, dark gray	86	1616
24.	Shale, dark greenish, pyritiferous, with much dolomite, and fragments of fine-grained argillaceous sandstone	100	1702
23.	Sandstone, white, grains angular and rounded, many faceted		1802

		THICKNESS.	DEPTH.
22.	Sandstone, as above		1865
21.	Sandstone, white, grains very fine, mostly angular		1900
20.	Sandstone, pinkish, fine-grained, in minute loosely coherent fragments		1990
19.	Sandstone, in fine reddish powder consisting mostly of microscopic grains of quartz		2100
18.	Sandstone, in fine powder, gray, consisting, as seen under the microscope, of grains of quartz, mostly angular		2150
17.	Sandstone, white, grains of moderate size, mostly angular, some with secondary enlargements	443	2220
16.	Sandstone, pinkish		2245
15.	Sandstone, reddish		2300
14.	Sandstone, pinkish, angular grains and grains with crystalline facets		2400
13.	Sandstone, light pink, in angular fragments.		2430
12.	Sandstone, reddish		2500
11.	Sandstone, as above, but lighter in tint		2550
10.	Sandstone, reddish brown		2575
9.	Sandstone, dark reddish brown, grains angular		2600
8.	Sandstone, fine-grained, brown		2630
7.	Sandstone, fine-grained, reddish		2640
6.	Sandstone, as above		2650
5.	Sandstone, as above		2665
4.	Sandstone, as above		2675
3.	Sandstone, in very fine pink sand		2685
2.	Sandstone, fine brownish		2696
1.	Sandstone, very fine, light reddish brown	45½	2696½

SUMMARY.

NUMBERS.		FEET.
54.	Drift	125
52.	Upper Silurian	325
49-52.	Maquoketa	295
48.	Galena	60
39-47.	Trenton	230
38.	Saint Peter	15-55
28-37.	Oneota	377
17-27.	Cambrian	783
1-16.	Algonkian?	451

Drillings of numbers 1 and 16 consist of quartzose sand or powder composed of angular fragments, though all are termed sandstone above, the degree of induration of the rock may reach that of quartzite.

VII. Davenport, Park Well.

Elevation about 799 feet above tide.

		THICKNESS.	DEPTH.
26.	"Loess," no sample	40	40
25.	"Boulder clay," no sample	60	100
24.	Shale, dark, no sample	30	130
23.	Limestone, pure, hard, gray, compact, of fine texture, non-magnesian	220	350
22.	Dolomite, hard, highly vesicular, light pinkish buff, with casts of crinoid stems, and casts of apex of *Platystoma niagarense*, Hall	30	280
21.	Dolomite, subcrystalline, cream colored, highly vesicular, with obscure cast of bryozoans	20	400
20.	Dolomite, hard, bluish gray, subcrystalline.	90	490
19.	Shale, lead colored, argillaceous, very slightly calcareo-magnesian, fossiliferous, blackens in closed tube, B. B., turns white	30	520
18.	Dolomite, white, arenaceous	80	600
17.	Dolomite, hard, gray, subcrystalline	50	650
16.	Dolomite, hard, rough, brownish white, some fine gray shale	75	725
15.	Dolomite, lighter in color, with obscure casts of fossils referred to Zygospira	50	775
14.	Dolomite, light brownish	125	900
13.	Dolomite, as above, with white chert	50	950
12.	Dolomite, magnesian limestone, white	75	1025
11.	Limestone, light bluish gray, non-magnesian, argillaceous, in thin flaky chips.	50	1075
10.	Shale, green, pyritiferous	10	1085
9.	Sandstone, grains rather coarse, rounded, white and pinkish	90	1160
8.	Shale, indurated, slightly arenaceous, fine grained, gray, green and purplish	30	1190
7.	Dolomite, light gray, arenaceous	60	1250
6.	Dolomite, light buff, arenaceous	50	1300

		THICKNESS.	DEPTH.
5.	Dolomite, buff, arenaceous	100	1400
4.	"No record"	25	1425
3.	"Sandstone"	10	1435
2.	"Limestone"	100	1535
1.	Dolomite, in minute fragments, with large admixture of silicious sand	...	1797

SUMMARY.

		THICKNESS.
25–26.	Pleistocene	100
25.	Carboniferous	30
23.	Devonian	220
20–22.	Upper Silurian	140
12–19.	Undetermined	535
10–11.	Trenton	60
8–9.	Saint Peter	120
2–7.	Oneota	345
1.	Undetermined	262

VIII. Davenport, Kimball House Well.

(Elevation 699 feet above tide.)

		THICKNESS.	DEPTH.
15.	"Modified Drift"	13	13
14.	Limestone, magnesian, compact, of fine texture, hard, light and dark gray in color	67	80
13.	Limestone, softer, lighter colored, similar in composition and texture	48	128
12.	Dolomite, hard, pure, subcrystalline, vesicular, light greenish gray, with casts and moulds of fossils	47	175
11.	Dolomite, as above, darker in color	130	305
10.	Dolomite, as No. 12	120	425
9.	Dolomite, light, bluish gray, with white chert	23	448
8.	Shale, black, pyritiferous, non-carbonaceous	27	475
7.	Shale, blue	90	565
6.	Limestone, blue, argillaceous, fossiliferous.	125	690
5.	Dolomite, hard, rough, subcrystalline, medium dark buff	40	730
4.	Sand, fine, buff, largely dolomitic, with rounded grains of quartz, also many grains of pyrite in minute, agglomerated crystals (water bearing)	45	775

		THICKNESS.	DEPTH.
3.	"Limestone," soft, yellow, magnesian (no sample)	75	850
2.	"Limestone," hard, buff, non-magnesian (no sample)	50	900
1.	"Limestone," argillaceous, ferruginous (no sample)	90	990

SUMMARY.

NUMBERS.		THICKNESS.
15.	Pleistocene or recent	13
13–14.	Devonian	115
9–12.	Upper Silurian	320
6–9.	Maquoketa	242
1-5.	Undetermined.	

RECORDS OF DEEP WELLS IN THE McGREGOR-CENTERVILLE SECTION.

IX. McGregor Section (above the town).

(Elevation about 862 feet above tide.)

		FEET.
3.	Trenton limestone	80
2.	Saint Peter sandstone	70
1.	Oneota limestone and shale	90

X. Monticello Well.

(Elevation 820 feet above tide.)

		THICKNESS.	DEPTH OF SAMPLE.
24.	Drift	85	60
23.	Dolomite, light buff	15	85
22.	Dolomite, lighter in color than above, porous, subcrystalline, with some chert,	40	100
21.	Dolomite, hard, buff, porous, with considerable chert	60	140
20.	Dolomite, gray, with chert	35	200
19.	Dolomite, hard, buff, porous	30	235
18.	Shale, greenish, slightly calcareous		265
17.	Shale, greenish, slightly calcareous	155	380
16.	Shale, dark brown, strongly bituminous, pyritiferous, slightly calcareous	30	420
15.	Shale, light greenish gray, magnesian	100	450
14.	Shale, as above, with some gray subcrystalline dolomite, or magnesian limestone,	65	550

		THICKNESS.	DEPTH.
13.	Dolomite, as that above, and limestone, soft, white	30	615
12.	Limestone, non-magnesian, in flaky chips, fossiliferous, rather soft, bluish gray in color	130	645
11.	Sandstone, grains rounded, fine	25	775
10.	Dolomite, cream colored, with some quartz sand, probably from above		800
9.	Dolomite, as above, darker in color		820
8.	Dolomite, light gray		920
7.	Dolomite, light yellowish		975
6.	Dolomite, highly silicious, or calciferous sandstone	10	1025
5.	Dolomite, hard, silicious, reddish buff	5	1035
4.	Shale, yellowish green, non-calcareous		1040
3.	Dolomite, gray	100	1085
2.	Sandstone, coarser than above, grains usually rounded, but some with crystalline faces		1140
1.	Sandstone, light yellow, particles mostly angular		1198

SUMMARY.

NUMBERS.		FEET.
19–23.	Upper Silurian	180
15–18.	Maquoketa	285
12–14.	Galena-Trenton	225
11.	Saint Peter	25
4–10.	Oneota	340
1– 2.	Saint Croix	58

XI. Cedar Rapids Well.

(See Section V.)

XII. Sigourney Well.

(Elevation 768 feet above tide.)

		THICKNESS.	DEPTH.
24.	Drift	98	98
23.	Limestone, impure, earthy	22	120
22.	Limestone, cherty,	15	135
21.	Shale, calcareous	20	155
20.	Limestone and shale	10	165
19.	Limestone, hard, bluish gray	5	170
18.	Limestone, light, cherty	17	187

		THICKNESS.	DEPTH.
17.	Shale	2	189
16.	Limestone, hard, white with brown pieces.	125	314
15.	Shale, dark green	1	315
14.	Limestone, grayish white, drab in places..	41	356
13.	Shale, soft, green	198	554
12.	Limestone	2	556
11.	Shale, soft, green	29	585
10.	Limestone (Cedar Valley?)	250	
9.	Sandstone (Montpelier?)	30	
8.	Limestone	6	
7.	Shale, blue clay	151	
6.	Limestone	245	
5.	Shale	6	
4.	Limestone	34	
3.	Sandstone	115	1430
2.	Limestone	287	1717
1.	Limestone	171	1888

SUMMARY.

NUMBERS.		FEET.
24.	Drift	98
18–23.	Saint Louis	187
14–17.	Augusta	168
11–13.	Kinderhook	229
9–10.	Devonian	280
8.	Upper Silurian	6
7.	Maquoketa	151
4–6.	Trenton and Galena	285
3.	Saint Peter	115
1–2.	Oneota	458

XIII. Ottumwa Well.

(Elevation 749 feet above tide.)

		THICKNESS.	DEPTH.
18.	Drift	23	23
17.	Limestone, Saint Louis	23	46
16.	Shale, Saint Louis	14	60
15.	Sandstone, Saint Louis	30	90
14.	Limestone, Saint Louis	14	104
13.	Shale and limestone, Keokuk	116	220
12.	Sandstone, Burlington	30	250
11.	Limestone, Burlington	180	430
10.	Limestone, Kinderhook	15	445

		THICKNESS.	DEPTH.
9.	Shale, Kinderhook	160	605
8.	Limestone, mixed with sand, Hamilton and Oriskan	200	805
7.	Limestone, Niagara	150	955
6.	Lime and sandrock, Galena and Trenton	90	1045
5.	Sandstone, Saint Peter	93	1138
4.	Slate, Lower Magnesian	20	1158
3.	Limestone, Lower Magnesian	100	1258
2.	Sandstone, Lower Magnesian	122	1380
1.	Limestone, Lower Magnesian	697	2077

The above section is republished from an article by Gordon. The assignment of the geological formations is given by him. If the identification of 5 as Saint Peter be correct, 3 represents the upper Oneota, here 100 feet thick, with the heavy sandstone, 2, below. No. 1, comprehended under the single term limestone, 697 feet, which is probably as complex in fact as in the corresponding part of the Centerville section.

XIV. Centerville Well.

(Elevation 1017 above sea level.)

		THICKNESS.	DEPTH.
90.	Drift	50	50
89.	Coal and shale		157
88.	Sandstone and calcareous shale		500
87.	Shale		595
86.	Sandstone, calciferous	10	610
85.	Limestone, hard, rough, gray, silicious, (same also at 620)	20	630
84.	Shale, calcareous		640
83.	Shale, light buff	70	650
82.	Shale, samples from 670 to 700 feet		700
81.	Shale, gritty, with small angular particles of flint, a bluish gray non-magnesian limestone and white quartz sand	10	715
80.	Shale (same as 725)	35	750
79.	Shale, calcareous, or limestone argillaceous	8	760
78.	Shale	77	768
77.	Limestone, white, non-magnesian, with much white flint as chips, and shale	10	845

		THICKNESS.	DEPTH.
76.	Shale, calcareous		855
75.	Shale	20	865
74.	Shale, calcareous	10	875
73.	Limestone, soft, white, non-magnesian, with some white flint	10	885
72.	Limestone, silicious	10	895
71.	Shale	10	905
70.	Limestone, dark brown, briskly effervescent with cold dilute hydrochloric acid, and much gray chert, as chips in shale	20	915
69.	Shale		935
68.	Shale, calcareous		955
67.	Shale		965
66.	Shale, arenaceous		975
65.	Shale	115	1023
64.	Limestone, bluish gray, non-magnesian, pyritiferous, siliceous		1030
63.	Shale	60	1090
62.	Limestone, fine-grained, white, non-magnesian	10	1100
61.	Shale	30	1130
60.	Shale, calcareous at 1140	20	1150
59.	Limestone, gray, rather soft, non-magnesian	8	1160
58.	Shale, arenaceous, samples from 1168	32	1189
57.	Limestone, gray, non-magnesian, silicious (water bearing)	10	1200
56.	Shale, arenaceous at 1210	20	1220
55.	Limestone, argillaceous, or shale, calcareous	10	1230
54.	Limestone, light gray, argillaceous, briskly effervescing in cold dilute HCl	20	1240
53.	Limestone, compact, fine-grained, light bluish gray	10	1260
52.	Shale, calcareous, or limestone argillaceous, light yellowish in color	10	1270
51.	Limestone, hard, somewhat argillaceous, brown and bluish gray		1280
50.	Limestone, white, compact, moderately hard, non-magnesian, with some darker gray in color and much shale in flakes	20	1290
49.	Shale, calcareous, or limestone argillaceous, light green in color at 1300	10	1310
48.	Shale, blue, free from grit, calcareous	30	1340

		THICKNESS.	DEPTH.
47.	Limestone, argillaceous, or shale calcareous, slightly arenaceous, buff in color...	10	1350
46.	Limestone, magnesian, argillaceous at 1360	20	1370
45.	Shale, blue at 1380..............	20	1390
44.	Limestone, soft, bluish, non-magnesian, with some white chert and much shale..................................	10	1400
43.	Limestone, hard, light bluish gray, compact, fine-grained, non-magnesian, cherty.....	10	1410
42.	Shale, blue, calcareous, briskly effervescing in cold dilute HCl, not gritty but leaving after treatment with acid a slight residue of flint flakes and angular quartz (microscopic)..........................	10	1420
41.	Sandstone, of clear quartz, the sample is a fine powder containing also grains of light colored limestone.................		1430
40.	Sandstone, light gray, calciferous.........		1440
39.	Sandstone, buff, calciferous		1450
38.	Sandstone, fine, white....................		1460
37.	Sandstone, calciferous, with some fragments of blue shale....................	50	1470
36.	Limestone, highly silicious, magnesian....		1480
35.	Limestone as above......................		1490
34.	Limestone as above, samples from 1510...	60	1530
33.	Limestone, hard, compact, gray, subcrystalline, slightly magnesian, with gray sandstone and much buff shale.............		1540
32.	Limestone, light buff, magnesian, residue after solution of quartz and chert........		1560
31.	Limestone, light buff, magnesian, residue cherty.................................		1570
30.	Limestone, light buff, magnesian, residue after solution composed of flakes of chert and some rounded grains of quartz from 1580....		1600
29.	Dolomite, magnesian, limestone, dark buff, cherty, and slightly arenaceous, samples from 1610		1630
28.	Limestone, hard, rough, dark gray, highly siliceous...............................		1640
27.	Limestone, magnesian or dolomite, buff, residue arenaceous and cherty, samples from 1650.....		1670

		THICKNESS.	DEPTH.
26.	Limestone, magnesian or dolomite, light yellowish gray, large cherty residue....		1680
25.	Limestone, magnesian....................		1690
24.	Limestone, magnesian, dark gray, pyritferous, with much green shale and moderately soft light bluish gray limestone, magnesian............................		1710
23.	Limestone, magnesian, hard, buff, residue of chert and rounded grains of quartz............................		1720
22.	Shale, blue, soft.........................	10	1730
21.	Sandstone, in clear quartzose grains, moderately fine and rounded, with a little green shale from 1740.................		1750
20.	Sandstone, as above, white in color from 1760................................	40	1770
19.	Dolomite, in buff powder, containing sand which may be derived from above, from 1780................................		1820
18.	Dolomite, gray, from 1805....		1860
17.	Dolomite, light drab......................	110	1880
16.	Sandstone, very fine, white, with dolomite and a little chert from 1890.............		1900
15.	Sandstone, grains rounded and angular, with considerable dolomite and chert, samples from 1915.....................		1935
14.	Sandstone, light yellowish-gray, with much dolomite and chert, also much finely laminated green shale, sample from 1945		1955
13.	Sandstone, as above, except that green shale is absent, sample from 1965.......	105	1985
12.	Sandstone, fine particles, angular, light yellowish-gray, with a slight admixture of white dolomite, a little green shale.....	130	2060
11.	Sandstone, calciferous or dolomite, arenaceous, buff, particles of quartz in drillings, angular...........................	12	2125
10.	Dolomite, gray, highly cherty, with flakes of green shale......		2140
9.	Dolomite, light gray, highly cherty.... ...		2210
8.	Dolomite, with considerable fine angular quartz sand		2240
7.	Dolomite, cherty, light yellowish gray, samples from 2250.........................	212	2260

	THICKNESS.	DEPTH.
6. Sandstone, calcareous or dolomite, arenaceous, grains rounded, smooth and of moderate size, with chips of very hard, gray, bluish dolomite	68	2352
5. Dolomite, gray, cherty samples from 2420,		2427
4. Dolomite, light gray, subcrystalline, with much green slaty shale		2435
3. Dolomite, as above, with less shale.......		2440
2. Dolomite, siliceous, light buff............		2445
1. Dolomite, gray, quartziferous and cherty, samples from 2465	75	2495

The interpretation of this section is made difficult by the absence of fossils to mark any horizon and because of probable lithological changes in the southward extension of the geological formations. Fortunately the drillings below 500 feet are exceptionally satisfactory in every respect. They are ample in quantity and were taken at such short intervals that no formation of any thickness could have been overlooked. The heavy shales above 1240 feet with their thin beds of interbedded limestones probably represent the entire Mississippian section and a portion also of the Coal Measures.

The shales and argillaceous limestones from 1240 to 1430 feet may be Devonian. Beneath these the Upper Silurian appears as a sandstone, and between 1480 feet and 1540 feet it merges into the arenaceous Trenton, the Maquoketa shales being apparently absent here as at Ottumwa. The basal shale of the Trenton (No. 22) immediately overlies the well-marked sandstone of the Saint Peter, Nos. 20 and 21, here 40 feet thick. The upper part of the Oneota, subjacent, is also well defined in Nos. 17-19 and is 110 feet thick. The passage beds of this dolomite to a typical sandstone are seen in Nos. 13 to 16, arenaceous dolomites, calciferous sandstones or interbedded sandstones and dolomites 105 feet thick. The typical sandrock itself appears as a purer sandstone in No. 12, thickness 130 feet. The lower Oneota, Nos. 1 to 11, consists of cherty dolomitic beds interstratified in places with arenaceous layers which at No. 6 seem to attain considerable thickness. The thickness of this formation so far as penetrated by the drill is 370 feet.

COMPOSITION AND ORIGIN OF IOWA CHALK.

BY

SAMUEL CALVIN.

COMPOSITION AND ORIGIN OF IOWA CHALK.

BY SAMUEL CALVIN.

As noted in volume I of the reports of the present Survey, the Cretaceous strata of northwestern Iowa include a considerable body of chalk and soft shelly limestone that has been variously known as the *Niobrara* of Meek and Hayden, the *Cretaceous No. 3* of the same authors, or the *Inoceramus beds* of White. The chalky deposit composing the Niobrara beds possesses no small degree of economic value, and there is little doubt that, in the not distant future, it will furnish the raw material for a number of important manufacturing industries. The peculiar characteristics of the beds referred to are such as to engage the attention of the most superficial observer. They are unique among the geological formations of the Northwest. Where typically exposed they are pure white, or yellowish white, in color; they are soft in texture, and they may be quarried in great blocks that are easily cut with a common saw into any required dimensions. Chalk-rock the common people of the region call the beds under consideration, but geologists have been somewhat chary about acknowledging that this soft, white, calcareous material is in reality chalk. For example, Professor Dana, in the second edition of his Manual, speaks of the beds of sand, marl and loosely aggregated shell limestone in the

Cretaceous strata of America, but he adds with intentional emphasis that "they include in North America *no chalk*." In the third edition of the Manual the statement is modified so as to read that "they include in North America no chalk, excepting in western Kansas, where, 350 miles west of Kansas City, a large bed exists." In the second edition of Le Conte's *Elements of Geology* we are told that chalk occurs "nowhere except in Europe"; but in the third edition the existence of chalk in America is recognized in the statement that "recently good chalk composed of foraminiferal shells, and containing flints, has been found in Texas." In the *Geological Studies* of Dr. Alexander Winchell the author, speaking of chalk, on page 64, says that "it does not occur in America," while the same impression is repeated on page 433 in the statement that the Cretaceous "produces no chalk in America."

These references are made for the purpose of showing how, until recently, the leaders of geological thought have been impressed with the notion that the American Cretaceous furnishes no true chalk. Notwithstanding all this widespread and long prevalent impression respecting the absence of chalk in this country, chalk does exist, and in immense quantities. The area over which it is spread extends from Texas probably to the Arctic ocean, and has a width reaching from western Iowa to the Rocky mountains. Chalk, soft and white as that obtained from the cliffs of southern England and made up of calcareous skeletons of Foraminifera and Coccoliths without the admixture of mechanical sediments, has a thickness of at least twenty-five feet along the Sioux river in Iowa (see plate viii); it is fifty feet thick at Ponca, Nebraska; a little further up the Missouri river, at Saint Helena, it stands in a vertical wall, above the Benton shales, with a thickness of ninety feet;

at Yankton, South Dakota, its thickness is 130 feet; and at the mouth of the Niobrara it attains a thickness of probably 200 feet. Near the mouth of the Sioux river some portions of the beds would be described as soft shelly limestone containing large numbers of *Inoceramus problematicus* Schlotheim, but at Saint Helena and points farther up the Missouri the material is soft and nearly homogeneous throughout, with no beds of Inoceramus, and with few mollusk shells of any kind except occasional small colonies of *Ostrea congesta.*

As has long been known the chalk of Europe is a deposit of calcareous material that was laid down in a clear open sea remote from land. The sea bottom on which it was deposited was at least so situated as to be beyond the reach of mechanical sediments carried by agents of erosion. Furthermore the chalk is composed of the more or less broken and comminuted skeletons of the simple unorganized animals called Foraminifera and of the still more minute limy structures that are probably parts of coralline plants, and which are known as Coccoliths. The bulk of all chalk indeed seems to be made up of Coccoliths, small disc-like bodies varying from 1-5000 to 1-2500 of an inch in diameter. The shells of the Foraminifera, often quite crowded and unbroken, are simply embedded in the fine chalky mud that is formed by the aggregation of foraminiferal débris together with thousands of millions of minute dust-like Coccoliths in each cubic inch of the deposit. Now our Iowa chalk resembles the English chalk in every essential particular. As to its present physical characteristics it is practically the same. It is white, soft enough to soil the fingers, may be used for writing on the blackboard, and may be put to all the commercial uses to which the chalk of Europe is adapted.

As to composition, it is the same as European chalk, for it is made up of shells of Foraminifera imbedded in a matrix of imperfectly cemented Coccoliths. The Coccoliths cannot be distinguished microscopically from those forming the larger part of the chalk of England; and the Foraminifera are, in many cases, identical with the species found in the corresponding deposit on the other side of the Atlantic. Furthermore the American chalk along the Missouri and the Sioux rivers was laid down on the bottom of a clear, open sea that received no gross sediments from contiguous shores. There is no reason in the world for refusing to recognize the deposit as true chalk.

Considering the attitude of geologists to our American chalk beds it may be interesting to note the successive steps whereby the foraminiferal origin and true chalky character of the deposits have finally come to be recognized. As long ago as 1841, Prof. J. W. Bailey received from a mission station in the Northwest a sample of what was called "prairie chalk," and in a communication to the *American Journal of Science and Arts*, volume 41, pp. 400–401, he describes it as being full of the "elegantly little." The "elegantly little" in this case are Foraminifera of which Professor Bailey gives four excellent figures drawn to scale under the camera lucida. No names are given to any of the species, but figure 2 may now be recognized as the form described by Ehrenberg a year or two later under the name of *Textularia globulosa*, a species common not only in our American chalk but occurring also in great abundance in the chalk of England. Figure 4 is one of the multitudinous varieties that have recently been marshalled by Brady under the name of *Globigerina cretacea;* figure 1 is a large Textularia, of the same species as 2, seen obliquely; while 3 is either a

Discorbina or a *Globigerina* seen from the concave or umbilical side.

In 1843, Ehrenberg published at Berlin an important *Memoir on the Extent and Influence of Microscopic Life in South and North America.* Most of the work is devoted to diatoms and desmids, but a few pages are given to the discussion of Foraminifera, including forms from the Cretaceous chalks and marls along the Missouri river. The identity of some of the species with forms from the European chalk is recognized, but other species, among which he describes *Textularia americana*, in his opinion are not known elsewhere. An extended notice of Ehrenberg's Memoir, by Prof. J. W. Bailey, was published in 1844 in the 46th volume of the *American Journal of Science and Arts.* A figure of what is supposed to be *Textularia americana* is given in a foot note, and copious extracts from the memoir are translated and incorporated in Professor Bailey's notice. In volume 48 of the *American Journal*, published in 1845, we have a list of American localities known at that time to Professor Bailey as affording material containing Foraminifera. The Cretaceous beds along the Missouri are mentioned, and the remarkable abundance of foraminiferal shells which they afford is noted.

For a number of years subsequent to 1845 little attention seems to have been paid to the composition of the chalk along the Missouri river. Dr. F. Roemer's *Kreidebildungen von Texas* appeared in 1852, with description and figures of *Orbitulites texana*, a gigantic foraminifer that seems to have furnished material for the construction of beds of chalk in Hill's Fredericksburg division of the Lower Cretaceous; and in 1857 Conrad, in the *Report of the United States and Mexican Boundary Survey*, volume

I, part II, describes and figures an even larger form from the Washita division of the same series, under the name of *Nodosaria texana*.

Between 1853 and 1861 Meek and Hayden worked out the succession of Cretaceous strata along the Missouri river. Numerous papers were published under the joint authorship of the geologists named. The chalk of the Niobrara division is frequently mentioned, sometimes as "chalk marl" and sometimes as "calcareous marl weathering to a yellowish or whitish chalky appearance above." In their detailed section published in the Proceedings of the Academy of Natural Sciences, Philadelphia, December, 1861, the "calcareous marl" of Formation number 3 is said to contain "several species of Textularia." They seem careful to avoid calling the deposit chalk, though lithologically and micro-paleontologically its practical identity with that material must have forced itself upon their attention. In the first Annual Report of the United States Geological Survey of the Territories, by Dr. F. V. Hayden, published in 1867, the author says concerning the Niobrara division that "Its principal character is a gray or light yellow chalky limestone; much of it so pure as to make a good chalk for commercial purposes." That the deposit is actually chalk is here for the first time rather hesitatingly acknowledged.

In 1870, Dr. C. A. White, in the Geology of Iowa, volume I, page 294, in discussing the Inoceramus beds, which represent in Iowa the Niobrara of Meek and Hayden, tells us that among other fossils, "minute Foraminifera (probably Globulina) are sometimes met with in great numbers." The *Canadian Naturalist* for 1874, volume VII, number 5, contains an article by Dr. G. M. Dawson, entitled *Note on the Occurrence of Foraminifera, Coccoliths, etc., in the*

Cretaceous Rocks of Manitoba. The rocks referred to in Dr. Dawson's paper are of the same age as the chalk beds in Sac, Woodbury and Sioux counties, Iowa, the same as the Niobrara of Nebraska, Kansas and South Dakota. In Manitoba the Niobrara beds seem to be harder and less like chalk than along the Missouri and the Sioux. Dr. Dawson takes pains to say concerning the American Cretaceous, that "this formation contains no beds of true chalk." The greater part of the rock that furnished his specimens was composed of shells of *Inoceramus problematicus* and *Ostrea congesta;* but the "soft, whitish, earthy matrix" in which the shells were imbedded proved to be rich in Foraminifera, Coccoliths and allied organisms. Four figures of Foraminifera are given and named respectively *Textularia globulosa, T. pygmæa, Discorbina globularis* and *Planorbulina ariminensis.* The Textularians are probably modifications of one species; the only form in Iowa chalk that can be identified with Dawson's figure named *Discorbina,* has the inflated, spherical chambers characteristic of the types referred by Brady to *Globigerina cretacea,* and the species referred to *Planorbulina ariminensis* by Dawson is a very thin Truncatulina slightly concave on one side and convex on the other, altogether unlike the figures of *Anomalina ariminensis* (*P. ariminensis*) given by Brady. All the forms are common in our Iowa chalk, and all but the last are characteristic of the chalk of Europe. After studying material from Nebraska as well as from Manitoba, Dr. Dawson says: "The general facies of the foraminiferal fauna of these Cretaceous rocks of Manitoba and Nebraska singularly resembles that of the ordinary English chalk. Both abound in Textularine and Rotaline forms of similar types, the most abundant in both being the form with globose chambers, and each having its rarer analogue, with chambers flattened and more delicate."

Dr. Dawson's paper is the first, so far as I know, that recognizes Coccoliths as important agents in the formation of American chalk. Figures are given of a number of these interesting structures under an amplification of 1,250 diameters. The forms figured are very common in our Iowa chalk and constitute no small portion of its entire bulk. The English chalk likewise contains many Coccoliths, some of which are indistinguishable from the American species, but with these are some possessing characters unknown thus far in the Niobrara beds along the Missouri. The peculiar calcareous rod-like objects called Rhabdoliths are not uncommon in the chalk of Nebraska, Iowa and Manitoba, and, in the paper cited, Dr. Dawson gives a number of figures showing quite a variety of forms. The amount of material contributed by Rhabdoliths is inconspicuous when compared with that furnished by Coccoliths and Foraminifera. Rhabdoliths were discovered in 1872 in the recent ooze of the Adriatic, and Dr. Dawson's paper of 1874 contains the first announcement of the existence of these bodies in the fossil condition.

Prof. Robert T. Hill is probably the first American writer who came out squarely and called our American chalk by its real name, chalk. In the *Annual Report of the Geological Survey of Arkansas* for 1888, volume II, Professor Hill writes on the *Neozoic Geology of Southwestern Arkansas.* The entire volume, with the exception of two brief appendices, is devoted to the subject, and from beginning to end the author refers to the soft calcareous deposits of the Lower and Upper Cretaceous of Texas and Arkansas as *chalk.* Chapter XIV is especially devoted to a discussion of the physical characters of the chalk in the southwestern states and the conditions under which it was deposited. The fact that Foraminifera make up a large proportion of the deposit is noted time and again, and the genera *Textularia* and *Globigerina* are identified.

In a *Check List of the Invertebrate Fossils from the Cretaceous Formation of Texas*, a publication issued in 1889 from the University of Texas — School of Geology — Professor Hill recognizes the fact that "the Cretaceous Rocks of Texas are mostly of foraminiferal origin including innumerable microscopic species." Only two, *Nodosaria texana*, Conrad, and *Orbitulites* (*Tinoporus*) *texanus*, Roemer*, are recorded; and they are both found in the Lower Cretaceous, in formations older than the Niobrara beds that contain the chalk of Iowa. In the same year, 1889, in Bulletin No. 4 of the Geological Survey of Texas, Professor Hill gives an *Annotated Check List of the Cretaceous Invertebrate Fossils of Texas* in which the Foraminifera mentioned in the preceding list are noted, and Textularia and Globigerina are added as forms found in the Upper Cretaceous. The Upper Cretaceous chalk of Texas is simply the southwestward extension of the chalk we find along the Sioux river in Iowa, and the Textularia and Globigerina noted by Hill are doubtless specifically identical with forms belonging to the same genera occurring in the Niobrara along the Missouri and the Sioux.

In the *American Geologist* for September, 1889, Professor Hill has a paper on *The Foraminiferal Origin of*

---

* It is not clear why Professor Hill should regard this species as belonging to the genus *Tinoporus*. The forms referred to *Tinoporus* by Montfort, Carpenter, Brady and others are all lenticular or disc-like with radiating marginal points or spines at more or less regular intervals.

certain Cretaceous Limestones and the Sequence of Sediments in the North American Cretaceous. That the material of certain horizons in the Cretaceous is chalk, and that it is composed in large part of the shells of Foraminifera, are propositions repeatedly and clearly stated.

Prof. S. W. Williston contributed a note on *Chalk from the Niobrara Cretaceous of Kansas*, which was published in the number of *Science* issued October 31, 1890, Vol. XVI, page 249. The fact is noted that "Professor Patrick, some years ago, stated that it, [the Niobrara chalk] contained no microscopic organisms, but afterwards, with the aid of a very high power objective found what he thought were organic remains. This is all the more remarkable" says Professor Williston, "as the chalk appears to be wholly composed of organic forms, very readily visible under a comparatively low power (a one-fifth or one-sixth objective and a C eye-piece)." The forms seen by Professor Williston are the minute Coccoliths and Rhabdoliths noticed by Dr. Dawson in 1874, and at the time of writing the note under consideration, the comparatively large Foraminifera that may be seen with a good pocket magnifier seem to have been overlooked. In the same volume of *Science*, page 76, there is a note from Dr. George M. Dawson referring to the note of Professor Williston and expressing the opinion that the organisms found by Williston are certainly the same as the Coccoliths and Rhabdoliths that Dawson had previously shown to occur in the chalk of Manitoba and Nebraska.

In a paper read before the Kansas Academy of Science in December, 1890, Professor Williston returns to the subject of the *Structure of the Kansas Chalk.* This time he recognizes in it the presence of Foraminifera and says: "The deposit seems wholly formed of Coccoliths, Rhabdoliths and Foraminifera, with, perhaps, radiolarians and sponges. The Coccoliths exist as complete, or broken oval, or circular bodies from 1-3500 to 1-4500 of an inch in diameter with from one to six depressions, or nuclei; the Rhabdoliths are slender spicules, rarely attached to a central mass, or as rarely with a trumpet shaped extremity. In addition there are other, less slender rods, from 1-1000 to 1-2000 of an inch in length, that may be radiolarian spicules. I have recognized at least a dozen forms of Foraminifera, the one most common and conspicuous very similar to, if not identical with a Textilaria [Textularia] of the English chalk. In view of the foregoing facts, it seems to be time that the assertions of some of our leading text-books that there is no chalk in America should be corrected."

Between 1890 and 1894 several papers were published in the *Bulletin of the Geological Society of America* and elsewhere in which the deposit under discussion is recognized physically as chalk and genetically as having been produced by Foraminifera and other microscopic organisms. The latest, which relates once more to the Texas region and is by Professor Hill, appears in the *Bulletin of the Geological Society of America*, published in March, 1894. The subject of the paper is the *Geology of Parts of Texas, Indian Territory and Arkansas adjacent to Red River*. The paper discusses the general geology of the region considered; but on pages 319 and 320 the foramiferal origin of certain beds of altered chalk is noted, and the genera Rotalia and Textularia are recognized.

The foregoing references, while incomplete as a bibliography relating to the physical characteristics and foraminiferal origin of American chalk, will yet help to make clear the successive steps whereby geologists have been led from complete skepticism regarding the presence of chalk on this side of the Atlantic to the conviction that the Niobrara beds along the Sioux and the Missouri rivers, are, in all the particulars relating to physical structure, composition and origin, identical with the chalk of Europe. Advantage has been taken of the facilities afforded by the geological laboratories of the State University to investigate anew, and more thoroughly than seems to have been done before, the composition of the Niobrara chalk. In thin sections under the microscope the unbroken shells of Foraminifera are very conspicuous. They lie in close proximity to each other, and their inflated chambers, filled with crystals of calcite, sometimes occupy more than one-third the area of the entire field. It is certain that more than one-fourth, and in some instances more than one-third, of the volume of the chalk is composed of foraminiferal shells still practically entire. The matrix in which the shells are imbedded is made up of a variety of objects, the most numerous, and the most conspicuous under proper amplification, being the circular or elliptical calcareous disks known as Coccoliths. The small rod-like bodies to which the name Rhabdoliths has been applied are not very common, although their presence is easily detected with a moderately high power objective. Mingled with Coccoliths and Rhabdoliths are numerous fragments that are evidently the débris resulting from comminution of foraminiferal shells. When the chalk is treated with acid there remains a small amount of insoluble matter consisting of clay, fine grains of quartz sand, minute pebbles not exceeding five millimeters in diameter, and a very few internal casts of the chambers of Foraminifera. Nearly all the foraminiferal shells have the chambers filled with calcite; a few have these cavities still empty or filled simply with air; but in a small number of cases the chambers were filled with an opaque, insoluble mineral, probably silica deeply stained with iron oxide, that remains as perfect internal casts after the shell has been dissolved in acid. The amount and composition of the residuum varies with the purity of the chalk. In some samples it scarcely exceeds one per cent; in others it is equal to ten per cent.

In all the chalk examined the Foraminifera are very numerous. Many are large, vigorous looking specimens of the types to which they belong, and an unusual number of the shells remain perfect. They are easily separated from the finer particles constituting the matrix by gently grinding the chalk with the finger in a shallow dish, using water enough to cover the material operated upon, and pouring off and renewing the water as long as it shows any traces of milkiness. The particular genera and species that will be found after the washing process is completed will depend somewhat upon the locality from which the material was derived. It is probable that the species differ at different levels in the formation, but the collections in the field were not made with a view to determining that fact. In a sample from the great bluff at Saint Helena, Nebraska, large forms of Textularia are most common. The chambers are inflated and spherical, and the shell widens rapidly toward the larger end as illustrated in figures 5 and 6, plate xix. This is the *Textularia globulosa* Ehrenberg, and, as has been already noted, it is one of the most common forms at certain horizons in the chalk of Europe.

A more slender form of Textularia, figure 7, plate xix, is often associated with *T. globulosa.* In some beds it is the prevailing type. Figure 7 illustrates an unusually large individual of this species. As a rule, however, it is not only more slender than the other, but is shorter and every way smaller, and it is doubtless the form figured under the name of *Textularia pygmæa* in Dawson's paper already cited, contributed to the *Canadian Naturalist* in 1874. The two forms grade into each other perfectly when a large number of individuals is examined, and there is little doubt that they are simply variations of a single species. I have seen nothing in all the thousands of specimens examined corresponding to Bailey's figure of *Textularia americana* as given in 1844 in the *American Journal*, volume 46. In some respects the internal casts left after dissolving the shell in acid resemble the figure in question, but the resemblance is not sufficiently close to render the hypothesis that it had been made from such a cast at all plausible.

Textularia globulosa attains its largest size and most perfect form at some distance above the mouth of the Sioux river — from Saint James or Saint Helena, Nebraska, westward. The shore line of the Niobrara sea in which the Foraminifera that make up so large a proportion of the chalk flourished and died, extended northeasterly from near the southwest corner of Iowa. From that old shore line the sea spread away westward to beyond the Rocky mountains; and the sites now occupied by Yankton, South Dakota, and Saint Helena, Nebraska, were many miles from shore and covered by moderately deep clear water unpolluted by detritus washed in from the land. In such pure, clear sea-water *Textularia globulosa* found the conditions exceedingly favorable. As, however, the shore was approached the conditions became more and more adverse, for the chalk from Sioux City, Hawarden, Auburn and other points east of the Sioux, contains specimens of

Textularia that on the average do not attain much more than half the size reached by the individuals from Saint Helena. In other words the smallest forms of *Textularia pygmæa* prevail. Furthermore the specimens from the localities named are often very irregular in their mode of growth, so that they were not only apparently starved and stunted, but they were very frequently deformed, by the unfavorable environment prevailing in regions nearer and nearer the shore. The most easterly point at which chalk used in the present investigation was collected was near Auburn, in Sac county, and here the Textularians are all of the ill fed pygmæan type; but at Sioux City, which is one of the intermediate points between Auburn and Saint Helena, the diminutive forms, while very numerous, have mingled with them a few conspicuously large individuals recalling those from the great chalk cliffs farther up the Missouri. There is one very marked difference however, scarcely any of the large specimens are symmetrical. Like the smaller individuals of the same region they are more or less distorted. What is more the later formed chambers of the larger specimens often depart from the biserial type and may be arranged in a single series, or, as more frequently happens, in three, four, or even five series, or, they may even be heaped together irregularly without any recognizable order.

The depauperating effects of the unfavorable environment seem to have acted in three ways; first, to retard growth; second, to cause deformity by unsymmetrical growth even when the biserial arrangement is maintained; third, to destroy the biserial arrangement of the later formed chambers among the more vigorous individuals and produce the irregular heaping together of the cells that is sometimes expressed by the term acervuline. It may be with safety assumed that the Textularians of the region, with their endless variations as to size and proportions, including departures from symmetry and biseriality, are all varieties of one species which for the present we may call *Textularia globulosa* Ehrenberg.

While Textularia seems to have flourished best in the deeper and purer waters remote from shore, the reverse is true of the forms illustrated in figures 1, 2, 3 and 4 of plate xix. These shells have been variously referred to species of the genera Rotalia, Rotalina, Planulina and Discorbina, but the spherical form of the chambers, the thin walls, large foramina and other characteristics would exclude them from either of the genera named. The revised definition of Globigerina, as given by Brady in his Report on the Foraminifera dredged by the Challenger, extends the genus sufficiently to include the forms under consideration, and it is probable again that they are modifications of a single species, the *Globigerina cretacea*. Figure 3 represents some forms that occur rather sparingly in the chalk of Nebraska. In their general aspect they resemble *Globigerina digitata* Brady. The earlier formed chambers are in all respects like those of figures 1 and 2, but some of the later chambers are very much elongated. The form of the abnormal chambers varies greatly; they stand sometimes in one plane and sometimes in another, and I have regarded them simply as accidental variations in the terminal cells of the species illustrated in figures 1 and 2. Brady's specimens of *G. digitata* came from bottom dredgings. The species was never taken with the tow net at the surface. It is probable that in each case the abnormal chambers were added to the shell after the organism settled to the bottom, and their abnormality, I take it, may be due to the fact that upon the bottom the restrictions to normal growth were very much greater than those affecting the animal when floating near the surface. We have seen in the deformed and otherwise abnormal Textularians that the simple protoplasm making up the bodies of Foraminifera responds to changes of environment in such a way as to affect profoundly the form and proportions of the shell, and it is at least conceivable that, in the crowded condition of the organisms resting upon the bottom, some of the Globigerine forms, accustomed in early life to perfect freedom from contact with other shells, were so unfavorably situated as seriously to interfere with normal symmetrical growth. It is an interesting fact that the deformed specimens of Globigerina are associated with the vigorous, symmetrical types of Textularia. Nearer the shores, in the material laid down at Sioux City, Hawarden, Auburn and elsewhere east of what is now the Iowa boundary, the Globigerine types of Foraminifera flourished in greater profusion than farther west; and distortion or deformity, when it occurred at all, affected only the regularity of the spiral without interfering with the globular form of the several chambers.

In the deposits about Saint Helena and Yankton, which were persumably laid down in deeper and clearer water than were the deposits farther east, Truncatulina, figure 10, and Bulimina, figure 8, are not uncommon, while in the eastern localities they seem to be entirely absent. Occurring more rarely than the preceding, but apparently confined exclusively to the exposures in South Dakota and Nebraska, we find Cristellaria, figure 9, Frondicularia, figure 14, and the Nodosarian forms, figures 11, 12 and 13. On the other hand the shallower sea, that during the Niobrara stage covered the region we now call Sac county, Iowa, contained a number of species not found in the western localities. For example there were Globigerinæ with a few large chambers like *G. bulloides*. There were also hyaline Foraminifera with small chambers very irregularly arranged and resembling some of the acervuline species of Planorbulina. This genus, as now restricted, has not been reported from strata older than the middle or later Tertiary and hence its presence in Cretaceous deposits in Iowa is somewhat improbable; and, furthermore, before deciding the generic relations of the forms in question it is well to bear in mind the possibility of monstrosities of one genus assuming a superficial resemblance to some other. Then again that shallower sea, as is well illustrated in slides made from chalk from near Auburn, in Sac county, contained a number of Lituoline forms resembling Reophax, in which the shells are composed of small particles of sand or of other minute objects cemented together.

The causes affecting the distribution of species in the different localities mentioned in this paper will be better understood after a consideration of the physical conditions under which the chalk was deposited. The Niobrara beds, whether made up of shells of Inoceramus or of Foraminifera, are a part of the Cretaceous series of the northwest. The series, above and below the mouth of the Sioux river, begins with the Dakota sandstone, a deposit well seen in the lower part of the bluffs at Sioux City. When the Dakota sandstone was accumulating the region about Sioux City was covered with shallow brackish water. The sand composing the deposit was carried into the sea from land that was not very far away, probably only a few miles to the eastward. The sea bottom was not stationary, but was slowly subsiding, the rate of subsidence being greater, however, than the rate at which the sandstone accumulated. As a result of the subsidence the sea became deeper over any given area, as for example Sioux City; it also for the same reason encroached gradually upon the land, and the shore line became more and more remote. With increasing depth of sea and increasing distance of the shore the coarser sand failed to reach Sioux City. Only the finer mechanical sediments were carried so far seaward, and then the second member of the Cretaceous, the Benton shales, was gradually built up. The subsidence continued, even after the Benton stage came to an end. The waters deepened still more over the site of Sioux City. The bottom was no longer affected by waves and currents, and the shore line, now east of the middle of the state, was so remote that practically no detritus from the land found its way to the area we are considering. Indeed it is possible that the continued subsidence had caused all the contiguous land areas to stand so low with reference to the sea that erosion was reduced almost to zero, and the whole area draining into this part of the Niobrara basin was reduced to the base level of erosion. Whatever the explanation, neither sand nor clay was deposited in any appreciable amount as far west as Yankton and Saint Helena; very little indeed as far west as Sioux City. Even in the localities east of Sioux City where Niobrara beds now occur, the amount of sediment derived from the land was so small as to be scarcely worth considering. Now it was in this clear, quiet sea that the Niobrara chalk was slowly deposited. Upon the bottom of this sea there flourished the Textularians and nearly all the other types of Foraminifera to which reference is made in the preceding pages. Floating in the same sea were the Globigerine forms already noted. It is only the younger individuals, however, of the

Globigerinæ that are able to float. For as the shells, with age, increase in size and thickness the animals sink to the bottom and their minute tests become mingled with those of other species that spend their entire life in that situation. Either floating in the water or resting upon the bottom were the peculiar coralline plants of which the bodies called respectively Coccoliths and Rhabdoliths were constituent parts. All these organisms, the microscopic plants and animals alike, secrete carbonate of lime, and it was the dead skeletons of successive generations of such organisms, accumulating under the conditions described, that made up the entire bulk of our American chalk. The units used in the construction of the Niobrara beds were, in the majority of cases exceedingly small; but their numbers were inconceivably great, and this fact coupled with the time during which the conditions lasted, was sufficient to pile up chalk over the whole area from Iowa to the Rocky mountains, and from Texas to the Arctic sea, to an average thickness of not less than two hundred feet.

The subsidence that began with the deposition of the Dakota sandstone reached its maximum near the close of the Niobrara. Then the opposite movement began and the sea gradually retreated toward the west. As the land became more and more elevated erosive agents became more and more effective. Mechanical sediments were carried by the drainage waters; and the conditions favorable to the growth and multiplication of the hosts of minute lime-secreting organisms that crowded the waters during the Niobrara stage came to an end as the mud which formed the shales of the Pierre group settled down and smothered out that whole array of microscopic life to which the chalk owes its origin. It was about the time that the subsidence reached its maximum that the chalk was deposited near Auburn, in Sac county, Iowa, and it was about the same time that the typical beds at Yankton and Saint Helena were built up. The differences already noticed between the Textularians at Saint Helena and those at Sioux City and Auburn are in some way connected with the facts that while the region about Saint Helena was covered with clear and relatively deep water, the waters covering the regions farther east were shallower and the bottom received the small amount of sediment which the sluggish, nearly base-leveled streams of the period carried into the sea. No one can tell how such slight differences of environment would react on the living matter of Textularia, but that they did affect it profoundly becomes obvious upon comparing the shells of the beautiful, symmetrical, thrifty-looking specimens from Saint Helena with those of the starved, impoverished, deformed specimens from Sioux City and Auburn.

In the case of the Globigerine forms that during most of their lives float near the surface, the condition of the bottom was not a matter of so much moment. The water at the surface was doubtless clear enough, for even the small amount of sediment carried into the region must have been limited to the lower strata of the water. Near the surface, too, food was even more abundant than it was at the same depth farther west, and thus it happened that near the shore the Globigerinæ flourished, and their full-grown shells bearing every indication of life under most favorable conditions settled down among the unhealthy and depauperated Textularians to which life had been a perpetual struggle with adverse surroundings. The shallow-water chalk is composed of large numbers of shells of vigorous Globigerinæ mingled with many small and deformed shells of Textulariæ, while the deeper-water chalk abounds in robust, normal Textulariæ with relatively few Globigerinæ. Among the Globigerine shells of the deeper water are a few rather remarkable monstrosities.

A few samples of English chalk have been investigated for the purpose of comparison with our Iowa product; but the opportunities for getting typical specimens have not been very favorable and the results are not satisfactory. The English chalk affords Textularia, rather smaller on the whole than our more vigorous examples of *T. globulosa*, but evidently of the same species. I recognize also a Bulimina, but it is specifically distinct from ours. Truncatulina somewhat different from the species in the Iowa chalk is present and is on the whole the most abundant form in all the specimens of foreign chalk I have been able to get. Nodosaria and Frondicularia are present, but the species are slightly different from those found on the Missouri. I have been led to believe that the specimens examined are not fair examples of the average chalk of Europe for the reason that they are all singularly poor in perfect shells of Foraminifera. From a gram, for example, of Iowa chalk we would get probably fifty times as many perfect Foraminifera as from an equal amount of the 'white cliff' chalk of England, so far as examples have come into my possession. The Coccoliths are practically the same in the two cases compared. There are some types in English chalk, as already noted, that I have not seen in ours, but they are not very common. Minute angular pieces, apparently of Foraminiferal shells, are more plentiful in the English chalk than in that of Iowa. But it is not claimed that the comparisons I have been able to make are at all satisfactory, and final conclusions must be deferred until a sufficient number of specimens of the English chalk to give fair average results have been examined. Enough, however, may be determined from the comparisons already made to prove that the two deposits considered are fundamentally the same in composition and origin. The water in which the English chalk was deposited was probably deeper than the Niobrara sea between the present site of Yankton and its eastern shore somewhere near the middle of Iowa. Differences in depth determine to some extent the species inhabiting the sea bottom; and the amount of mechanical sediments accumulating in any given region will also, as a general rule, bear some relation to the depth of the water.

It is interesting to know that while Textularian and Globigerine Foraminifera were revelling in clear, quiet seas in the longitude of the first meridian, and contributing their dead shells to form the chalk of Europe, almost exactly similar conditions existed more than a quarter of the way around the globe; and in another clear sea with low flat shores, the same or very similar species of Foraminifera were contributing material to form the chalk beds of Iowa.

DESCRIPTION OF PLATE XIX.

(All figures magnified 100 diameters.)

1. *Globigerina cretacea*, with right spiral, seen from convex side.
2. *Globigerina cretacea*, with reversed spiral, from convex side.
3. Form resembling *G. digitata*, from concave or umbilical side.
4. *Globigerina cretacea*, concave side.
5. *Textularia globulosa*, average form.
6. Similar, more rapidly expanding form, Saint Helena.
7. Very large individual of the less robust type, figured by Dr. Dawson as *T. pgymæa*.
8. *Bulimina*, a form common at Saint Helena.
9. *Cristellaria*, rare at Saint Helena.
10. *Truncatulina*, common at Saint Helena and Yankton.

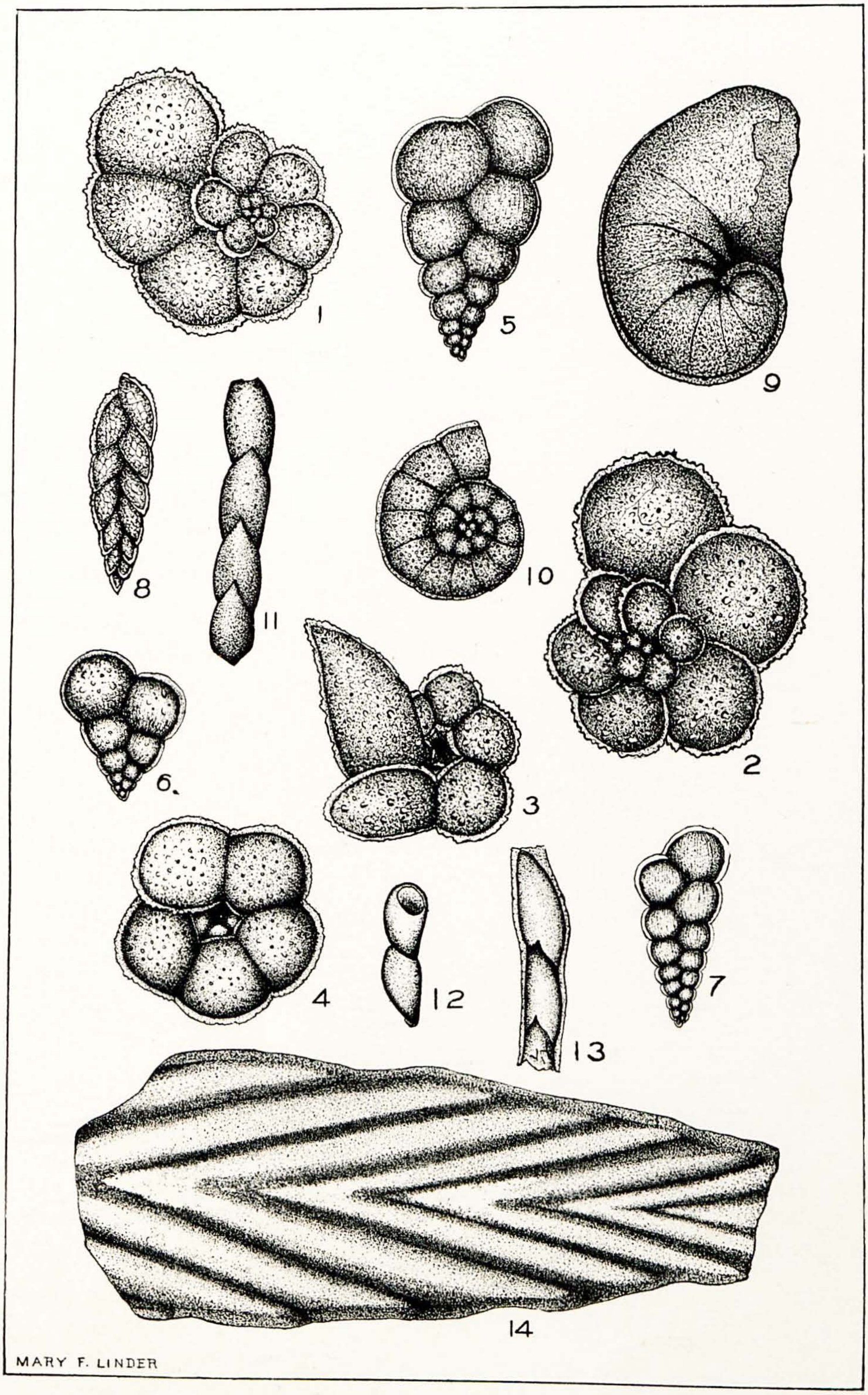
11, 12, 13. Nodosarian forms, undetermined, from Saint Helena.

14. *Frondicularia*, fragment of a very large and very beautiful specimen from Saint Helena.

NOTE.—While it is true, as stated on page 220, that Professor Hill was the first American writer broadly and persistently to affirm the existence of chalk beds on a large scale and covering wide areas in North America, it is justice to say that the chalky character of certain portions of the Niobrara beds had been pointed out a number of times by previous writers. For example, in 1863 Professor Jules Marcou had noted the existence of chalk in the Cretaceous deposits around Sioux City and in the adjacent parts of Nebraska. He communicated the fact to the scientific world in papers read before the Geological Society of France. Referring to these papers in the American Geologist, volume IV, page 366, Professor Marcou says respecting one of them: "I took the precaution to carry with me pieces of rough chalk taken from near Sioux City, and I drew on the blackboard with them the three sections which accompany the paper, and at the end I said, writing with that chalk, 'Craie d' Amerique,' that in order to prove the constancy of lithological characters on vast surfaces of the earth, I had used only American white chalk that evening for my communication before the Geological Society of France."

Another writer, Mr. D. C. Collier, in the American Journal of Science for May, 1866, describes beds of chalk occurring 350 miles west of Leavenworth. The following language leaves no doubt as to how Mr. Collier regarded the deposit: "On one occasion, in company with a companion, I was able to climb to the top of a bluff of pure chalk, so soft that I could cut and carve it with the knife I carried in my belt, and so fine that it covered my clothes as thoroughly as when in my college days a classmate wiped the blackboard with my back."

There are other references equally as pointed, but a complete bibliography of the subject, I take occasion to repeat, is aside from the purpose of the paper.



ORGANISMS IN IOWA CHALK.

BURIED RIVER CHANNELS IN SOUTH-EASTERN IOWA.

BY

C. H. GORDON.

BURIED RIVER CHANNELS IN SOUTHEASTERN IOWA.

BY C. H. GORDON.

Reference was made long ago* to the great development of glacial material along the west bank of the Mississippi river in the vicinity of Fort Madison. The existence of an old valley in that vicinity was, however, first made known by Major G. K. Warren, in 1878.† Although the conclusions arrived at were based entirely upon observations made at the surface, they have been confirmed in all essential points by later investigations. At that time no data bearing upon the depth of the channel were available.

In 1890, without knowing of Warren's work, the author reported the existence of an ancient course of the Mississippi between Montrose and the Des Moines river.‡ A map corresponding in all essential respects with that of Warren's accompanied the announcement, and additional details were given bearing upon the depth of the channel. Recent investigations have not only confirmed previous conclusions, but added much to the knowledge of the change of drainage here recorded.

Stratigraphy.—The indurated rocks exposed in Lee county belong chiefly to the Lower Carboniferous series.

*Geology Iowa, Vol. I, p. 187. 1858.

†Bridging of the Mississippi, Annual Report Chief Engineers for 1878. Appendix X, p. 3.

‡Paper read before the Geological Society of Chicago. Not yet published.

They are, however, overlain in places by more or less extended outliers of the Coal Measure formation. In the interval comprised between the deposition of the Lower Coal Measures and the beginning of the Ice Age, this region must have been above sea level for a long period of time, as shown by the extensive denudation and channelling which the rock surface has suffered. The evidence appears conclusive that the Coal Measures, and possibly later formations, originally extended over the whole of the area, but of these there now remains only the small detached areas of the former, preserved by some fortunate circumstances of position or structure. The general surface of the indurated rocks, irrespective of the channels, though corresponding in the main with the land surface, is much more irregular. At Keokuk it has an elevation of 610 feet. It rises toward the north, attaining an altitude of 625 feet at Nashville, 640 feet at Donnellson, and about 675 in the vicinity of Saint Paul. Upon this uneven surface drift has been spread in sufficient amount to fill the depressions and raise the surface forty to sixty feet above the highest rock level. The result has been a gently sloping plain, dissected more or less by subsequent drainage.

Topography.—West of East Sugar creek the plateau slopes to the southeast, descending from about 700 at Donnellson to 656 feet at Keokuk. The average slope is thus about two feet per mile. The plateau has been reduced on the west by drainage leading into West Sugar creek, while its eastern margin has been cut away in part to form the Viele terrace plain. The divide which separates the two drainage systems is marked on the map by the line of the Keokuk & Northwestern railroad between Mooar and La Crew. The profile of this road gives the following elevations:

	FEET.
Donnellson	696
Charleston	694
New Boston	689
Mount Clara	679
Summitville	670
Keokuk (level of plateau)	656

The summit of the divide west of Montrose lies just at the top of the bluffs which form the eastern border of the plateau. A comparatively broad and deep trough leads from the bend of Little Cedar creek, southwest of Salem, to the Mississippi, at Viele.*

This valley, which has been traced a considerable distance beyond the limits of Lee county, is chiefly, if not entirely, confined to the drift, and hence has its origin at least subsequent to the withdrawal of the first ice sheet. The newer channel of East Sugar creek lies within the older one. In places this stream flows above or upon the floor of the older valley, while in other points it has cut twenty-five feet to forty feet into the underlying Saint Louis limestone. Most of the old bottom is floored with rock at a slight depth, but at several places drift intervenes. Six miles directly west of Fort Madison (Tp. 68 N., R. V. W., Sec. 32, W. ½) there is a remnant of the old valley bottom in the form of a ridge fifty feet high, and composed of boulders, chiefly of limestone, more or less firmly cemented together. The top of this ridge has an elevation of about 600 feet, while at the bend of Little Cedar the old valley lies about 660 feet above sea level. This shows the comparatively rapid fall of sixty feet in a distance of about fifteen miles.

East of this old valley the plateau has a greater elevation than towards the west, and along the crest of the

* Acknowledgement is due Mr. Frank Leverett, who has freely contributed notes and suggestions.

divide between East Sugar creek and Skunk river is a group of low irregularly distributed mounds marking the location of a moraine. West Point, which is somewhat above the general plateau level, has an elevation of 762 feet, while at its border above Fort Madison the plain lies about 700 feet above sea level.

South of Skunk river for a distance of two miles the bluffs on the west side of the present valley coincide with the limits of the old channel. They then gradually approach the river, which washes their base just above Fort Madison. The triangular area of bottom lands thus set off occupies nearly the whole of Green Bay township. Towards the river it is low and abounds in sloughs. It rises gradually towards the west in a series of sand terraces to a height of about sixty feet at its western border. The terrace on which the station at Wever is situated is forty feet above low water at Fort Madison. Below the latter place the bluffs again recede from the river, leaving another terrace plain of crescentic outline cut off below by the approach of the bluffs on the river bank at Montrose. Viele station, which is situated near the outermost border of this plain, has an elevation of thirty-three feet above low water at Montrose. In this portion of its course the river flows upon drift, and is characterized by sandbars and sloughs. It has a fall of two feet only for a distance of nine miles. From Montrose to Keokuk it is confined within a narrow, rockbound valley with precipitous slopes, and flows over a rocky floor. The river has a fall of twenty-three feet between these places, or a little more than two feet per mile. This part of the course is known as the lower, or Des Moines, rapids. South of the Des Moines river, the Mississippi occupies a uniformly broad, alluvial valley.

At Sand Prairie, a sand plain similar to the Viele terrace plain intervenes between the river and the bluffs on the left, and another but smaller one occupies most of sections 29, 30, 31 and 32 (Tp. 65 N., R. V. W.). Between these the river flows at the base of the bluffs which in section 30 (Tp. 65 N., R. V. W.) are especially prominent and are called the "Yellow Banks." Above Sand Prairie the river valley is comparatively narrow and bounded by more or less precipitous rock escarpments. From Farmington to its confluence with the Mississippi the river has a fall of about two feet per mile.

At "Yellow Banks" the bluff rises about ninety feet above the adjoining bottom lands. The following section was obtained here:

Yellow Banks Section.

	FEET	INCHES
8. Clay, yellow, pebbleless..................	5	
7. Silt, drab, pebbleless.....................	1	3
6. Earth, black, with a few small pebbles; apparently an old flood plain deposit......	12	
5. Clay, yellowish (local)..................		6
4. Sand, with a few small pebbles; layer of boulders one foot thick as base.....20 to	25	
3. Earth, black, with yellow streaks; apparently old flood plain deposit........5 to	6	
2. Gravel, with some sands; pebbles two inches or less in diameter..............	20	
1. Clay, blue till (exposed to level of railway)	15	

About a mile west of this locality at the mouth of West Sugar creek the top of the blue till is about on a level with the railroad track. The sand and gravel above is considerably indurated and a distinct plane of junction between the sand and the clay evidently represents an erosive surface. The section at Yellow Banks with the exception of number 2 represents alluvial deposits and the bluff the extremity of a terrace plain. Northward from the "Yellow Banks" this plain occupies sections 18 and 19 with portions of adjoining sections east of the creek. West of the stream it occupies the interval between the creek and the river northward to Melrose chapel. On the north and east this plain is bounded by a low bluff rising twenty-five or thirty feet to the general plain level. This terrace plain has suffered a slight reduction towards the river. It has not been traced above Melrose chapel, but a well defined terrace probably to be correlated with this appears at intervals along the Des Moines. At Keosauqua a series of terraces extends up to a height of 135 feet above the river.

OLD MISSISSIPPI CHANNEL.

Location.—The limits of an ancient valley which was once occupied by the Mississippi river are indicated approximately upon the accompanying sketch map (figure 5). Between the mouth of Skunk river and Montrose the present valley lies within the older one and adjacent to its eastern margin. Also below the mouth of the Des Moines river ten miles distant the present valley represents a revival in part of the earlier channel. Between Montrose and the mouth of the Des Moines river, however, the river flows in a rockbound gorge which runs from four to five miles east of that of its former course.

Limits of the Channel.—No rock exposures appear within the area occupied by the channel as indicated upon the map. Usually the wells of the region fail to penetrate the drift, but at Fort Madison and Mount Clara deep borings have been made which pass completely through the drift and continue several hundred feet into the indurated rocks (figure 6). Above Montrose, rock outcrops along the eastern bank of the stream mark approximately the eastern boundary of the old valley. In a southwest direction from the town no rock appears until the Des Moines river is reached. At the mouth of this stream, on the north side, the limestone stands 100 to 140

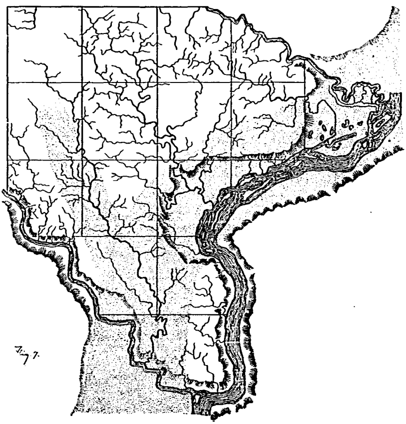


Figure 5. Sketch Map of Lee County, showing courses of old Channels.

feet above the level of the river. About one and one-half miles to the west the Keokuk formation outcrops at the base of a hill fifty feet high, lying between the railroad and the river. From this point to Sand Prairie the bluffs are composed entirely of unconsolidated materials. At the latter place the Saint Louis limestone makes its appearance in the bluffs, of which it constitutes a prominent feature for many miles. Northward from Sand Prairie the limits of the channel are marked approximately by outcrops at the following localities:

1. Painter's creek (Tp. 67 N., R. VI W., Sec. 13).
2. Railroad bridge over East Sugar creek (Tp. 67 N., R. V W., Sec. 5).
3. Lost creek (Tp. 68 N., R. IV W., Sec. 6).
4. Skunk river (Tp. 69 N., R. III W., Sec. 32).

Well Records.—Several deep wells have been put down at Fort Madison, all of which agree in showing a great thickness of clay and sand below the level of the river.

*Paper Mill Well, Fort Madison.**

	THICKNESS.	DEPTH.	ELEVATION TO SEA LEVEL.
5. Loam, black, quicksand and blue clay; not separated in the record	145	145	379
4. Limestone	35	180	344
3. Shale, blue and white	250	430	94
2. Limestone	180	610	-86
1. Sandstone (water-bearing rock).	77	687	-163

The surface at the well is twenty-one and one-half feet above low water datum, or 524 feet above sea level.

At the Atlee well, where the surface is thirty feet higher, the depth to limestone is 190 feet, while at the Hospital well, where the elevation is about the same as at the Atlee, it is 185 feet. A comparison of these figures shows a variation of fifteen feet in the elevation of the rock plain, due doubtless in part to irregularities in the old surface.

*This record was obtained from Mr. Frank Leverett, for whom it was copied from the books of the Fort Madison Paper Company, by the secretary, Mr. A. P. Brown.

At Mount Clara, two miles west of Montrose, a well has been put down at the summit of the divide on the farm of W. J. Beck.

Mount Clara Well.

		Thickness.	Depth.	Elevation to sea level.
12.	Clay	250	250	429
11.	Sand	55	305	374
10.	Limestone	25	330	349
9.	Shale, blue	8	338	341
8.	Limestone	5	343	336
7.	Shale	325	668	-11
6.	Limestone	115	783	-104
5.	Limestone	10	793	-114
4.	Limestone, flinty	25	818	-139
3.	Limestone	40	858	-179
2.	Limestone, hard	5	863	-189
1.	? No sample; carried away by water	76	939	-260

The well is on a level with the station, which is 679 feet above sea level.* The rock is here 305 feet from the surface and has an elevation of 374 feet above sea level, or five feet lower than at the Paper Works. The two wells are about eleven miles apart.

Extent of the Old Valley.—The old channel has an estimated width of about six miles. At Fort Madison it has a depth of 123 feet, at least, below low water level, and at Mount Clara it is 126 feet below low water at Montrose. The elevation of the rock surface is about 620 feet above tide at Sonora, and at Keokuk slightly less. On this basis the amount of rock excavation in the old channel is 245 feet as compared with 135 feet in the new one. The relation of the two valleys are shown in the accompanying section from the Sonora quarries to Argyle (figure 6).

*Record furnished by the owner.

In considering the data bearing upon the depth of the channel, it is to be mentioned that a possible source of error may arise in the difficulty of distinguishing in a well boring between glacial clay and the shale of the Kinderhook group. At Burlington, about sixty feet of these shales appear above the level of the river. The strata descend quite rapidly toward the south and then, together with the overlying Burlington beds, disappear below the level of the river just above Fort Madison. While admitting, therefore, the possibility of such a mistake in identification, yet that no such error has been made

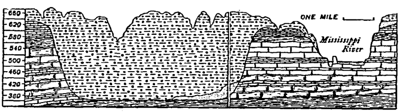


Figure 6. Cross-Section from Sonora to Argyle showing old and new Channels of the Mississippi River.

would appear from the following considerations: (1) the wells at Fort Madison and Mount Clara, while showing agreement in all essential points, were put down by different people; (2) the persons putting down the latter well were personally known to the writer as experienced well men who would be quite unlikely to make the mistake suggested; (3) the most conclusive evidence is the presence at both places of a great thickness of shale below the clay and separated from it by thirty to forty feet of limestone. A comparison of the records with those of wells at adjacent localities, as at Keokuk, Hamilton and elsewhere, leaves little doubt that the shales represented by number 3 of the Paper Works well and number 7 of the Mount Clara section are to be correlated, in part at least, with the Kinderhook beds, while the limestone above probably represents the base of the Augusta.

ANCIENT DES MOINES CHANNEL.

The existence of a buried channel tributary to that of the Mississippi and corresponding in position to the Des Moines river, was first suggested in 1893. Though incomplete, sufficient evidence has been gathered to warrant the conclusion that, in the vicinity of Argyle, an old valley of considerable magnitude joins that described above. Its position is marked approximately by the present course of West Sugar creek. It has been noted already that above Sand Prairie the present channel of the Des Moines river is comparatively of recent date. The indurated rocks which form bold escarpments along the stream, however, are almost entirely wanting on West Sugar creek notwithstanding the fact that the valley of the latter south of the Chicago, Burlington & Kansas City railroad extends considerably below the level of the rock surface. The only exception is a limited exposure of Saint Louis limestone occurring in Tp. 67 N., R. VI. W., Sec. 5, about one and one-half miles southwest of Donnellson. At this place the limestone forms the bed of the broad shallow ravine opening into the valley from the east. The upper line of the exposure is estimated to be at least fifty feet above the bottom of the valley adjacent. It is evident, therefore, that West Sugar creek is engaged in reviving an older valley, the limits of which are as yet but imperfectly known. The only deep drilling known to have been made within the limits of the channel is on the Bell farm, one and one-half miles east of Big Mound. The record of this well could not be obtained, but it is reported to have been abandoned on account of the unusual thickness of the drift and the difficulty encountered in penetrating it. The location of the channel is indicated provisionally upon the map.

HISTORY OF THE DRAINAGE DIVERSION.

The extent of the channels here recorded may be taken as in some degree a measure of the vast denudation which the region suffered previous to the Ice Age, while the evidence as to the cause leading to their abandonment must be sought in the deposits made during that period. The evidence at hand seems to warrant the assumption that at least two ice movements are recorded in the deposits of the region, one from the northwest and another and later from the northeast.

Des Moines Lobe.—The position of the new channel indicates that the obstruction which forced the river out of its old course must have been introduced from the northwest. Moving down the old valley of the Des Moines, it probably occupied the whole of the region between the Skunk and Des Moines rivers, and pushing across the old valley of the Mississippi as far as Keokuk, effectually dammed the stream and caused it to seek a new course farther east. Whether the movement here recorded was the first ice invasion is not clear, but it would seem that it was the first of sufficient magnitude to cause a marked change of drainage.

Later Movements.—From some of Mr. Frank Leverett's investigations in eastern Iowa, the results of which are soon to be published, there is reason to believe that an invasion of the Illinois ice lobe occurred long subsequent to the first displacement of the river. The limits of this movement are recorded in a morainic ridge extending south from New London in Henry county, entering Lee county near Pilot Grove and passing through West Point to the river north of Viele. From this point to Warsaw, Illinois, its position is not clearly determined. Aside from its general relations evidence of its connection with the Illinois invasion is found in the presence of jaspery conglomerate identical with the Huronian conglomerate within (east of) its border, while similar material is not yet known to occur outside of it. Prof. T. C. Chamberlin, to whom specimens were submitted, thinks it improbable that they could have come from a point any farther west than the Green Bay movements, and he doubts if they could have come from even that far west, since the fragments of jaspery conglomerate found within the range of that movement are not of the typical kind. The broad valley of East Sugar creek, already noted, borders this moraine on the west. The position of this depression suggests that it may represent the position of the Mississippi at the time the West Point-New London ridge was forming; though this is not yet clearly proven. Upon this point Mr. Leverett writes: "I have not yet been able to get decisive evidence that the Mississippi flowed around the west branches of the West Point-New London ridge. There is no channel across from the Iowa to the Skunk river valleys; and the trough or channel from the Wapsipinicon at Dixon to the Cedar at Moscow may prove to be independent of the Illinois invasion. Were it not for these two intervals there would be a continuous channel from the mouth of the Maquoketa through Goose Lake, Wapsipinnicon, Cedar, Iowa, Skunk river, Big and Little Cedar and East Sugar creek to the Mississippi." The glacial phenomena of the region are extremely complex and difficult of interpretation, but evidence thus far available points to a long interval of erosion between the two invasions. A study of the rock gorge between Montrose and Keokuk favors this conclusion, though it has not yet afforded grounds for a satisfactory demonstration.

Montrose-Keokuk Gorge.—The average depth of the new channel is 180 feet, of which 135 to 140 feet is in indurated rocks. Keokuk lies in a small ampitheatrelike depression facing southeastward towards the river. This small basin is intersected and drained on the south side by Soap creek. Between the foot of Main street and the mouth of this creek the height of the rock escarpment

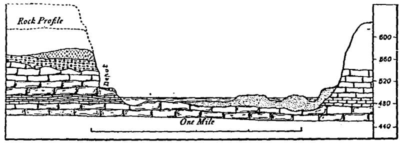


Figure 7. Present Channel of Mississippi River at Keokuk.

does not exceed fifty feet, though both to the north and south it reaches a height of 130 to 140 feet (figure 7). Along the front of this recess and resting upon its rock bed is a deposit whose explanation is not without difficulty. In consists of a bed of loose boulders at the base, overlain by stratified sand, which is succeeded by fine, gray, pebbleless clay or loess. The boulder bed is about twenty feet thick and is composed in large part of coarse, more or less rounded material, chiefly of local origin. Large blocks of limestone but little abraded are occasionally seen. Mingled with the local material are boulders of crystalline rocks, two and three feet in diameter. The interstices between the boulders are filled for the most part with sand, though pockets of clay are sometimes present. Towards the top the material becomes finer and takes on a stratified arrangement.

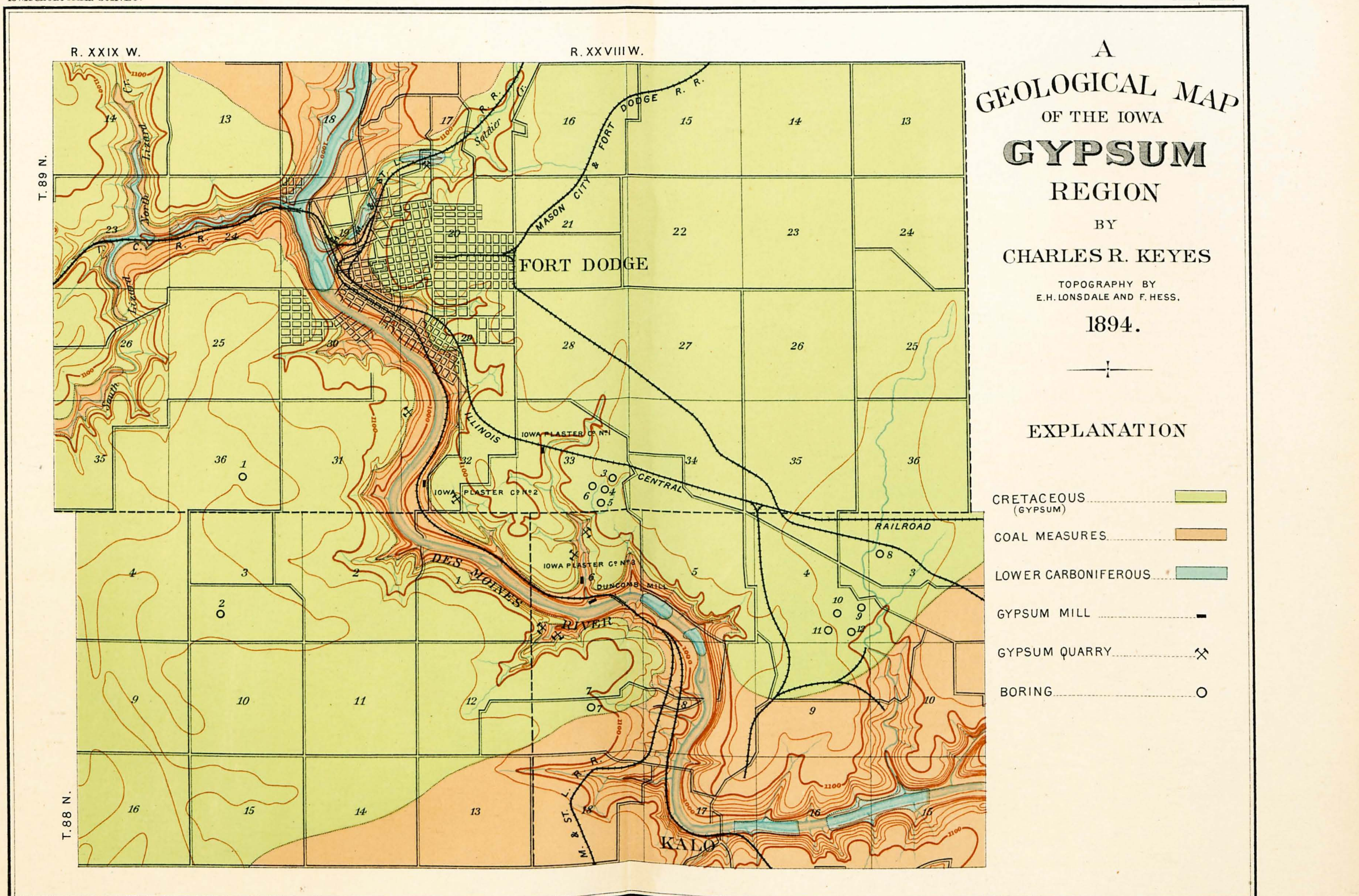
At one place the material is cemented with lime, forming a coarse conglomerate. Above this are ten or twelve feet of sand, fine below, becoming coarser above, and arranged in thin layers alternating with similar layers, in which the sand grains are encountered with iron oxide. Upward this bed passes gradually into fine, gray loess, which is fifteen feet thick. The latter includes occasional fragments of chert, a band of which exists about three feet above the base of the deposit. At Warsaw a boulder bed similar to that noted above and three to five feet thick rests upon blue till fifteen to thirty feet in thickness, which is much eroded at the top. Below Nauvoo, rock terraces occur up to an altitude of seventy feet. A rock shelf of the latter height bears a deposit of loess twenty feet in thickness. The loess is of the typical kind and highly fossiliferous. In this case no till intervenes between the loess and the limestone. Between Nauvoo and Hamilton there is very little drift. At several points sand deposits occur below the loess as at Keokuk. No explanation of the Keokuk boulder bed has yet received satisfactory demonstration. The coarseness of the material precludes the belief that it is due to river agencies alone.

A second hypothesis ascribes it to the cutting down of a till sheet. As the current removed the finer material the coarser would settle downward while the infilling of sand may have occurred subsequently.

A third view is that the deposit may have been formed in running water at the edge of the ice sheet or within its periphery. If the ice just reached the border of the river its melting would furnish both coarse and fine material, of which the former would accumulate at the bottom of the stream while the latter would be carried by the current. In some respects the second suggestion offers the most satisfactory explanation; while in others the third seems to be most satisfactory. The occurrence of the boulder bed at Warsaw capping a deposit of blue till favors the former. If this be the true explanation, then a question arises as to what till sheet it owes its derivation. Its position is eighty feet or more below the level of the rock surface, indicating that erosion to this extent had progressed before its formation. It is evident, therefore, that it does not belong to the drift of the Iowa invasion, unless the depression in which it lies be held to represent preglacial channels tributary to the old valley. If it can be shown that it belongs to the Illinois invasion, then it is evident that a measure of the time intervening between the two invasions appears in the eighty feet of rock excavation, plus an unknown thickness of overlying drift belonging to the earlier till sheet. Evidence apparently confirmatory of this view is supplied by the terrace in the Viele sand plain. These terraces occur up to a height of between fifty and sixty feet above the river, while the bordering bluffs show little if any traces of terrace formations. If the Illinois ice sheet reached across the river between Viele and Keokuk, the drift derived from it would probably wash the terraces formed before its advent, and the present terrace would apparently represent the time since that invasion. The occurrences of the loess at the height of seventy feet above the river resting upon a rock ledge near Nauvoo make it evident that erosion had progressed to this depth previous to the deposition of the loess.

If it can be shown that the loess represents the closing events of the Illinois invasion, then the preceding erosion period belongs to the interval between the two invasions as above suggested; and would sustain the view advanced by Mr. Leverett in the study of the Rock river basin* that the two invasions were more widely separated than the whole length of postglacial time. The relations of the loess to the drift, however, are not yet sufficiently clear to justify a final conclusion. The presence of a soil at the base of the former indicates a time interval of considerable importance, but a fuller elucidation of the Pleistocene history of the region must await further study.

*Proc. Am. Acad. Adv. Sci., vol. XLII. 1893.



A. Hoen & Co. Lith. Baltimore.

GYPSUM DEPOSITS OF IOWA.

BY

CHARLES ROLLIN KEYES.

GYPSUM DEPOSITS OF IOWA.

CHARLES ROLLIN KEYES.

CONTENTS.

INTRODUCTION.

Gypsum forms one of the most valuable of Iowa's mineral deposits. It is one which has never been appreciated to the extent that it should have been; and one which will, as years go by and the state becomes more and more densely populated, constantly increase in importance.

Though a substance widely distributed in small quantities throughout the region and occurring in nearly every geological formation having a surface exposure within its limits, the only deposits of commercial value are those which exist in Webster county, in the northcentral portion of the state. The gypsum of this locality is not only the most extensive occurrence in Iowa, but it may be regarded as one of the most valuable formations of the kind in the United States. Furthermore, its geographical position makes it the most important deposit in the entire Mississippi valley.

The existence of gypsum in the neighborhood of Fort Dodge has been known for nearly half a century; but its extent and adaptability for commercial purposes have not been made generally known. So far as can now be ascertained, attention was first called to the deposits by Dr. David Dale Owen, in 1852. In his ascent of the Des Moines river in canoes in the year 1849, he found the gypsum outcropping in Webster county, and he observed that "everywhere in the region of the plaster-stone the banks of the Des Moines river were clothed with an extraordinarily thick vegetation; indeed, the undergrowth and vines were so densely interlaced that it was penetrated only with great labor." The recognition of the deposit as one of considerable extent is important, as it first brought to the notice of the world the existence of the mineral in Iowa. It was regarded to be "by far the most important bed of the plaster-stone known west of the Appalachian chain, if not in the United States." Worthen, who, a decade later, undertook the same trip as Owen, mentioned the gypsum briefly, but added nothing to the former description except that the deposit did not appear to lie regularly upon the Coal Measures. Hall also referred to the beds

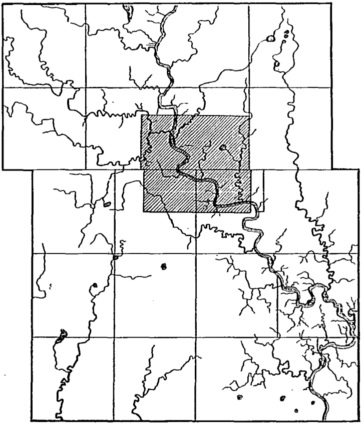


Figure 8. Sketch of Webster County, showing area of detailed Map.

incidentally. White, St. John, McGee, and later others have also visited the gypsum region at different times, so that incidentally and otherwise frequent mention has been made of this formation, yet little special investigation has been undertaken.

The rapid growth and development of the Mississippi valley and the constantly increasing use of cements of different kinds, for which the gypsum is admirably adapted, creates a new interest in the Iowa deposits, since they are the only ones of commercial importance known in the region.

GEOLOGY OF THE GYPSUM REGION.

The gypsum beds of Iowa cover a district of nearly fifty square miles. The deposits form an irregular triangular or rectangular area lying chiefly to the south of the town of Fort Dodge, in the central portion of Webster county. The tract occupied by the gypsum trends approximately northeast and southwest, a direction nearly at right angles to the valley of the Des Moines river. (Plate xx.)

The location of the area represented cartographically by plate xx is shown in the accompanying sketch (figure 8) of Webster county, the shaded portion being covered by the map.

TOPOGRAPHY.

The area containing the gypsum deposits is a part of a very level stretch of prairie, whose surface is so slightly rolling that the drainage is very imperfect, and the depressions are occupied for the greater part of the year by wet sloughs, often impassable by vehicles of any kind. Traversing the district in a southeasterly direction, and cutting it into two nearly equal halves, is the Des Moines river. While a few miles back from the stream on either side the surrounding country is quite level with no marked contrasts of elevation, toward the chief water course deep ravines begin to appear, sloping steeply toward the river, whose bed is 130 to 150 feet below the general level of the upland plain.

TOPOGRAPHY OF GYPSUM AREA.

In Webster county the Des Moines river valley is very narrow, with scarcely any alluvial flood plain. The sides of the valley are very steep, even precipitous. (See plate xxi.) All the minor tributaries of the chief water course likewise flow in narrow steep-sided ravines, very deep toward their lower extremities, but in the opposite direction, spreading out into small, broad, shallow, drainage basins. The ravines are very numerous, close together and very tortuous. They are separated from one another by sharp, narrow ridges.

Glacial deposits cover the entire region, often to a very considerable depth; these, therefore, have an important influence in the moulding of the topographical types, which are characteristically drift in aspect, except in the immediate vicinity of the larger water courses. Chiefly on account of the many steep-sided valleys and ravines cutting through the entire district, the outcrops of the different formations and the various beds occur with great frequency. The district may therefore be regarded as a broad, level plain, deeply trenched through the middle by the Des Moines river.

GEOLOGICAL FORMATIONS.

The Fort Dodge gypsum region is remarkable, geologically, in having present in so small an area four distinct geological formations. Between the periods of their deposition there elapsed long intervals of time. They are:

(4) Drift (Pleistocene).

(3) Gypsum beds and associated deposits (probably Cretaceous).

(2) Lower Coal Measures (Des Moines formation, Upper Carboniferous).

(1) Saint Louis Limestone (Lower Carboniferous).

Saint Louis Limestone.—This formation is the uppermost member of the Lower Carboniferous in Iowa. In Webster county it extends southward from the northern boundary line, in a rapidly narrowing tongue, one-third of the way across the district, to a point just below the mouth of Lizard creek, opposite Fort Dodge. The chief exposures consequently are in the valley of the Des Moines river, though the rock is also bared in the beds of many of the smaller streams for some distance from where they enter the larger water course.

Outcrops showing the details of the lithological characters are well exhibited at the Lenahan quarry (Tp. 89 N., R. XXVIII W., Sec. 19, NW. qr., NW. ¼) on west bank of the Des Moines river just above the mouth of Lizard creek, as well as on the latter stream a few hundred yards above its mouth.

Section at Lenahan Quarry.

	FEET.	INCHES.
9. Drift (exposed)	3	
8. Shale, sandy, nodular	4	
7. Sandstone, argillaceous, soft, white, evenly bedded	3	4
6. Sandstone, white, rather massive, hard	1	
5. Limestone, rather heavily bedded, compact, hard, breaks with well pronounced conchoidal fracture	2	3
4. Limestone, sandy, ferruginous, often with some chert	1	3
3. Limestone, white, hard, compact, heavily bedded, breaks with conchoidal fracture; with occasional clay parting	5	2
2. Limestone, like 3, but more massive (exposed)	3	
1. Hidden to water level	8	

The limestone, which may be regarded as the floor upon which the Coal Measures were deposited, thus reaches into the gypsum area only a short distance, at its extreme northern margin. The formation itself is made up chiefly of a compact, ash-colored or bluish limerock, which breaks with a conchoidal fracture. In some places sand beds occur, very white and pure, and often sufficiently indurated to afford a fairly compact stone such as might be used in rough masonry. Occasionally, also, beds of light colored shales are intercalated. Fossils, which in places occur very abundantly, show clearly that the limestone belongs to that part of the Lower Carboniferous, or Mississippian, series which is known farther southward as the Saint Louis division.

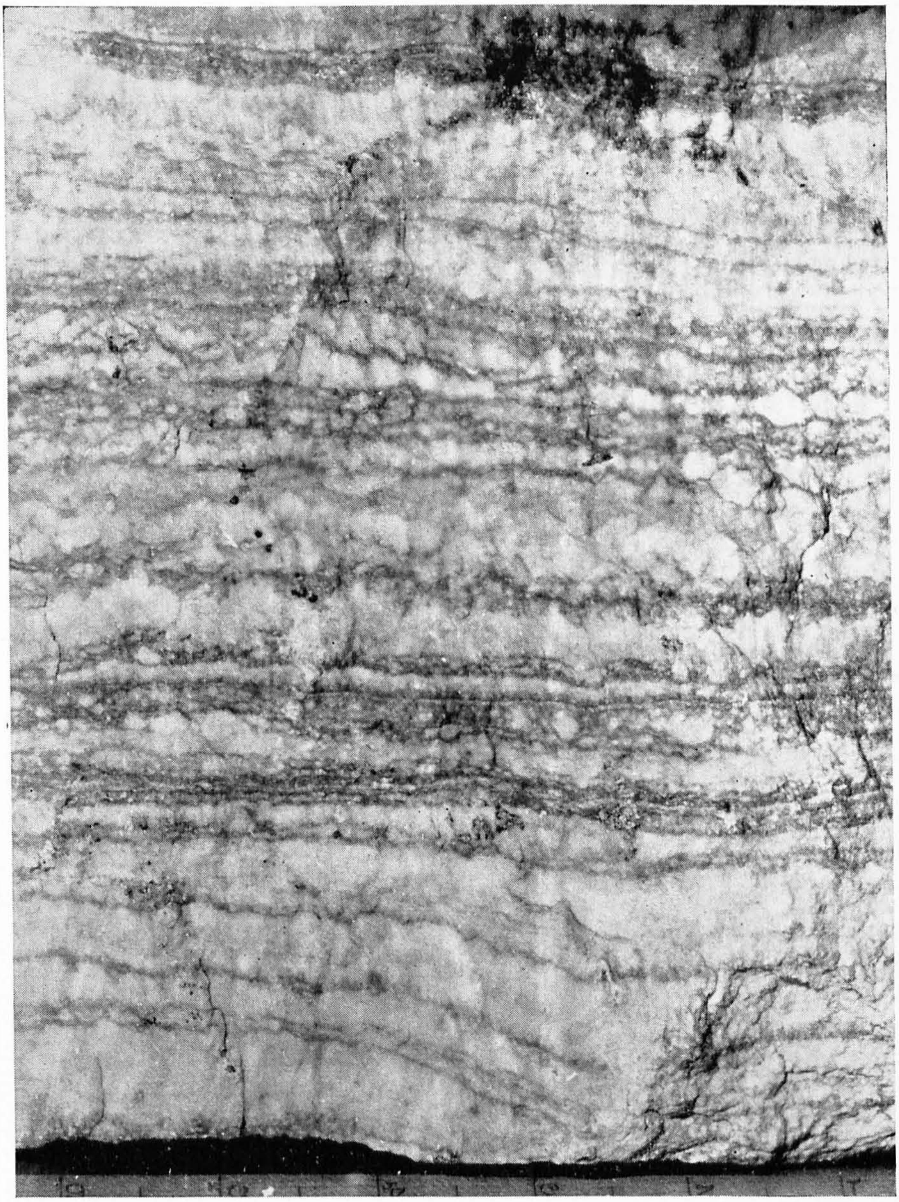
Lower Coal Measures.—Immediately underlying the gypsum throughout the greater part of its areal extent are characteristic Coal Measure deposits. In the northern part of the district the formation thins out completely over the old elevations of Lower Carboniferous limestone, allowing the gypsum beds to rest directly upon the Saint Louis formation; but farther south more than one hundred feet of Lower Coal Measures intervene between the two. Both the upper and lower limits of the coal bearing strata are readily made out. The superior line is perhaps the more prominent of the two for the reason that the gypsum often juts out beyond the softer underlying strata forming a prominent topographic feature. As elsewhere in the state the Lower Coal Measures are made up largely of clay shales. Sandstones are present, but not in such force as in some other parts of Iowa.

The general character of the formation may be inferred from the bluff section shown three-fourths of a mile west of the Minneapolis & Saint Louis railroad bridge over the Des Moines, six miles south of Fort Dodge, and a short distance southwest of the Duncomb mill, near the coal mine operated by the mill company (Tp. 88 N., R. XXVIII W., Sec. 6, SW. qr., SW. ¼).

Bluff Section, six miles South of Fort Dodge.

		FEET.
17.	Drift	5
16.	Shale, red (Cretaceous) exposed	4
15.	Shale, drab	8
14.	Sandstone, hard, shaly, with ferruginous concretions	3
13.	Shale, blue or variegated, containing abundant gypsum crystals	9
12.	Limestone, impure	1
11.	Shale, light colored	2
10.	Shale, drab to black	7
9.	Coal, impure, shaly	½
8.	Fire clay	3
7.	Coal, with clay parting	2
6.	Fire clay and white sandstone	3½
5.	Shale, black, fissile	4
4.	Shale, sandy, or sandstone	1
3.	Shale, sandy, gray	1½
2.	Shale, dark	6
1.	Shale, dark, fissile (exposed to water level)	16

Gypsum and Related Beds.—The gypsum and the deposits genetically associated with it comprise several kinds of strata. At the base, everywhere so far as has been observed, there appears to be a layer of red, ferruginous, clayey and sometimes sandy nodular shale, variable in thickness, usually from a few inches to two or three feet, and resting directly upon the Carboniferous beds. Upon this stratum lie the gypsum deposits, which vary in thickness from three or four to thirty or more feet, the average measurement being about sixteen feet. The gypsum is the perfectly massive variety, made up of numerous thin, alternating bands of white and gray calcic sulphate, the differently colored layers measuring from one-eighth to one-half of an inch in thickness and finely corrugated. (Plate xxii.) The lower part of the deposit, although not strikingly different from the upper portion,



STRUCTURE OF GYPSUM.

often contains some impurities, and on this account this part is usually ground into land plaster, while the upper portion is made into stucco. The gypsum beds appear to be thoroughly crystalline throughout, the individual crystals being columnar or needle-like, arranged closely together with their long axes at right angles to the sedimentation planes. This arrangement seems to be uniform throughout the entire deposit.

Nearly everywhere glacial detritus immediately covers the massive gypsum layer; but above the main bed in certain places, as along Soldier creek for example, there are exposed beds which were manifestly deposited at the same time as the principal gypsum mass. These are chiefly red and often somewhat sandy shales, which pass upwards into friable, massive sandstone. At various levels throughout a vertical height of twenty-five or thirty feet there are thin layers of typical gypsum, from one-quarter to one-half an inch in thickness, widely separated both from each other and from the massive beds below. These thin gypsum layers are highly corrugated, broken portions appearing like a letter ϖ, with a width often of fully three inches. At first glance the beds immediately overlying the gypsum appear to have been deposited unconformably, but closer investigation shows plainly that such is not the case. Percolating waters have dissolved and carried away portions of the upper part of the great gypsum bed, allowing the superimposed beds to settle down on an apparently uneven surface. The shales, which are commonly light reddish in color, are friable, and present few indications of bedding planes. Upon exposure they break down and crumble into a fine, dry, incoherent mass, which rapidly hides the gypsum from view, except where the streams are constantly sweeping away the talus. Upward the reddish shales give way to the similar layers of a brownish or drab color, acquire more and more fine sandy material and soon pass into a massive yellowish sandrock.

The exposure showing the fullest vertical section of the gypsum is near the mouth of Soldier creek, in North Fort Dodge. The place is a quarry face at Kohl's brewery.

Section at the Kohl Brewery.

		FEET.
8.	Drift	30
7.	Sandstone, soft, friable buff, heavily bedded	5
6.	Shale, argillaceous and sandy, alternating	25
5.	Sandstone, buff, massive, quite friable	2
4.	Shale, blue, argillaceous	2
3.	Gypsum, thin, undulatory band	⅓
2.	Shale, brown and reddish, with sandy layers and white and gray bands of gypsum from four to six inches thick and very undulatory	7
1.	Gypsum, massive, gray and white (exposed)	10

Number 1 of this section is doubtless thicker than that shown in the exposure. It probably rests directly upon the Saint Louis limestone, which is exposed in the creek bed a short distance away. A noteworthy fact in the present section is the superposition immediately above the massive gypsum of sandy shales with their bands of gypsum intercalated. These shales are of such character lithologically as to render favorable the finding of leaves of plants, whereby the exact age of the deposits may be determined with certainty.

Drift.—The glacial clays, which have a very considerable thickness over most of the district under consideration, have in a great measure protected the gypsum from complete destruction through solution and erosion. It seems to be a well established fact that the deeper the drift is over the gypsum the thicker is the deposit of calcic sulphate. Many of the gypsum exposures have fifty or sixty feet of glacial detritus overlying them. The effect, aside from protecting the deposit, is to add very materially to the ruggedness of the surface relief of the county.

STRUCTURAL RELATION OF FORMATIONS.

The four formations to which attention has been called manifestly do not represent a continuous sequence of deposition. Each one rests unconformably upon all the others beneath it. The arrangement of the different beds are perhaps best shown in the northern part of the gypsum area in the vicinity of the mouth of Lizard creek. An east and west cross section presents a very notable irregularity in the superposition of the beds (figure 9). The Lower Carboniferous limestone (Saint Louis) occupies the principal part of the section at the base (St L). It is well exposed in the beds of the Des Moines river, Lizard and Soldier creeks, as well as in some of the lesser streams. The unconformable relations of this formation and the Coal Measure (CM) is very marked.

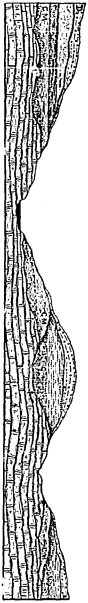


Figure 9. Cross Section east and west through the Gypsum Area.

The Saint Louis limestone throughout Webster county has the upper surface very unevenly eroded so that the rocks reclining upon it present an unconformity which apparently is much more pronounced than it really is. It is quite probable, therefore, that the greater thickness of the Coal Measure in the southern part of the area than in the northern portion is due largely to the fact that in the latter region the ancient elevations of erosion are higher. The unevenness of the upper surface of the Lower Carboniferous limestone is especially well shown near the old Bæhring quarry north of Fort Dodge. The lower part of the section is a blue, fine grained limerock, in many places closely resembling lithographic stone. This is the Saint Louis. It is overlain by a friable sandstone somewhat shaley and buff in color. Above it, a few yards back from the face of the exposure, are dark colored Coal Measure shales. Similar sandstones are known to occupy eroded depressions in the Saint Louis limestone at numerous other localities in the state.

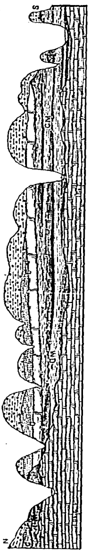


Figure 10. Cross Section through Gypsum Region, north and south.

At another point not far away on the Des Moines river, near the old dam site, the upper part of the Saint Louis limestone, for a depth of several feet, is completely honeycombed, apparently through wave action, and the Carboniferous shales of the Coal Measures are laid down immediately upon the surface, filling all the cavities.

A careful determination of a number of the leading gypsum exposures show that the difference in actual elevation between the extreme southern and more northern outcrops, is in the neighborhood of thirty feet. The real difference in measurement on the two sides of the gypsum basin between the base of the deposit and the Saint Louis limestone is much greater. In the northern part of the area the gypsum rests directly upon the limestone; the shales of the Coal Measures having thinned out completely, while at the southern margin fully 100 feet of sediments intervene between the two horizons. The cross section (figure 10) made through the gypsum region at right angles to the last shows practically the same relations between the four geological formations. The irregularities of the surface upon which the gypsum rests are not so marked as in the former section, but the interesting fact is brought out that the Coal Measures are much thicker at the south than at the north. The dividing line between the two formations, on the whole, is not nearly so well marked as that between the two former and the Saint Louis limestone. Often a thin ferruginous band is present at the base of the gypsum, the whole resting directly upon the shales. While the juncture of the two is readily determined approximately, it is rarely well exposed. The irregularities of the base of the gypsum appear to be nearly as great, as in the case of the Lower Coal Measures.

The drift (Pleistocene) presents the greatest irregularities of all the formations mentioned. Not only is the present surface of the ground profoundly carved out and trenched through erosion, but a similar set of conditions existed previous to the deposition of the glacial detritus.

OCCURRENCE AND ORIGIN.

GYPSUM EXPOSURES.

The gypsum beds over the greater part of the Fort Dodge area lie well up in the hills. The layers are cut through by most of the water courses, thus displaying numerous good outcrops, and showing in the various sections the relations of the different strata. From the natural exposures which are confined chiefly to the immediate vicinity of the Des Moines river, the gypsum comes to lie gradually deeper and deeper as it recedes from the chief stream until, towards its known eastern and western limits, it is found at depths, as shown by borings, of 75 to 125 feet.

While there are numerous natural outcrops of gypsum the quarry faces of course afford by far the best exposures for examination. The quarries which supply the mills with the material are the most extensive, though smaller openings where the rock is taken out for building purposes disclose very considerable vertical sections.

Soldier Creek.—This stream traverses the northern border of the gypsum area east of the Des Moines. The gypsum beds here rest partly on the Saint Louis limestone and partly on the Coal Measure shales. They occur at a lower level than at any other place known, coming down within a very few feet of the water level of the Des Moines river. One of the most instructive sections is a short distance above the mouth of the creek near the old site of Kohl's brewery in the north part of the city of Fort Dodge and a short distance directly west of the Des Moines and Fort Dodge, or Des Moines Valley, railway station.

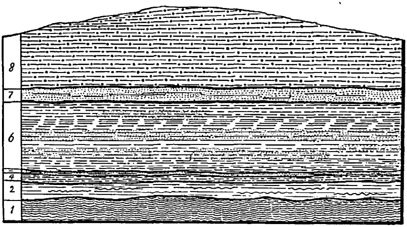


Figure 11. Quarry-face at the Kohl Brewery.

		FEET.
8.	Drift	30
7.	Sandstone, friable, buff, heavily bedded	5
6.	Shale, argillaceous and sandy, alternating	25
5.	Sandstone, buff, massive, quite friable	2
4.	Shale, blue, argillaceous	2
3.	Gypsum, thin undulatory band	⅓
2.	Shale, brown and reddish, with sandy layers and white and gray bands of gypsum from four to six inches thick and very undulatory	7
1.	Gypsum, massive, gray and white varied (exposed)	10

This exposure of over fifty feet of stratified rocks appears to lie in a depression in the Coal Measures, since a short distance to the north bituminous shales rise to a level considerably higher than the top of the section. The red shales which often accompany the gypsum are exposed better here than anywhere else yet observed and a detailed account of them is given in connection with the remarks on the geological formations. Farther up the stream for a distance of one or two miles the exposures are numerous. Some show the Saint Louis and gypsum in conjunction; others with the Coal Measures and gypsum in the same relation. One-quarter of a mile farther up the stream, opposite the Bœhring quarry, is an exposure whose base is at the water level and but a few feet above the base of the Kohl brewery section. No gypsum whatever is shown; the heavy drift deposits come down within twenty-five feet of the creek bed and rest directly upon the Saint Louis limestone. The section shows:

Section Opposite the Bœhring Quarry.

		FEET.
6.	Soil	2
5.	Gravel, with considerable clay and sand, and a layer of small boulders of granite and other crystalline rocks at base	15
4.	Clay, yellow, with numerous small pebbles and some sand	15
3.	Clay, blue, otherwise same as 4	25
2.	Sand, irregularly stratified; contains lumps of coal, twigs, sticks and streaks of peaty material	8
1.	Limestone (Saint Louis), blue in part, heavily bedded, with thick marly parting (exposed above sea level),	25

On the opposite side of the creek, a distance of one hundred yards, ten to fifteen feet of Coal Measure shales appear directly over the Saint Louis limestone; and above them traces of the red sandy shales associated with the gypsum. A short distance farther up the creek is the old Cummins quarry, now deserted, but formerly furnishing much of the material for foundation walls in and around Fort Dodge. The gypsum bed is fully twenty-five feet in thickness and comes down to within seven or eight feet of the creek bed. The Saint Louis limestone is here exposed, rising a few feet above the water level. Between it and the massive gypsum bed there intervenes one to three feet of clayey and sandy material, highly ferruginous, sometimes forming thin beds of iron ore. The red sandy shales overlying the gypsum have a thickness of about twenty feet on the exposed surface; with doubtless a greater thickness farther back in the hill.

Section at the Old Cummins Quarry.

		FEET.
5.	Drift	10
4.	Shales, red and yellow, sandy, with considerable gypseous material	20
3.	Gypsum, gray, massive	23
2.	Shale, sandy, ferruginous, with irregular bands and nodules of iron ore	2
1.	Limestone, gray or ashen, compact, breaking with conchoidal fracture, rather heavily bedded (exposed to creek level)	4

Up stream from the Cummins quarry the Saint Louis limestone is exposed only for a short distance. Coal Measure shales appear in most of the outcrops with the red shales above. These may be traced along the creek for nearly a mile northeast of the quarry. Beyond, the slopes are too gentle and the drift too thick to permit of outcrops of the indurated strata.

Des Moines River, East Side.—Southward from the Kohl brewery section, near the mouth of Soldier creek, gypsum is rarely exposed for a distance of fully two miles, chiefly on account of the comparatively gentle slopes on the east side of the stream. However, indications of the presence of red sandy shales are noticeable at several points. The first important exposure of the gypsum met with in passing down the river is about one mile south of the Minneapolis and Saint Louis railway station, in the bluffs near the old Des Moines river. Between forty and fifty feet above the railroad track a small opening of gypsum occurs. It has been quarried to some extent at this point, but in such a desultory manner that the thick overlying drift nearly covers up the quarry face as soon as the opening

ing is left unworked for a time. Twelve feet beneath the gypsum layers are Coal Measure shales, which give the subjoined section (numbers 1 to 7):

		FEET.
9.	Drift	15
8.	Gypsum, gray, massive (exposed)	5
7.	Unexposed	12
6.	Shale, dark colored, with layer of cone-in-cone at the base, six inches in thickness	2
5.	Limerock, black, hard, compact	1
4.	Coal	1
3.	Shale, dark colored	2
2.	Shale, light colored, calcareous	8
1.	Unexposed (to level of railroad)	8

The exposures of the gypsum continue at short intervals for a distance of nearly a mile down stream; but for the succeeding mile few traces are to be seen until near the mouth of a small creek which enters the Des Moines river a mile below Mill No. 2 of the Iowa Plaster Company. For the greater part or its course gypsum outcrops on this stream. Near the head of the creek are the quarries which supply the mill, which is about one-third of a mile to the west. At the quarry (Tp. 89 N., R. XXVIII W., Sec. 31, SW. qr., SE. ¼) the massive gypsum bed is twenty feet thick. Below the base of this ledge the material is not so pure, and is not worked. The top of the bed quarried is very irregular; forty feet of drift overlie it.

Section at Iowa Plaster Quarry, No. 2.

		FEET.
3.	Clay, yellow and blue, with abundance of pebbles, small boulders and sand	40
2.	Gypsum, gray, massive	20
1.	Gypsum, gray, massive, somewhat impure (exposed)	2

The most important gypsum exposures in the region are in a deep trench known as "gypsum hollow." It

GYPSUM QUARRY FACE. IOWA PLASTER COMPANY, FORT DODGE.

opens into the Des Moines river a short distance above the Minneapolis and Saint Louis railroad bridge. Large quarries have been opened and worked for many years. The chief openings now in operation are those which supply the plaster mills. They are situated a short distance above Mill No. 3, and about three-fourths of a mile above the mouth of the creek. The exposures of gypsum are almost continuous for a distance of nearly two miles along this creek. The base of the valley is occupied by Coal Measure shales which, being more easily effected by the action of running water, allow the massive gypsum to form a protecting cap as it were to the underlying strata, giving the valley a strikingly gorge-like appearance.

At the present time the base of the gypsum bed at the quarry is more than sixty feet above the creek bed. In quarrying at this place it is the practice to strip off the drift for a considerable area, clearing off the upper surface as much as possible to prevent the clay from mixing with the gypsum (plate xxiv). The surface, when exposed, is found to be formed into a complete set of small hillocks much after the manner of the well known *roches moutonnées* (plate xxiv). The depression between the elevations vary from one or two to three feet or more, often forming intricate labyrinths. Deep pot holes are also not infrequent.

Section at Quarry of Iowa Plaster Company, Mill No. 3.

	FEET.
5. Soil	2
4. Silt, yellow, fine, sandy in places, loess-like	7
3. Clay, yellow, pebbly, with occasional small boulders,	25
2. Gypsum, gray, massive, with occasional thin partings	23
1. Gypsum, gray, somewhat impure (exposed)	3

In this vicinity the lower bed in the section (number 1) appears to lie on a surface quite uneven, sometimes resting upon one member of the Coal Measures and sometimes on another. On the opposite side of the ravine directly east of the quarry the following sequence is shown:

		FEET.
11.	Drift...............	50
10.	Gypsum, gray, heavily bedded............	30
9.	Shale, rather sandy, reddish............	15
8.	Shale, red and white..	2
7.	Shale, clayey, gray...	1
6.	Shale, clayey, drab and dark colored.......	1
5.	Sandstone, yellow, massive, hard, fine grained............	4
4.	Sandstone, white.....	2
3.	Shale, bituminous, fissile................	1
2.	Shale, drab (exposed),	1
1.	Hidden to creek bed..	12

Figure 12. Section North of Mill No. 3.

From the mouth of "gypsum hollow" southward along the river the gypsum is shown at short intervals in the bluffs. The last good outcrop met with is near the site of an old milldam, about half a mile northwest of Coalville (Tp. 88 N., R. XXVIII W., Sec. 5, SE. qr., SW. ¼). The gypsum rests directly upon six to eight feet of brown sandy shale, below which is a seam of coal.

UPPER SURFACE OF GYPSUM BED. MILL No. 3.

Bluff Section Near Coalville.

		FEET.
6.	Drift	25
5.	Gypsum, gray, massive	12
4.	Shale, sandy, brown or yellowish	6
3.	Shale, black, fissile	1
2.	Coal	2
1.	Shale, brown, sandy (exposed)	3

Lizard Creek.—A short distance above the mouth of the stream the red shales, which are so prominently associated with the gypsum on Soldier creek, on the opposite side of the Des Moines river, are found on the north side a short distance above the Saint Louis limestone. On the south side of the creek the red shales appear, well up in the bluffs, and are also exposed at one or two points between the mouth of the stream and the junction of the north and south branches.

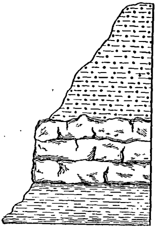
On the North Lizard, drift deposits occur nearly to the Des Moines and Fort Dodge railroad bridge, four miles above the confluence of the two branches. At this point there is quite an extensive exposure from eight to twelve feet high. It is chiefly a soft, white, fine grained sandstone, with some red sandy shales. This is the only known outcrop on the north branch which is thought to be associated with the gypsum.

On the south branch of Lizard creek, a short distance above the juncture with the main stream, the red sandy shales crop out on the east bank (Tp. 89 N., R. XXIX W., Sec. 26, NE. qr., NW. $\frac{1}{4}$). Farther up the creek the exposures appear to be entirely Coal Measure shales.

Des Moines River, West Side.—From the mouth of Lizard creek, for a distance of nearly two miles down stream, no good outcrops of gypsum occur. At the mouth of the creek the red sandy shales which are known to overlie the gypsum on the opposite side of the river, are exposed in the pit of the Fort Dodge Clay Works, recently opened. Elsewhere, also on the west bank of the river, the same shales are found in limited exposures. While an accurate measurement of the maximum thickness is impossible, the outcrops indicate upwards of fifteen feet. The first good ledge of gypsum met with is in a deserted quarry well up in the bluff (Tp. 89 N., R. XXVIII W., Sec. 32, NW. qr., NW. ¼). At this place sixteen feet of gypsum is presented. Below it are the Coal Measure shales, which reach down to the water's edge.

At the sharp bend of the river, nearly opposite Mill No. 2 of the Iowa Plaster Company, the steep bluffs show an extensive outcrop of massive gypsum twelve to thirty feet in thickness (Tp. 88 N., R. XXIX W., Sec. 2, NE. qr., NE. ¼). Above it are the reddish sandy shales. The same beds are also shown in a number of ravines which open into the Des Moines valley in the neighborhood, and the exposures extend from one-half to three-quarters of a mile back from the river. Coal Measure shales rise to a height of thirty-five to fifty feet above the water level at this point. In the next mile and a half only a few traces of the gypsum are noticed.

In a deep labyrinthine ravine one-half a mile above the Minneapolis and Saint Louis railroad bridge, numerous outcrops of gypsum occur for a distance of more than one-half a mile up the branch. Extensive quarries have been opened, the output being used by the Duncomb Stucco Mill, which is situated about three-fourths of a mile to the east, on the opposite side of the Des Moines river. At the Duncomb quarry (Tp. 88 N., R. XXVIII W., Sec. 7, NW. qr., NW. ¼), thick deposits of drift overlie the gypsum, and the upper surface of the latter is profoundly eroded into rounded hillocks and winding trenches.



		FEET.
3.	Drift................................	35
2.	Gypsum..............................	18
1.	Shale, sandy, light colored (exposed).	12

Figure 13. Section at the Duncomb Quarry.

Beneath number 2 of the section there are, as shown farther down the ravine, about seventy-five feet of Coal Measure shales between the gypsum and the water level in the Des Moines river.

For some distance down stream from the mouth of the ravine on which is situated the Duncomb quarry, gypsum outcrops at short intervals. The last good exposure seen is less than a mile below the railroad bridge or nearly opposite the old dam site on which was formerly situated the Goss mill.

Borings.—In prospecting for coal or in boring for water, gypsum has been encountered at a number of places some distance from the Des Moines river. This information has extended very greatly the known range of the gypsum deposits, and has enabled the limits of the deposits to be made out with much greater accuracy than was at first anticipated. The results of these borings are further suggestive of an even wider geographical distribution of gypsum-bearing beds than was thought of before, and of the directions in which the gypsum layers are to be looked for with success.

Southwest of Fort Dodge and from one and one-half to two miles from the river, several drill holes have been put down in the vicinity of the county poor farm. The well on the poor farm (Tp. 88 N., R. XXIX W., Sec. 3, SW. qr., NE. ¼), passed through seventeen feet of gypsum at a depth of eighty-three feet. The record is as follows :

Well on Webster County Poor Farm.

		FEET.	INCHES.
23.	Soil	2	
22.	Clay, yellow	13	
21.	Clay, blue	47	
20.	Sand	1	6
19.	Clay, "hard pan"	19	4
18.	Gypsum	17	
17.	Shale, blue, "soapstone"	6	2
16.	Limerock, black	2	
15.	Coal		9
14.	Fire clay	1	6
13.	Shale, light colored	1	4
12.	Coal	1	3
11.	Sandstone	4	
10.	Shale, black	4	2
9.	Coal		3
8.	Fire clay	1	
7.	Sandstone, white	4	6
6.	Shale, with limestone bands	34	6
5.	Shale, light colored	5	
4.	Shale, blue	4	
3.	Limestone, or hard calcareous shales	6	5
2.	Shale, blue	21	2
1.	Limestone (penetrated)	40	

One mile to the north, the Craig Coal Company has prospected at the head of what is known as Elkhorn ravine (Tp. 89 N., R. XXIX W., Sec. 36, SE. qr., NW. ¼). Sixteen feet of gypsum was found at a depth of seventy-six feet. A third layer one foot thick exists just above the main mass and is separated from it by seven inches of clay or shale.

Southeast of Fort Dodge, a couple of miles, a number of borings have been made to the east of the head of "gypsum hollow," showing from fifteen to twenty feet of gypsum at a depth of about fifty feet. One of the holes made in township 89 north, range 28 west, section thirty-three (SE. qr., SW. ¼) showed the following succession of strata:

		FEET.	INCHES.
22.	Soil	6	
21.	Clay, yellow and blue	14	
20.	Shale, red and yellow	6	
19.	Gypsum	16	10
18.	Shale	1	6
17.	Sandstone, white	2	
16.	Sandstone, brown	1	
15.	Shale, reddish	2	
14.	Shale, yellow	2	4
13.	Shale, dark colored	14	6
12.	Fire clay	3	1
11.	Shale, black	3	
10.	Coal	1	10
9.	Sandstone	3	
8.	Shale, light colored	2	2
7.	Shale, black		3
6.	Sandstone	1	
5.	Shale, black	4	
4.	Fire clay	1	6
3.	Shale, black	3	
2.	Sandstone, soft		4
1.	Limerock, black (penetrated)		3

There were other holes drilled on the same quarter section, each giving practically the same sequence of strata.

Two and one-half miles to the southeast, on the Holiday farm and near by (Tp. 88 N., R. XXVIII W., Sec. 4, SE.

qr.), four holes have been put down. Gypsum was struck at depths varying from 50 to 125 feet, the variation in depths being due largely to the differences in altitudes of the surface. In the two holes farthest north the gypsum was nine to twelve feet thick. Hole number 3 was near the center of the quarter section indicated:

		FEET.	INCHES.
11.	Soil	2	
10.	Clay, yellow	17	
9.	Clay, blue	25	6
8.	Shale, red	2	6
7.	Gypsum	12	
6.	Shale, black	5	6
5.	Coal	2	
4.	Fire clay	4	6
3.	Shale, gray	5	6
2.	Sandstone	16	
1.	Shale, black	1	

Northwest of Kalo, for a distance of one mile, numerous prospect holes have been put down by various coal companies. Near the center of section 7, township 88 north, range 28 west, the gypsum is fifty-eight feet from the surface, and only one foot thick. South of this point no gypsum has been reported, though a large number of drill holes have been put down much below this level.

Five miles northeast of Fort Dodge on the Groebner farm (Tp. 89 N., R. XXVIII W., Sec. 12), a well eighty feet in depth gave this section:

		FEET.
4.	Soil	2
3.	Clay, yellow above, blue below	50
2.	Shale, red, sandy	26
1.	Gypsum (penetrated)	4

In the Flattery well, which is about one mile east of the Groebner place (Tp. 89 N., R. XXVII W., Sec. 7, SE. qr., SW. ¼), the same bed was encountered at a depth of forty feet, and fifteen feet of gypsum penetrated. This is an extension of the gypsum fully four miles east of any previously known occurrence.

Disposition of Deposits. — Broadly speaking, the gypsum beds of Iowa form a broad plate at least ten or a dozen miles in length and about six miles in breadth, with a thickness varying from a few to thirty or more feet. Through the middle of the area the Des Moines river has cut a deep trench, removing a narrow belt of gypsum half a mile in width, yet at the same time exposing the deposit in its best development, and making it more accessible than would ever have been otherwise.

Taking into consideration the results of the recent geological investigations in northcentral Iowa, it may be inferred that the gypsum has a much greater extent than is at present known. To all appearances the deposit lies in a long but narrow area not very unlike what would in all likelihood be laid down in a shallow estuary, stretching out into a broad open sea. The gypsum area has its long axis directed nearly northeast and southwest, a direction at right angles to that which it has always been thought to have. Starting upon the hypothesis that this was the true direction of a long estuary deposit, as all facts seemed to point to, and that in geological age it was probably Cretaceous, outcrops of the latter formation were looked for beyond the borders to the southwest of any heretofore known exposures. The result was the finding of extensive chalk beds east of Auburn in the extreme southeastern corner of Sac county, a locality eighty miles farther east than any other previously reported Cretaceous chalk outcrop, and within thirty miles of Fort Dodge gypsum area. Moreover, it was directly in line with the prolonged axis of the gypsum deposit as determined some months before. Should these observations be correct, it is to be expected that extensive gypsum beds will eventually be found to exist at very moderate depths for considerable distances beyond both the northeast and southwest limits of the Fort Dodge gypsum district.

ORIGIN OF THE GYPSUM.

Gypsum originates in a variety of ways. Of the half a dozen methods by which it is commonly formed in nature the last here mentioned is manifestly the one which applies strictly to the Iowa beds. One of the most universal methods, perhaps, though carried on usually on a comparatively small scale, is by the breaking down of lime carbonate in the presence of the sulphates of iron or copper as in many clay shales. Another similar way is by the action of decomposing sulphides, as iron pyrite in limestone. In volcanic districts gypsum is a common resulting mineral, where sulphurous fumes or accidulated waters pass through lime-bearing rocks. The common mineral anhydrite taking up water, frequently forms more or less extensive deposits of gypsum. Still another way and probably the most prevalent, is through chemical precipitation.

As already remarked, the Fort Dodge gypsum beds appear to have originated according to the last of methods mentioned. It will be seen hereafter that the Iowa gypsum deposits are probably Cretaceous in age ; that they doubtless belong to the upper part of the Mesozoic formation as represented in the state. At the time of deposition the area within the present boundaries of Iowa had been depressed, allowing the Cretaceous sea to invade the northwestern half of the territory. Owing to another slight oscillation of the land the waters rapidly retreated.

Depressions in the old land surface would be occupied for a while by saline lakes of greater or less extent, cut off more or less completely from the ocean. As evaporation went on rapidly in these land-locked bodies of salt water, they would become more and more dense and assume greater salinity, until finally the various salts would be precipitated one after another in these different bodies of water. Now, these salts fall in the inverse order of their solubility: anhydrite, gypsum, rock salt, and the others still more easily soluble. The process is not unlike that now going on in existing saline lakes, where it has been found that the gypsum is formed where the degree of saturation of the water is such that thirty-five to forty per cent of the ordinary sea water has been driven off. When more than twice this amount of water is evaporated, common rock salt begins to crystallize out. With the deposits of gypsum and common salt so closely associated, it seems not improbable that the latter may be discovered sooner or later in the neigborhood of the Iowa gypsum area. Rock salt, however, is not a necessary accompaniment of the gypsum. The waters may originally never have become so concentrated as to allow this mineral to be thrown down. Or, if it once had been deposited upon the gypsum, percolating waters may have removed all the sodium chloride, for the reason that it is very much more soluble than the gypsum.

The conditions, however, which must have existed at the time of the deposition of the Iowa gypsum are manifestly not very unlike those which prevailed when the celebrated Permian deposits of rock salt and gypsum were laid down at Stassford, in Saxony. These, in alternating beds, have a total thickness of more than 1000 feet. It is a remarkable fact, also, that the more soluble salts which are comonly not precipitated by the evaporating sea water are here preserved. Among them are the sulphates and chlorides of lime, potash and magnesia and also the borate of the latter. In some of the Triassic strata of England, salt, gypsum and red marl alternate with one another. The New York gypsum fields exhibit similar phenomena. Above the main gypsum beds of the Iowa region are numerous thin bands of the same mineral interstratified with clayey or sandy shales. This, with the narrow banding of the principal bed and the relations of associated strata seem to point clearly to the origin of the Fort Dodge gypsum as a chemical precipitate.

GEOLOGICAL AGE.

The gypsum deposits form one of the few formations of Iowa whose geological age has long remained undetermined. Recent investigations, however, have practically settled this question so that now there is but small doubt that it is a Cretaceous in age. As remarked by White, neither in the gypsum nor the associated shales have any traces of organic remains been found. All considerations as to relative age must therefore be based upon the evidence derived from a comparison of the relations of the different formations to one another, taken in connection with the general geology of the region.

The first person to touch upon the geological age of the Iowa gypsum was Owen,* in 1852. His notes were taken three years previously on a hurried reconnoissance up the Des Moines river, and his remarks on the subject are somewhat obscure. Nevertheless the impression is given that the gypsum beds lie comformably upon the

* Geology Wisconsin, Iowa, Minnesota, p. 126. Philadelphia, 1852.

Coal Measure shales, and that they are Carboniferous in age.

Worthen,* who visited the locality in 1856, added little to Owen's observations, yet was led to believe that the gypsum did not lie conformably upon the Coal Measures.

Hall,† in his remarks upon the Supra-Carboniferous Formations of Iowa, refers only incidentally to the gypsum, yet he regarded it as being doubtfully connected with the Coal Measures, and as having the appearance of "a position intermediate with them and the Cretaceous above."

As early as 1865 Hall‡ incidentally correlated these deposits with certain red marls and ferruginous sandstones in southwestern Minnesota, which he regarded as "not older than Triassic."

Shortly afterwards White and St. John‖ directed some attention to the gypsum, describing the beds with considerable detail. In regard to the age it is stated that "it therefore seems in a measure conclusive, that the gypsum is of Mesozoic age, perhaps older than the Cretaceous."

In the course of his account of the building stones of Iowa in 1884, McGee§ alludes casually to the age of the gypsum, and suggests that it might provisionally be given the stratigraphical designation of Fort Dodge beds, and be placed with the Cretaceous.

Quite recently¶ the geological formations of the state have been reviewed. In connection with the remarks on

* Geology Iowa, vol. I, p. 177. 1858.

†Geology Iowa, vol. I, p. 142. 1858.

‡ Trans. American Philosophical Soc., (2), vol. XIII., pp. 329-339. Philadelphia, 1867.

‖ Geology Iowa, vol. II, p. 229. Des Moines, 1870.

§ Tenth U. S. Census, vol. X, Building Stones, p. 258. Washington, 1884.

¶ Keyes: Iowa Geological Survey, vol. I, p. 137. Des Moines, 1893.

the Fort Dodge beds the statement was made that since "in the light of recent geological observations in northwestern Iowa, which indicate that exposurés which are undoubtedly Cretaceous, occur much farther eastward than had hitherto been regarded, it would appear that the gypsum beds and the accompanying overlying shales may be considered as Cretaceous in age, and that they were probably deposited at the same time as the Niobrara chalks along the Missouri river near Sioux City." It was also remarked that the Cretaceous deposits of Iowa were laid down on a gradually sinking shore; that the Cretaceous sediments — Dakota sandstone and Benton shales — were deposited at the beginning of the period of depression, and were afterwards covered by the Niobrara chalk. But eastward from the open sea deposits of the last named stage, shore depositions were also formed. The Niobrara stage thus represents the greatest expansion of the Cretaceous waters within the present limits of Iowa.

As already stated in regard to the origin of the gypsum, there is no reason for not believing that all the gypsum deposits of the region are to be considered as chemical precipitations in saline lakes which had originally been cut off from the sea during a period of land elevation. This being the case, it would be only during the retreat of Cretaceous waters in the Iowa territory that such salt or land-locked lakes could be formed.

It may be inferred then that since the gypsum deposits appear to lie unconformably upon the underlying strata and since the only period for the formation of the saline lakes was during the retreat of the Cretaceous waters, the gypsum deposits of Fort Dodge were doubtless laid down during the latter part of the Niobrara epoch.

COMPOSITION AND USES.

CHEMICAL ANALYSES.

For so thick and so extensive a deposit of this mineral the Fort Dodge gypsum is remarkably pure chemically. The whiter portions show considerably less than one and one-half per cent of impurity; while the darker portions, which are taken from near the base and which are used for land plaster, give only ten to fifteen per cent of impurity. The largest proportion of the impurity is probably clay which, however, is usually concentrated more or less into narrow bands. The argillaceous matter even in its most concentrated form seldom amounts to more than one-tenth of the entire portion of these thin zones which are called the impure parts. The other impurities are minute quantities of silica in a finely divided condition. Of lime and iron there are commonly but small quantities amounting to only a fraction of one per cent.

Analyses of a number of samples of the Fort Dodge gypsum were recently made by Prof. G. E. Patrick. A selected piece which was slightly weathered and taken from the quarry which supplied Mill No. 3, of the Iowa Plaster Company, showed only .65 of one per cent of impurities. This analysis gave:

	PER CENT.
Calcium sulphate, $CaSO_4$	78.44
Water of Crystalization (calculated)	20.76
Insoluble matter (impurities)	.65
	99.85

Three samples from the top, middle and bottom of the quarry face at the same locality gave the following results:

	Top.	Middle.	Bottom.
Calcium sulphate, $CaSO_4$	78.37	78.54	78.44
Water of Crystalization	20.75	20.79	20.76
	99.12	99.33	99.20

Specimens from the Duncomb quarry, on the opposite side of the river, yield very similar results with the indications that the gypsum is a trifle more pure. Two analyses by Emery of light and dark bands of the gypsum, probably from the lower portion of the deposit, which is ground into land plaster, gave 98.63 and 85.53 per cent of gypsum.

A fresh sample from the middle of the quarry ledge above Mill No. 3, showed:

	PER CENT.
Calcium Sulphate, $CaSO_4$	79.23
Water of Crystalization (determined)	20.23
Insoluble matter	.84
	100.30
Error in analysis	.30

It will be noticed that the amount of water of crystalization in this sample which was accurately determined was considerably lower — .70 of one per cent — than the theoretical amount of water in pure gypsum. This taken in connection with the fact that there is a slight excess of lime and sulphuric acid in the different analyses would indicate that a small amount of calcium sulphate in the form of anhydrite is present in the gypsum. In this connection it would also be of interest to know whether or not the ordinary gypsum crystals which are so abundant in many of the formations has always the theoretical amount of water of crystalization.

PRESENT USES OF THE IOWA GYPSUM.

Stucco.—As already stated nearly all of the gypsum produced in Iowa is converted into stucco, or plaster of Paris. The processes involved from the time the material leaves the quarry until it appears as the finished product ready for shipment are fully described farther on.

The most extensive use to which the stucco is put is in the finishing coat of the inside of buildings. Hard plaster for walls also consumes considerable amounts.

Land Plaster.—Fertilizers are used so sparingly in Iowa at present that very little gypsum is ground for this purpose. The total amount used in this way for 1891 was only valued at $4,845. Consequently little need be said in regard to the use of this material in Iowa.

In other states, as New York, nearly all of the gypsum is ground into land plaster. Its chief value in affecting the soil is that with ammonia, which is an element in plant food, it forms the sulphate of that compound which is capable of being retained in the soil, whereas ordinary ammonia is a volatile gas escaping into the air as rapidly as formed. In general it may be said that the gypsum yields up to the soil a part of its lime in return for potash and magnesia.

Building Materials.—Thirty years ago, before the railroads were constructed through the Fort Dodge region, gypsum was quarried largely for building purposes. Not only were foundations and retaining walls built of it but houses and culverts. Split up into large slabs it also served as flagging for side walks on some of the principal streets. Of recent years comparatively little of the material has been used for constructional purposes. Of the buildings erected of it the most prominent is the Illinois Central railroad station at Fort Dodge; several residences have also been built largely of it. As a facing for building and for cut stone work, it retains its primitive freshness only for a few years, a decade or more perhaps. Generally the exposed surfaces become bleached and finely cracked as in the natural ledges. Notwithstanding this, however, the blocks do not crumble or become parted; and the appearance of the building is unimpaired.

OTHER USES TO WHICH THE IOWA GYPSUM IS ADAPTED.

Besides the uses now made of the gypsum there are many others which might be adopted with advantage.

Deodorizing.—On account of being such a good absorbent of ammonia, gypsum in the powdered state forms an excellent material for destroying the unpleasant odors arising from stables and sewers in cities. It may also be used advantageously in allaying other foul smells.

Cements.—There are a number of ways in which gypsum may be utilized in the manufacture of cements of different kinds. Aside from various high priced cements and mortars, which are used more or less extensively, there are several low priced articles which may be made on a large scale from the poorer grades of gypsum, those which cannot be utilized in the formation of stucco.

The Straub process of manufacturing cements from land plaster is especially adapted to gypsum deposits such as occur in New York. Briefly stated, the preparation of the composition consists of the use of sulphuric or muriatic acid to which is added about four parts of oil or glue to retard the action of the acid. Water and any calcined calcareous base with a little silicate of potash are then added. After drying, it is pulverized and mixed with ten to twenty parts of calcined land-plaster.

Portland and hydraulic cement may be readily made from gypsum. With the excellent qualities of clay associated with the Iowa gypsum, even in the same vertical section, unlimited quantities could be readily and cheaply made in the Fort Dodge area.

Sulphuric Acid.—The process of manufacturing sulphuric acid from gypsum is such that in the preparation of hydraulic cement the acid is collected as a by-product instead of being allowed to go to waste. By this method 1,260 pounds of gypsum and 400 pounds of clay produces 711 pounds of Portland cement and 580 pounds of sulphuric acid. The cost of production of the Portland cement is about the same as usual, but the disposition of the sulpuric acid greatly reduces the real cost.

GYPSUM INDUSTRY.

CHARACTER OF BEDS.

From the description of the gypsum exposures already given, the general character of the beds may be readily inferred. Still, there are other particulars which require further consideration in connection with quarrying. In some of the other localities in the United States where gypsum is known to occur in commercial quantities, the mineral is found in concretionary masses scattered along a particular horizon of a few feet in vertical extent; or in comparatively thin layers interstratified with sediments of various kinds. The gypsum of New York, for instance, is associated with red shales and mixed with considerable impurity. In Ohio, part of the gypsum occurs in small masses imbedded in limestone; part is intercalated with thinly bedded limestones; and part forms a massive bed, the portion chiefly used being only from three to five feet in thickness.

In Iowa, besides the thin sheets of gypsum which are included in the reddish layers at the top of the formation, there is a bed of perfectly massive gypsum over thirty feet thick in places. This main bed has scarcely a parting or separation of sediment or impurity. Vertical cracks a few inches in width traverse the mass at intervals of twenty to fifty feet, but these only facilitate removal. The character of the beds, their disposition and arrangement with respect to the associated deposits, and their freedom from extraneous sediments and other impurities, make them especially valuable in whatever way they may be used. So far as Nature can do it the cost of getting out the material is reduced to a minimum.

EXTENT OF DEPOSITS.

Recognizing the excellent character of Iowa gypsum, it becomes a matter of considerable interest and importance to determine, approximately at least, both the areal and vertical extent of the beds, and the amount of material that is practically available. While, as already said, the deposit is variable in thickness, ranging from a few feet to upwards of thirty feet, it is not an unusual thing to find the maximum measurement exhibited in numerous sections. Most of the many exposures show the mean vertical measurement of the gypsum, so that it would probably be no over estimation to place the average thickness of the entire bed at sixteen feet.

Although a part of the gypsum has been removed through the erosion of the Des Moines valley and its tributary ravines, and a still larger portion has been carried away through solution since its original deposition, there yet remains an amount which is sufficient to supply all demands for many years to come.

Careful mapping of the gypsum area, accurate measurements of the outcrops, and comparisons of boring records have enabled the areal extent of the deposits to be made out with considerable detail. In making the various estimates regarding the quantity of material which is available, all figures are low, so that a wide margin is left, which will amply make up for any minor discrepancies in the calculations.

The amount of good gypsum which different parts of the field will yield is of course variable. In the thinner portions only 10,000 or 20,000 tons to the acre can be relied upon; on an average the yield would be probably in the neighborhood of 50,000 tons for the same area; while at those points where the best sections are exposed, with the bed thirty feet and over in thickness, the number of tons per acre would be nearly 100,000.

By reference to the accompanying map (plate xxi) the known areal extent of the gypsum (represented by the green color) will be seen to be in the neighborhood of forty-five square miles. But this doubtless is not one-half of the entire deposit. On the basis of the average thickness the total amount of available gypsum on the area represented by the map is something more than 40,000,000,000 tons. At the present rate of production it would require not less than 800,000 years to exhaust it. Although the present condition of the industry appears to be quite flourishing and important no adequate idea of the immense actual extent and value of the Iowa gypsum deposits can be acquired without making some comparison of what is now being done with what a full development would make possible.

AVAILABILITY.

The conditions for obtaining the gypsum are exceptionally favorable. Instead of its being necessary to mine the mineral, or in quarrying it to remove large quantities of hard rock, only a soft, incoherent covering is present. This covering, though sometimes thirty to sixty feet thick, is easily disposed of since the position of the gypsum high up in the hills enables it to be reached readily. At the present time the stripping is done by scrapers after the manner of ordinary highway work. Introduction of hydraulic apparatus for the removal of the drift material overlying the gypsum would greatly facilitate stripping, and at the same time very materially reduce the cost. Carefully made estimates indicate that the removal of the covering of the gypsum could be accomplished at somewhat less than one-fifth of the present expenditure for this purpose. The deep gorges and ravines which intersect the region in all directions, especially near the principal water course, with the gypsum lying high above the creek beds, makes this method of stripping particularly commendable.

The gypsum is not only readily removed from the natural bed, but the facilities for transportation are unusually good. Four railway lines give outlets in seven directions with good connections with other systems, affording means of reaching any part of the surrounding country and especially direct connections with all the larger cities of the northwest. These railroads are: the Illinois Central; the Chicago, Rock Island and Pacific; the Minneapolis and Saint Louis, and the Mason City and Fort Dodge.

PRODUCTION.

The production of gypsum has rapidly increased during the last few years, nearly all of the amount quarried being converted into stucco. In the manufacture of plaster of Paris Iowa ranks second, and in the total production of gypsum, third, among the states of the Union. According to the report of the Eleventh Federal Census the total production of the United States for 1889 was as follows:

STATE.	TONS.	VALUE.
Michigan	131,767	$373,740
New York	52,608	79,476
Iowa	21,784	55,250
Kansas	17,332	34,235
Utah	16,000	25,000
Ohio	9,920	51,491
Colorado	7,700	28,940
Virginia	6,838	20,336
California	3,000	30,000
Wyoming	500	3,000
Total	267,769	$764,118

Since the above statistics were taken the output of the gypsum in Iowa has more than doubled, and it is reported that it has increased to something over 50,000 tons per annum. The stucco forms the largest proportion of the production, very little land plaster being made.

Aside from the local use of gypsum as a building stone, from ten to a dozen carloads are annually shipped to the western points in the state.

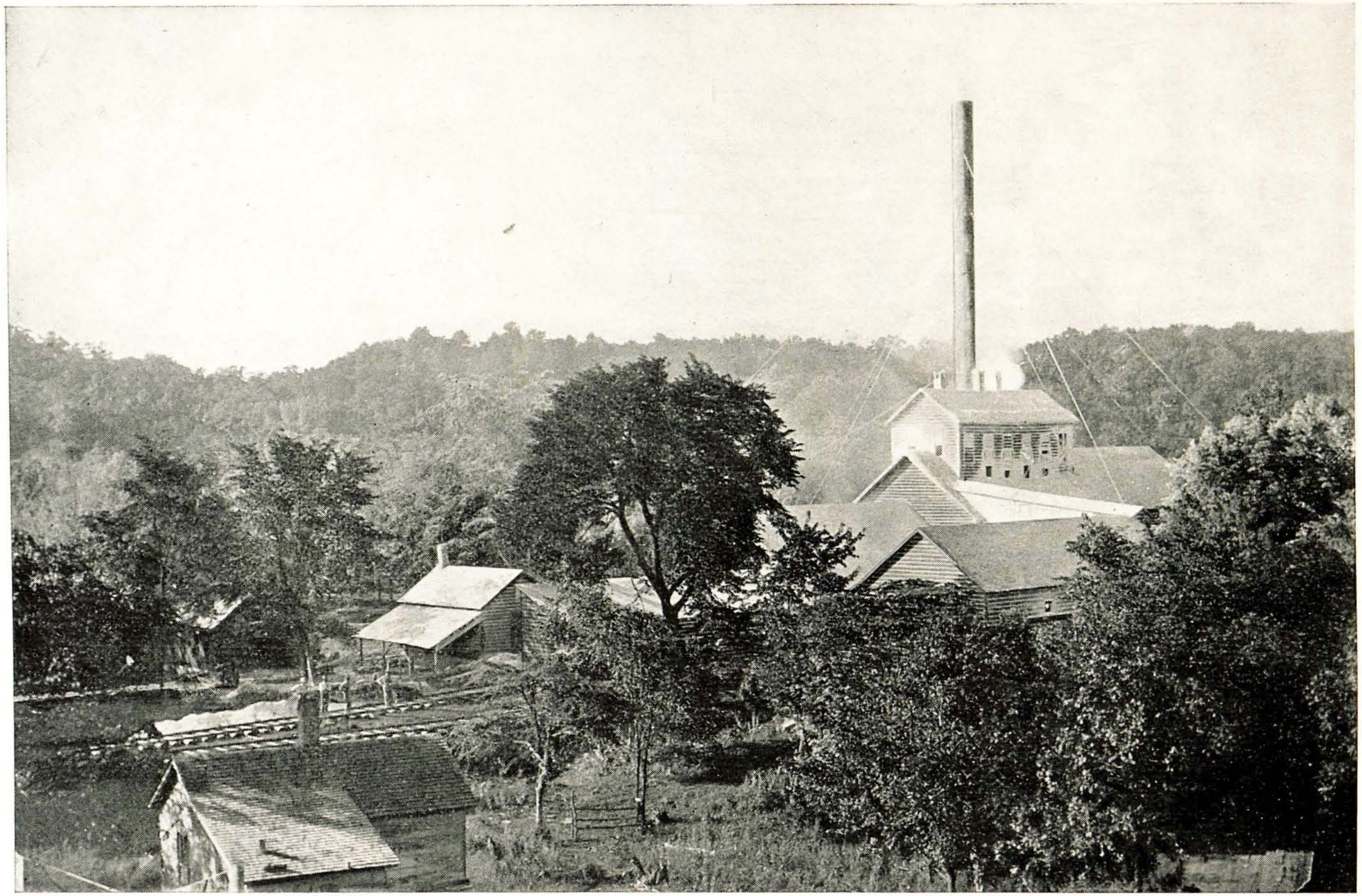
MARKETS.

The gypsum product of Fort Dodge supplies a wide market. The plaster of Paris manufactured finds ready sale all through the northwest, and goes as far south as Tennessee. Most of the small amount of land plaster made goes to Wisconsin, where it is distributed chiefly from Milwaukee.

MILLS AND METHODS.

The gypsum mills are four in number. Three of them are situated three to four miles south of Fort Dodge, on the Minneapolis and Saint Louis railroad. The fourth is only a short distance away, on the Illinois Central railroad. The mills consist of: (1) Large sheds where the gypsum blocks are piled as they come from the quarry; (2) the mills proper, which are tightly closed buildings containing all the machinery, boilers and kettles; and (3) storage sheds which are rather open structures, but protecting the stucco effectually from the weather until shipment. All the mills have private switches from the railroad, so that the coal used is brought in and unloaded directly in front of the furnace openings, and the output is loaded from the storerooms. (Plate xxv.)

The gypsum is quarried in the same manner as ordinary building stone. The stripping, which is from ten to fifty feet thick, is removed by iron grading scrapers, each worked by two horses. The covering is removed for a considerable distance, and the upper surface of the gypsum made as clean as possible. The immediate quarry faces are not very large, usually not more than fifty or sixty feet across, though several of them may be driven forward close together in a single ledge. A number of holes are made near the edge of the ledge by means of ordinary hand drills, and large masses blasted from the bed. Further breaking for ready handling, into sizes about as large as paving blocks, is accomplished by means of sledges. The material is then loaded on wagons and transferred to the sheds near the crusher, where it accumulates in large piles. The blocks are then fed to the crusher, which consists of a heavy steel jaw working horizontally against a large thick anvil, allowing the small fragments to drop beneath. After passing through the crusher the small gypsum fragments are conveyed to the grinder, modeled after flouring buhrs, but somewhat coarser. Coming out as a flour-like product, it is carried to the kettles, which are large iron vats under which heat may be applied, and which hold about six tons. Here the gypsum



DUNCOMB GYPSUM MILL.

is heated or "boiled," by which process the water is driven off. The heating process takes about one and one-half hours, and the filling of the kettles about as much more time. Considerable fine gypsum goes off with the steam, and passing up the tall smokestack spreads out and settles upon every object within a radius of a quarter of a mile. The mills, sheds, trees and ground have the appearance of being covered with snow, forming in summer time a very striking effect. After "boiling" sufficiently the stucco is allowed to cool, and is transferred to barrels or bags and made ready for shipment.

Several years ago an improved method of calcining the gypsum was patented for the Fort Dodge Gypsum-Stucco Company. It is known as the Marsh process.

Previously gypsum or plaster had been calcined by placing the material in a metallic vessel, which was provided with flues extending upwardly from different points in its bottom or horizontally from different points in its sides, to heat the plaster in the body of the kettle. The kettle or vessel was heated by fire built beneath and about its bottom in the usual way. This process was liable to several objections. First, it was expensive, because the bottoms of the kettles were costly, and as they burned out rapidly, required frequent replacing by new ones, occasioning much expense as well as loss of valuable time; secondly, the process was wasteful, owing to leaks through the bottoms, which frequently and unavoidably cracked when the kettle was full of plaster and under a full head of fire, thus causing much loss of plaster as well as delay for repairs; thirdly, the process was generally unsatisfactory, for the reason that it was impossible to maintain uniformity of heat in boiling kettle after kettle, or in several kettles run at the same time, which resulted in giving a product differing in quality according to the difference or irregularity of heat with which it was treated.

The object of the new method was to overcome the defects mentioned, to secure perfect uniformity in the application of heat, and in the quality of the product, as well as generally to improve the method of calcining gypsum.

The invention consists essentially in employing steam to expel the water from the gypsum and reduce it to a friable state, and in the construction and arrangement of a mechanism by which this result is accomplished. The apparatus embraces a kettle with an agitator and coils of pipe instead of a steam jacket about its inside.

The kettle which may be of any desired size, but preferably six or seven feet high and about eight feet in diameter, is provided with a bottom, concavo-convex in form, riveted to its sides. A continuous steam jacket is formed in the bottom and sides of the kettle by a casing or cylinder extending to a point near the top of the kettle and firmly secured at intervals thereto by bolts. The casing also is provided with a bottom fashioned to correspond to the outer bottom and riveted to the casing in a similar manner. There is an inner jacket having about half the diameter and extending about two-thirds the height of the outer jacket. It is supported a short distance above the floor or bottom of the kettle by four flanged feet or standards which are secured to the floor by screw bolts. A steam pipe, the outer extremity of which may be connected to any ordinary boiler or other source of supply, and passed through the furnace where it is lapped or otherwise bent to expose the required extent of surface to the action of the heat, enters the jacket at the bottom of the kettle. A cock or valve in the pipe serves to regulate the flow of steam to the kettle. A short connecting-pipe, with its ends turned in opposite directions, has one extremity entering the inner jacket immediately behind or within one of its standards, and the other end penetrating the bottom jacket at the side of the standard. A section of straight pipe answers fully as well to establish communication between the jackets. An exhaust or drip-pipe extends from the bottom of the kettle through the jacket, and the jacket likewise is provided with a drip-pipe entering the bottom of the kettle near its outer edge. Both pipes are furnished with suitable cocks to control their action. A discharge-pipe, which extends through the jacket to the interior of the kettle, is provided with a valve having a rod and wheel-handle for opening and closing. This rod is made of considerable length to avoid contact with the intense heat about the kettle. In the bottom of the kettle is a shaft having a bearing of any suitable form. To it is secured an agitator, consisting of a crosshead carrying hangers, which are connected to a crossbar secured on the lower end of the shaft. The hangers serve to agitate the gypsum in the space between the two jackets, while the crossbar moving over the bottom, serves a similar purpose within the inner jacket. The top or cover of the kettle is provided with a door, through which the gypsum is introduced, and a flue or pipe, for carrying off the vapor generated in the calcining process. Notches are formed in the top of the kettle, in which are placed wooden or metal bars to aid in supporting the cover.

In operation the steam passing through the supply-pipe is superheated by the furnace to any desired degree, the measure of which may be determined by a thermometer or other appliance, and entering the outer jacket in the bottom of the kettle, is equally distributed by its own pressure to all parts of the jacket, and to the interior of the inner jacket, through a pipe. By this means is obtained not only the amount of heat required to calcine the gypsum under treatment, but a control to its quantity and degree, whereby uniformity of heating and of the quality of the product are easily and certainly secured.

There is a modification of the structure just described in which the coil of pipe is arranged on the inside of the kettle instead of the side jacket, the pipe, connecting with the bottom jacket at the side and coiling downward, has a discharge or drip extending through the kettle near its bottom. A further modification contains two, instead of one, inner jackets. If it should be found that the gypsum in the body of the kettle does not dry as rapidly as that which is more exposed about the sides, two or more interior jackets may be employed; but one is deemed sufficient for a kettle the size mentioned. In other respects the construction of the modifications is the same as that described at first. It is not absolutely essential that the steam should be superheated, as fair results may be obtained by using steam directly from a boiler; but superheating improves the strength and quality, and makes it thoroughly effective to do this work.

GEOLOGY OF LEE COUNTY.

BY

CHARLES ROLLIN KEYES.

ECONOMIC GEOLOGY OF LEE COUNTY.

BY CHARLES ROLLIN KEYES.

CONTENTS.

INTRODUCTION.

AREA AND LOCATION.

Lee county occupies the extreme southeastern corner of Iowa. In shape it is very irregularly trapezoidal, with an acute angle extending in a southeasterly direction and forming the southernmost point of the state. Three-fourths of its boundary is made up of large streams, which separate it from the two states of Illinois and Missouri on the east and south. It thus holds a somewhat isolated position geographically, as compared with the other counties of the state. The entire eastern border is washed by the great "Father of Waters." Northeastward the Skunk river forms the boundary between it and Des Moines county. On the west flows the Des Moines river. Van Buren and Henry counties bound the northwest quarter of the district. The greater portion of Lee thus lies in the apical portion of the broad triangular area lying between the Des Moines and Mississippi rivers. The total area is a little more than 500 square miles.

PREVIOUS WORK.

Although considerable geological investigation has been carried on in Lee county during the past forty years, it has been carried on chiefly in the interest of pure science. The results have been incorporated mainly in short papers which are now widely scattered through perodicals and official reports of other states. No systematic examination of the county's mineral possessions has heretofore been made.

Among the early workers who visited this region was Dr. D. D. Owen, who under the auspices of the Federal land office, undertook to study the mineral lands of the northwest during the years 1847–1850. To him must be credited the honor of giving to the scientific world the first accurate accounts of the geology of the region. In 1858 A. H. Worthen, afterwards State Geologist of Illinois, made a hurried reconoissance of the county and his brief description is given in Professor James Hall's report. Twelve years later appeared Dr. C. A. White's geological account of the state. The references made in this report to the geology of this part of Iowa are brief and very general in character.

During the past few years several important papers on the geology of the region about Keokuk have appeared, but they are strictly scientific in their bearing and discuss problems of wide geological interest.

The formations exposed within the limits of the county are geologically among the most interesting occuring in the Continental Interior. The sections along the Mississippi river between Keokuk and Burlington have become classic in the annals of geological science. They were the starting point for the classification of the great series of Lower Carboniferous limestones throughout the entire Mississippi basin. It was in southeastern Iowa that these rocks were first defined and described according to modern geological methods. From this locality the strata have been traced with scarcely a break into the northcentral part of the state. They stretch out in an irregular zone southward to the mouth of the Missouri river, where a branching takes place, one arm passing westward around the Ozark uplift and continuing to the southwest far into New Mexico; the other arm extending eastward and southeastward through Illinois, Indiana, Kentucky and Tennessee into central Alabama. Thus even from a historical standpoint the rocks of Lee possess much more than ordinary interest.

PHYSIOGRAPHY.

SURFACE RELIEF.

Lee county occupies an elevated plateau whose surface, for the most part, is gently undulating or rolling. This broad general plain continues without serious interruption nearly to the margin of the area. There it suddenly drops a couple of hundred feet or more to the water-level of the bounding streams. This marginal declination is so abrupt, that there are formed on all sides steep declivities, often running into bold mural escarpments with prominent salients. Everywhere in the immediate vicinity of the plateau border, steep-sided ravines and deep gorges have been cut. In these the torrential water-courses dash along in their narrow beds, breaking here and there into foaming rapids or miniature falls and cascades. A short distance back all these rivulets flow gently along in broad valleys, their respective drainage basins forming shallow swales in the general upland surface. Broadly speaking, the district then, may be said to be characterized by the plain level and the forms impressed upon it by post-glacial erosion. This is not strictly true, however, as a careful consideration of the phenomena presented show that the present drainage is in large part dependent upon conditions ante-dating the glacial period. Viewed in a broad way the area comprises two wide, shallow troughs trending and sloping southeast. To the northwest these depressions merge into the general level of the plain itself. The axis of the more northerly of these troughs is occupied by East Sugar creek and its branches; the other by the West Sugar. The narrow divide separating the two basins terminates at the high salient overlooking the Mississippi, known as "Keokuk Point." The line of the Keokuk and Northwestern railroad closely follows this ridge.

The area between the East Sugar and Skunk river is trenched for a part of the way by Lost creek; while a similar irregularly elevated district constitutes the divide between West Sugar creek and the Des Moines river. These plateaus represent the portions remaining of the original gently southward sloping plain upon which the present more or less incised topography has been impressed.

Along the Des Moines river the narrow valley is bordered for the most part by steep bluffs, intersected by small ravines, with abrupt, widely branching, dentritic systems and short, steep, V-shaped trenches. A similar topography prevails between Montrose and Keokuk along the Mississippi. Above Montrose the bluffs are destitute of rock exposures and, while generally high and steep, are characterized by the rounded contours so common to drift regions. So also the absence of rock between Sand Prairie and the mouth of the Des Moines is marked by similarly rounded bluff outlines.

The profile (plate xxvii, figure 1) along the line of the Keokuk and Northwestern railroad expresses the general southeastward slope of the plateau. In approaching Keokuk the railroad leaves the divide and follows the valley of Soap creek. The continuation of the plateau is indicated by a dotted line. A second profile transverse to the last shows the manner in which the plateau has been intersected by the drainage systems (plate xxviii, figure 1).

The highest place in the county is West Point, which has an elevation of 758 feet above tide; the next highest is Big Mound with an elevation of 748 feet. Lacrew which stands on the main divide almost directly between these points has an elevation of only 709 feet. It is evident, therefore, that there is a very considerable depression between the two points.

The accompanying table of elevations gives the most reliable estimates derived from all records available. Discrepancies at numerous places have been found in the data at hand, but care has been taken to eliminate all the errors possible:

Table of Altitudes in Lee County, Iowa.

LOCALITY.	ABOVE LOW WATER LEVEL AT KEOKUK.	ABOVE SEA LEVEL.	AUTHORITY.
Arygle	191	668	C., S.F. & C. RR.
Belfast	68	545	Des Moines Valley RR.
Big Mound	271	748	Barometer.
Charleston	217	694	K. & NW. RR.
Cottonwood	236	713	C., Ft.M. & DM. RR.
Croton	73	550	Des Moines Valley RR.
Donnellson	219	696	K. & NW. RR.
Fort Madison:			
Low water level	25	502	Mississippi River Com.
C., S.F. & C. RR	40	522	C., S.F. & C. RR.
Franklin	219	699	C., B. & KC. RR.
Galland (Nashville)	30	507	U. S. P. B. M.
Keokuk:			
Low water level	0	417	Mississippi River Com.
Union Depot	28	505	St.L., K. & NW. RR.
Hubinger well	160	637	City Water Works.
Fourteenth & Grand Ave	178	655	City Water Works.
Lacrew	232	709	K. & NW. RR.
Mount Clare	202	679	K. & NW. RR.
Mertensville	231	708	C., Ft.M. & DM. RR.
Montrose:			
Depot	46	513	St.L., K. & NW. RR.
Low water	23	500	Mississippi River Com.
New Boston	212	689	K. & NW. RR.
Pitman	237	714	C., Ft.M. & DM. RR.
Pilot Grove	168	645	C., Ft.M. & DM. RR.
RR. Crossing (near Mertensville).			
C., Ft.M. & D.M. track	209	686	C., Ft.M. & DM. RR.
K. & NW. track	223	700	K. & NW. RR.
Sawyer	234	711	C., Ft.M. & DM. RR.
Saint Paul	166	643	C., Ft.M. & DM. RR.
Sand Prairie	76	553	Des Moines Valley RR.
Sandusky	29	506	St.L., K. & NW. RR.
Sugar Creek:			
East, on RR. bridge	56	526	C., B. & KC. RR.
West, on RR. bridge	146	623	C., B. & KC. RR.
Summitville	193	670	K. & NW. RR.
Viele	56	533	C., B. & KC. RR.
West Point	281	758	C., Ft.M. & DM RR.
Warren	226	703	C., B. & KC. RR.
Wever	65	542	St.L., K. & NW. RR.

In the lower portion of their courses alluvial plains always border the smaller streams. On the Mississippi, however, the river bottoms have an important development at two points only, one being in the triangular area between the mouth of the Skunk river and Fort Madison, and the other in the crescent-shaped tract between Montrose and the great lobe of drift which, a short distance above Fort Madison, meets the river in almost vertical bluffs one hundred and fifty to one hundred and eighty feet in height. The more northerly of these alluvial districts comprises nearly the whole of Green Bay township; while the other includes a large part of Jefferson township and a small part of Montrose. Near the river the plains are low and wet, intersected by numerous sloughs and subject to overflow during the stages of high water. Farther away the surface rises in a series of sand terraces to a height of about fifty feet, where it meets the bluffs on the west. In both areas three or four well marked terraces occur, each varying from five to fifteen feet in height. In the upper plains these embankments converge toward the south; while in the lower they are approximately parallel and correspond in direction to the crescent shaped outlines. These terraces represent the flood water stages of the river in times somewhat remote, yet subsequent to the deposition of the drift which once covered the area and which was removed by the river in the process of widening its valley.

Another plain exactly similar in character to those already described and evidently having the same origin, occurs at Sand Prairie on the Des Moines. Above this point on that river and below Montrose on the Mississippi, the streams flow in comparatively narrow channels, bounded by more or less abrupt rock escarpments which rise directly from the water's edge.

DRAINAGE.

The drainage of the county passes through three important rivers, one of which finally receives the waters of the other two. They are the Mississippi, the Skunk and the Des Moines. Together they form more than three-fourths

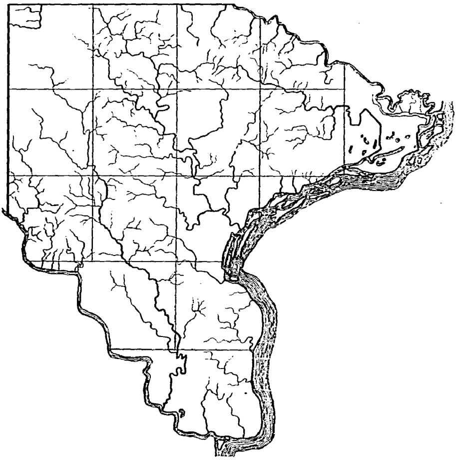


Figure 14. Sketch Map of Lee County, showing Drainage.

of the boundary line of the district. The immediate drainage areas of the bounding streams is relatively very small, and is accomplished by means of numberless short rivulets which cut the margin of elevated upland or plateau. Almost the entire drainage of the area is effected by three creeks, all of which rise near the extreme northwestern corner of the county.

Mississippi River. This stream passes along the entire eastern edge of Lee, in a southwesterly direction or nearly at right angles to the direction of the general drainage slope. Except at two points, below Fort Madison and east of Wever, it flows in a rock-bound gorge, having almost perpendicular walls. The fall of the river between Fort Madison and Keokuk is twenty-five feet, or an average of about one and two-thirds feet per mile. From Fort Madison to Montrose, however, there is a fall of but two feet, so that the greater part of the descent takes place in the nine miles from Montrose to Keokuk where the stream passes over the chert beds at the top of the Burlington limestone. This gives an average of a little more than two and one-half feet per mile, between the two points last mentioned.

Des Moines River. For more than one-half its distance in Lee county the Des Moines river like the Mississippi flows in a narrow gorge-like valley, with little or no flood plain. Towards its mouth, however, the stream meanders through the broad bottoms of the Mississippi which abruptly begin to appear a few miles below Keokuk. The river flows in a southeasterly direction, its course coinciding closely with that of the general drainage of the entire area. The small rivulets emptying directly into it seldom reach very far back into the interior, rarely more than three or four miles. The Des Moines river between Farmington and its confluence with the Mississippi, has a fall of about forty-eight feet, or an average of about one and three-fifths feet per mile.

Skunk River. The third most important water-course is the Skunk river which has a general southeastward course parallel to the Des Moines, and like that stream drains a very narrow belt of territory.

Interior Streams. As already stated the county is drained chiefly by three large creeks. The principal one is Sugar creek in the western part. It flows into the Des Moines a few miles above the mouth of the latter.

West Sugar creek is marked throughout its course by rounded, drift-covered slopes. Its channel is confined entirely to the drift, in which it has cut a rather wide trench usually with steep banks. In the upper part of its course the stream flows southeastward, approximately parallel to the Des Moines river, but when it meets the small branch rising near Mount Clara it turns abruptly southward into the Des Moines. The fact is significant, for the small branch is developing its channel in the clays filling an old trench of the Mississippi, while the main stream is making a comparatively feeble like effort to revive an old channel of the Des Moines.

East Sugar creek takes its rise in the southeastern part of Henry county, flows southeastward and discharges its waters into the Mississippi about midway between Fort Madison and Montrose. In the upper part of its course it flows over glacial deposits, but penetrates these in the southeastern part of Marion township, exposing the underlying Coal Measures and Saint Louis limestone, the latter as far down the stream as the southern part of West Point township. The irregularities in different beds of the formation have caused more or less abrupt deflections in the course of the main stream and its tributaries in this part of its course. This feature is easily recognized on the map and thus becomes an index to the uneven character of the rocky floor.

Lost creek is smaller than either of the two just mentioned. Its course is near the Skunk river and parallel to it. The other minor creeks flowing eastward into the Mississippi are Jack, Lamelee, Price and Soap; those emptying into the Des Moines are Lick, Mumm and Monk; all of which are quite small. The parallelism and southeasterly trend is a very marked feature in the streams of Lee county and evidently is but an expression of the general drainage slope of southeastern Iowa.

STRATIGRAPHY.

Geological Relations of Formations.

The rocks of Lee county consist of (1) a series of more or less evenly and regularly bedded deposits comprised chiefly of limestone, sandstones and shales, and (2) a mantle of incoherent clays and sands which covers the harder beds.

The stratified, or indurated, rocks are almost entirely Lower Carboniferous limestones. These form the great basement upon which the Coal Measures of the region were laid down. Although lying on the extreme eastern margin of the western interior coal field and having the basal limestones exposed over a large part of its surface, there are in Lee county several areas, in the aggregate of considerable size, which are occupied by Coal Measure strata.

All the bedded rocks have been subjected to profound erosion which has carved out deep channels and numberless minor depressions. Over this uneven surface the glacial materials have been spread, obscuring in great part the harder rocks. Subsequent action of running waters has cut through the drift mantle and laid bare the underlying strata at many places.

The general scheme of classification of the geological formations exposed within the limits of the county is shown in the accompanying table:

GROUP.	SYSTEM.	SERIES.	STAGE.	FORMATION.
Cenozoic	Pleistocene.		Drift.	Terrace. Loess. Till.
Paleozoic.	Carboniferous	Coal Measures.	Des Moines.	Basal sandstone and shales.
		Lower Carboniferous. (Mississippian)	St. Louis.	Concretionary and brecciated limestones.
			Augusta.	Warsaw shales. Geode shales. Keokuk limestone. U. Burlington limestone. L. Burlington limestone.
			Kinderhook.	Shales.

General Section.—The total thickness of the rocks exposed above low-water level in Lee county is not far from 400 feet, though the actual vertical measurement of an outcrop at any one place is probably nowhere more than

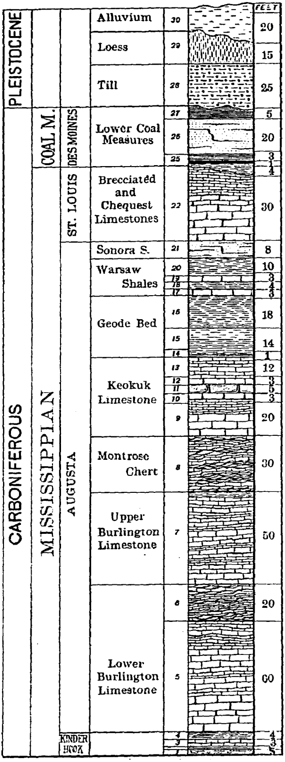


Figure 15. General Geological Section.

one-half of this maximum. Numbers 1 to 5 are best exposed just across the Skunk river, near Patterson station in Des Moines county (section IV); 5 to 9 are well shown at several points on the same stream between its mouth and Augusta (section XVII); 9 to 16 are well exhibited at the mouth of Soap creek (section II); 12 to 27 outcrop in the bluff at the old McGavic mill site (section I); 28 to 30 are found in numerous places capping the bluffs around Keokuk. These several outcrops serve as standards to which all sections in the county may be readily referred; and they may therefore be described more in detail.

Typical Exposures.

STANDARD SECTIONS.

About two miles below the Union depot at Keokuk, in the vicinity of the old McGavic mill, the bluffs are high and almost perpendicular. Here is exposed a nearly complete section of the rocks of the county (see plate XXIX).

I. Bluff Section at Old McGavic Mill.

		FEET.
17.	Drift	30
16.	Shale, gray, clayey	2
15.	Sandstone, ferruginous	1
14.	Shale, black, fissile, filled with small nodular concretions	3
13.	Coal	1½
12.	Fire clay and light colored shale, passing into a coarse, quartzose sandstone, the latter becoming massive and well developed locally; 2 to 6 inches	⅓
11.	Limestone, brecciated, fragments small and large, with interstices filled with green clay; varies in thickness from 10 to 30 feet	20
10.	Sandstone, massive, blue, calcareous, weathers brown; quartz grains more or less angular, and sometimes large, approaching the size of small pebbles; quarried at several places	8
9.	Shale, blue, argillaceous	10
8.	Limestone, coarse, encrinital, gray, quite fossiliferous, not persistent	3
7.	Shale, blue, argillaceous; becomes somewhat friable on weathering	4
6.	Limestone, blue and brown, magnesian, irregular in development 2 to	3
5.	Shale, argillo-calcareous, breaking down readily to a yellowish clay. No geodes at this point, but abundant farther north	18
4.	Shale, calcareous, with bands of chert, and irregular layers of thin-bedded, gray limestone, which are increasingly prevalent towards the base	14
3.	Shale, blue	½
2.	Limestone, blue, encrinital, coarse grained, composition and stratification somewha variable, nodular chert in considerable quantity	12
1.	Limestone, blue, encrinital, black impressions of *Orthis keokuk* abundant; "White Ledge" of quarrymen 3 to	4

The members of this section may be grouped geologically as follows:

	FEET.
Pleistocence (No. 17)................................	30
Lower Coal Measures (12 to 16 inclusive ; 23 to 27 general section)................	10
Saint Louis (10 and 11 ; 21 and 22 general section)....	28
Augusta : Warsaw formation (6 to 9 ; 19 to 20 general section)..	20
Geode Shales (3 to 5 ; 14 to 16 general section).. ...	30
Keokuk limestone, proper (1 and 2 ; 12 and 13 general section).....................	66

The base of the section is the track of the Chicago, Rock Island & Pacific railroad which is here about thirty-five feet above the level of the Mississippi river at low water. One mile above this place near the mouth of Soap creek there is shown the following section in which three of the beds lying below the base of the previous section are given.

II. Section at Mouth of Soap Creek.

		FEET.
7.	Shale and chert..................................	6
6.	Shale, calcareous, with intercalated beds of limestone ; some geodes....	8
5.	Limestone, drab, impure, heavily bedded, shaly below.........................	12
4.	Limestone, light colored, with nodular masses of chert ; the "White Ledge".....................	3
3.	Limestone, argillaceous and massive, or massive, calcareous shales ; with subspherical massess of calcite, sometimes carrying millerite...........5 to	6
2.	Limestone, coarse, gray, encrinital ; with much chert...........	3
1.	Limestone, with chert in irregular beds (exposed)..	5

The section given discloses the strata which are exposed above the water level of the stream. In regard to the character of the rocks below the level of the river it is of interest to note the results of sinking several deep wells which have recently been put down at Keokuk to depths of nearly 2000 feet beneath the base of the exposures mentioned and over 1150 feet below sea level.

The record of the Hubinger well especially, was very carefully kept by Mr. C. H. Gordon. The list of beds passed through and their probable position in the general geological section of the state are given below.

III. Record of Hubinger Well, Keokuk.

		THICKNESS.	DEPTH.
19.	Clay and sand, boulder clay below Pleistocene	28	28
18.	Limestone, (Saint Louis)	5	33
17.	Sandstone	5	38
16.	Limestone, (Augusta, 12 to 16)	12	50
15.	Shale	58	108
14.	Limestone	62	170
13.	Shale	10	180
12.	Limestone	110	290
11.	Shale, (Kinderhook, 10 and 11)	65	355
10.	Limestone	10	365
9.	Shale, (Devonian, 7 to 9)	195	560
8.	Limestone, shaly	65	625
7.	Sandstone, (water)	20	645
6.	Limestone, sandy in part (Upper Silurian, 5 and 6)	55	700
5.	Sandstone, (water)	37	737
4.	Shale, (Lower Silurian, 1 to 4)	63	800
3.	Limestone, arenaceous in lower part	140	940
2.	Sandstone, fine, white	110	1050
1.	Limestone, alternating with sandstone, chips carried away by water	755	1805

The correlation of certain of the above formations is evident. Number 2 doubtless is the Saint Peter sandstone. Four may represent the Maquoketa shales. Ten appears to be the northward attenuated extension of the Louisiana limestone of Missouri. Eleven seems to be the shales of the Kinderhook, so well exposed at Burlington;

in Missouri the median member or Hannibal shale. The lower part of 14, together with 12 and 13 probably corresponds to the Burlington; while 15 and 16, and the upper part of 14 represent the Keokuk. Eighteen forms the lower part of the Saint Louis.

MISSISSIPPI RIVER SECTIONS.

Along the Mississippi river (see plate xxvii, figure 2) natural exposures are almost continuous from Keokuk to beyond Augusta, so that the entire eastern border of the county from the mouth of the Des Moines, at the extreme southern point of the district to the north county line on Skunk river, may be regarded as open to view above the water level. The two leading Keokuk outcrops, the one at the old McGavic mill and the one at the mouth of Soap creek, have already been noticed. In the latter section there often exists between numbers 2 and 3 lenticular layers which bear numerous forms of fossils, chiefly crinoids. In some cases the decomposition of beds 3 and 4 exposes large numbers of the fragmentary remains of brachiopods, particularly *Spirifera keokuk* Hall. Two constitutes the base of the Geode shale. In the two sections mentioned there is shown nearly the full thickness of what has been widely known as the Keokuk group. The limestone formation fully shown in the second (II) of the two sections has a total thickness of about twenty-five feet. The upper part is well exposed along the bluff between this point and the Union depot as well as between Soap creek and the mouth of the Des Moines river. The base of the Keokuk limestone is here somewhat below the level of the railroad track. A gradual descent of the beds to the north brings the Geode bed nearly to the level of the railroad track above the lower lock of the canal,

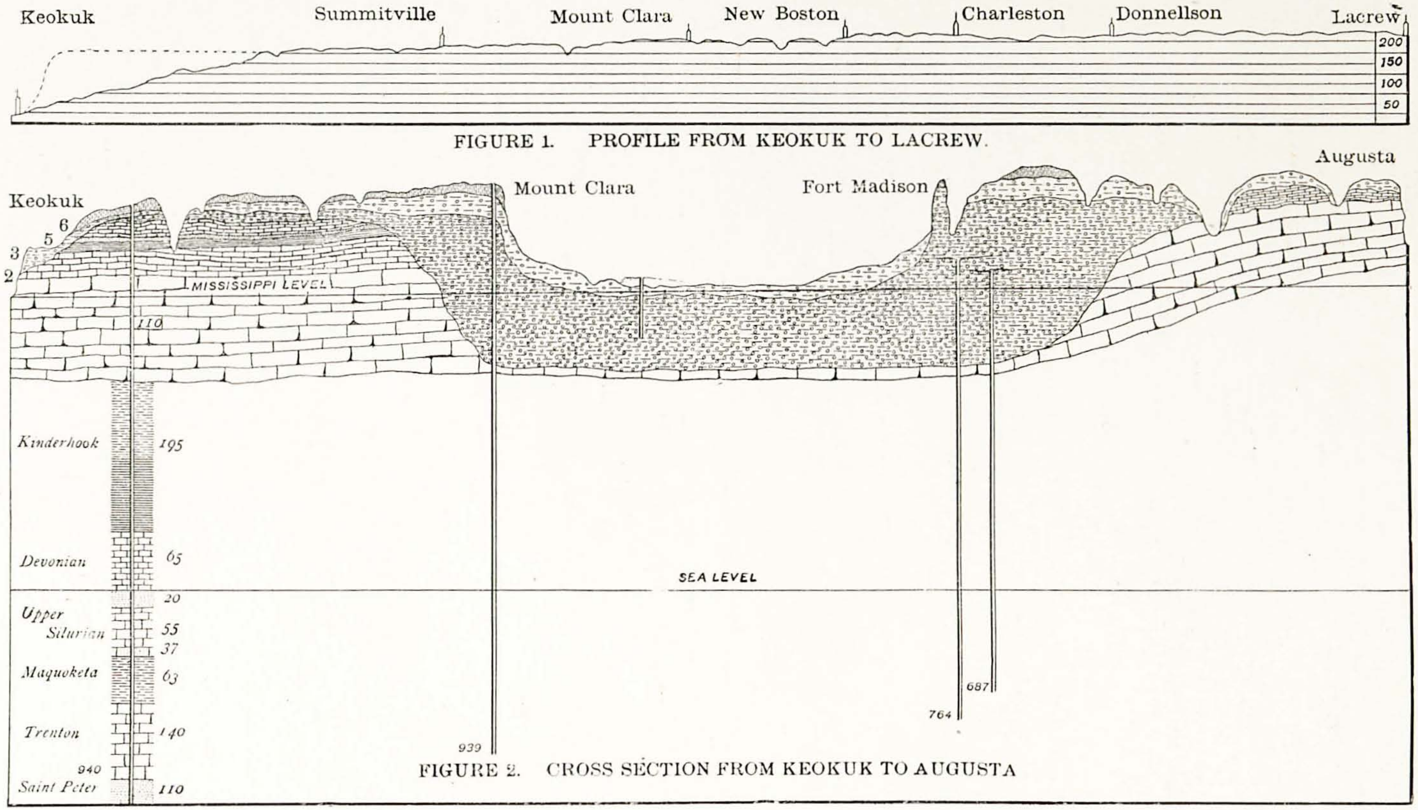


FIGURE 1. PROFILE FROM KEOKUK TO LACREW.

FIGURE 2. CROSS SECTION FROM KEOKUK TO AUGUSTA

GEOLOGICAL CROSS SECTIONS IN LEE COUNTY.

but this does not seem to continue very far, as the top of the Montrose cherts is five to fifteen feet above water level all the way to Montrose.

The rocks exhibited in section II are exposed on Soap creek for some distance above its mouth, as are also the overlying rocks in ascending order. About one-half mile above, near Twelfth street, there is presented:

VII. Soap Creek, near Twelfth Street, Keokuk.

		FEET.
6.	Unexposed	10
5.	Shale, blue, clayey 3 to	5
4.	Limestone, magnesian, blue; weathering to brown; thin band of chert at middle	5
3.	Shale, calcareous, but readily breaking down upon exposure; geodes numerous, generally small and thin shelled	20
2.	Shale, calcareous, massive; breaks down less readily; cherty above, geodes larger	20
1.	Limestone, gray (exposed)	1

Numbers 4 and 5 constitute the basal part of the Warsaw formation, while 2 and 3 represent a maximum development of the Geode shales. About one-half mile above this locality number 4 is quarried; and a little distance beyond, near a cooper shop, the upper shales of the Warsaw, which are exposed by stripping, are used for the manufacture of brick at the Hubinger Brick Works. On the south of the creek, below the cooper shop, the following arrangement was determined:

VIII. Soap Creek, west of Cemetery, Keokuk.

		FEET.
7.	Concealed	5
6.	Limestone, brecciated (exposed) 5 to	10
5.	Shale, bluish, partly concealed	15
4.	Limestone, coarse, sub-crystalline; largely composed of fragments of Fenestellids, crinoid plates and brachiopods	3
3.	Shale, argillaceous 5 to	6
2.	Limestone, blue, magnesian	3
1.	Shale, calcareous, with geodes	10

Numbers 2, 3 and 4 constitute the base of the Warsaw, the upper part of which is here concealed. The following fossils were obtained from 4:

Spirifera lateralis, Hall.
Spirifera subcardiformis, Hall.
Spirifera pseudolineata, Hall.
Archimedes wortheni, Hall.
Polypora spinninodata, Ulrich.
Polypora varsovenis, Ulrich.
Lioclema punctatum, Hall.

The Hubinger well section which is important in the present connection is given in another place (section III).

A short distance above Rand park there is an exposure showing in an excellent way the juncture of the Saint Louis limestone with the basal sandstone of the Coal Measures. The sandstone is about fifteen feet thick and rests upon the unevenly eroded surface of the brecciated limestone (see plate XXX; also figure 18). A ravine intersects the bluff at this point showing, towards the west, a replacement of the sandstone, in part at least, by shales, fire clay and coal. At the same time the brecciated limestone becomes thicker apparently causing the sandstone to thin out somewhat in that direction. Beyond this point, so far as Montrose, exposures are frequent in all the ravines and along the creeks which intersect the bluffs. The Coal Measure rocks do not appear to extend continuously over the area but are represented by small isolated basins similar to that seen near Galland. They are likewise exposed at the Sonora quarries on the opposite side of the Mississippi river where they rest unconformably upon beds of brecciated limestone and the sandstone member beneath.

From Montrose to a point above Fort Madison the exposures occurring along the west side of the river are chiefly of drift. At the latter place the following is given:

IX. Bluff Section at Fort Madison.

		FEET.
4.	Soil	4
3.	Loess	30
2.	Clay, yellowish-brown, with pebbles and small boulders; "yellow boulder clay"	50
1.	Clay, as above, but dark colored; "blue boulder clay" (exposed)	100

East of the town about four miles (Tp. 68 N., R. III W., Sec. 32, SE. qr.) a limited exposure of Burlington limestone is said to occur near the river. Directly north of Wever station at the low salient jutting out at the confluence of the Mississippi and Skunk valleys the Lower Burlington limestone is well exposed and a quarry opened there. Immediately west of the same station (Tp. 68 N., R. IV W., Sec. 12, NW. qr., SE¼) a similar sequence is shown at the Lange quarry. It is evidently the Burlington limestone.

X. Section in Lange Quarry, west of Wever.

		FEET.	INCHES.
5.	Drift	4	
4.	Limestone, encrinital, brownish, thinly bedded, with some chert	1	6
3.	Limestone, white, rather soft, somewhat cherty in places		6
2.	Limestone, yellowish	2	4
1.	Limestone, hard, brown, encrinital, heavily bedded (exposed)	2	

An outcropping showing the beds below the base of the exposure just given appears on the north side of the

Skunk river in the bed of Spring creek. The details are shown in section VI.

SKUNK RIVER SECTIONS.

From the last Lee county outcrop on the Mississippi the natural exposures continue at short intervals for a long distance up the Skunk river.

Begining with the Patterson section (VI) in which is exhibited the lowest rocks exposed along the stream, the strata dip rather rapidly to the west until at the first good outcrop on the south side of the river, in the section north of Wever, the Lower Burlington limestone appears at the base of the bluff. Farther up the stream, at Augusta, the Upper Burlington is well exposed in the bed of the river below the mill dam. In the north bluff of the stream at the same place the Upper Burlington, the Keokuk and the Montrose cherts, which separate the other two formations, are displayed in a quarry face.

In the south bluff the same beds are exhibited, but the dividing lines are not so distinct, owing to the heavy talus which covers the hill-sides.

Four miles farther up the river, and two and one-half miles north of Denmark (Tp. 69 N., R. IV W., Sec. 17, NW. qr.) the following section is shown:

XVII. Denmark Section.

		FEET.
5.	Concealed.......................................:	3
4.	Limestone, coarse, dark blue, sub-crystalline with *Orthis Keokuk*, *Spirifera pseudolineata* and Fenestella ....10 to	12
3.	Limestone, like 4, interbedded with chert.......6 to	8
2.	Shale, blue, calcareous, with much chert...........	10
1.	Chert and calcareous shales, with included beds of limestone and clay............................	20

The Montrose cherts exposed at the bottom of the outcrops are found grading upward into the Keokuk limestone, with no clearly defined line of separation.

A couple of miles northwest of Denmark, well up in the bluff (Tp. 69 N., R. V W., Sec. 13, NE. qr.) is a section showing the upper portion of the Warsaw beds (2) in its normal phase; while a mingling of arenaceous and magnesian characters is exhibited in the beds above (3 and 4).

XVIII. Bluff Section Northwest of Denmark.

		FEET.
5.	Concealed	10
4.	Limestone, brown, magnesian, thin-bedded, varying to a more or less arenaceous rock; undulating below; seems to graduate downward into next.	10
3.	Shale, arenaceous, and calcareous sandstone, irregularly stratified	6 to 8
2.	Shale, blue, somewhat arenaceous at top	10 to 12
1.	Limestone, magnesian, (exposed)	2

A short distance west of the last mentioned section, instructive exposures of the Saint Louis limestones are shown in the old Klopfenstein quarry (Tp. 69 N., R. V W., Sec. 13, NW. qr.)

XIX. Section in Klopfenstein Quarry.

		FEET.
4.	Concealed	10
3.	Limestone, white, granular, oolitic, with a thin bed of chert	12
2.	Limestone, fine-grained, white, not oolitic, showing cross-bedding	2
1.	Limestone, brecciated	20

DES MOINES RIVER SECTIONS.

From the standard section so well exhibited at the McGavic mill (section I), below the Union railway station at Keokuk, the outcrop along the Mississippi southward, gradually becomes less exposed to view until at the mouth of the Des Moines river the bluff recedes quite gently (see plate xxviii, figure 3). About a mile above the place where the latter stream empties into the larger water-course there is a low hill which lies between the Des Moines Valley railroad and the river, the greater part being composed of limestone, as is well shown in a cutting on the north side. At this point six or seven feet of the geode shales are exposed on a level with the track. No exposures of rock occur between this place and Sand Prairie. At the last mentioned point the Saint Louis brecciated limestone is seen in limited exposures in the ravines above the station. On the opposite side of the river, near St. Francisville, there are good exposures of the limestone. One-half mile beyond the Chicago, Santa Fé & California railroad bridge over the Des Moines, a quarry is operated by the railway company. The following is the section:

XII. Section at Deamude Quarry.

		FEET.
6.	Clay, yellow above, red below	6
5.	Limestone, brecciated, with pockets of green clay; sometimes rudely and coarsely stratified...20 to	30
4.	Limestone, blue, encrinital.....1 to	3
3.	Shale, blue, calcareous.....1 to	3
2.	Sandstone, blue, calcareous, with discontinuous beds of blue shale, the principal quarryrock......6 to	8
1.	Shale, blue	15

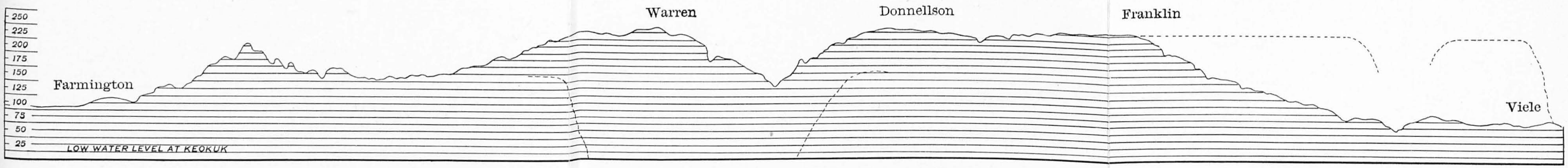


FIGURE 1. PROFILE FROM VIELE TO FARMINGTON.

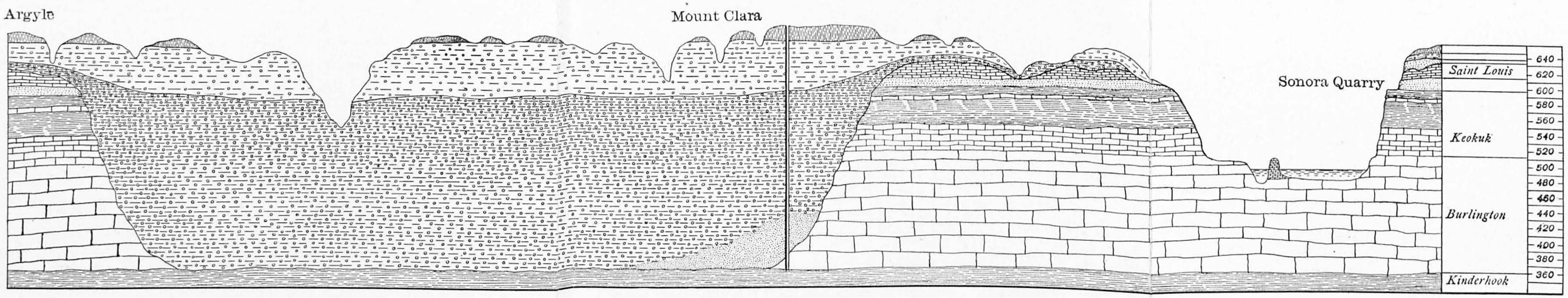


FIGURE 2. SECTION FROM SONORA TO ARGYLE.

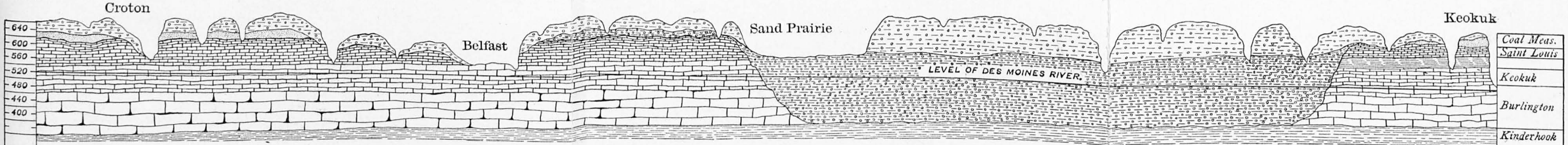


FIGURE 3. DES MOINES RIVER SECTION, FROM KEOKUK TO CROTON.

GEOLOGICAL CROSS SECTIONS IN LEE COUNTY.

Shale 1 is referred to the superior division of the Keokuk (Warsaw); while the remainder of the section is classed as Saint Louis. On the other side of the hill, facing the river, numbers 2 and 3 have a much greater thickness and present considerable variation in bedding, there being rapid alterations from sandstone to shale. In some places these shales are twenty to twenty-five feet thick, nearly all of which may be replaced by sandstones. The bedding is too irregular, however, to make it available for quarrying except at a very few points. At one of these a quarry is being worked by the Chicago, Rock Island & Pacific railroad.

In the south bank of a small stream, discharging into the Des Moines river below Belfast, ten feet of brecciated limestone are seen to be underlain by about ten feet of the massive brown sandstone, the latter resting upon twelve feet of blue shale without geodes and evidently representing number 6 of the Deamude section. About two and one-half miles west of Belfast, some instructive exposures occur on Mumm creek, a short distance above its mouth, (Tp. 67 N., R. VII W., Sec. 33, SE. qr.) The section is readily correlated with the preceding one.

XIV. Mumm Creek Section.

	FEET.
3. Concealed	5
2. Sandstone, bluish, weathering brown, somewhat micaceous, thinly bedded in places	15
1. Shale, blue, argillaceous, readily breaking down into clay; no geodes	5

One-fourth of a mile above on the same stream is a second exposure at which the arrangement disclosed is:

XIV. Bluff on Mumm Creek, above its Mouth.

		FEET.
8.	Concealed	10
7.	Limestone, brecciated, with little if any clay; light colored	8
6.	Limestone, brown, magnesian; lower ledge lighter colored	8
5.	Limestone, magnesian, dovecolored, breaks down quite readily on exposure	2
4.	Limestone, brown, magnesian, quite regular on upper surface but irregular below, conforming to surface of succeeding ledge; not brecciated	2
3.	Limestone, more or less brecciated; sandstone and shale; latter predominates at the middle and separates the bed roughly into two parts	6
2.	Shale, blue, sandy	1
1.	Shale, blue, no geodes (exposed)	1

The shale number 2 is exposed along the edge of the creek and is to be correlated with number 1 of the section just given, while the sandstone of that section is replaced here by limestones 3 to 6 inclusive. Still farther up the stream other rocks appear. One-fourth mile beyond the last is:

XV. Mumm Creek; one-half mile above its Mouth.

		FEET.
4.	Concealed	5
3.	Limestone, hard, white, granular or sandy textured; in thin flag-like beds, with included quartz grains at base	12
2.	Limestone, hard, blue, breaks with conchoidal fracture and is cut by thin veins of calcite	10
1.	Limestone, magnesian, thickly and regularly bedded, slightly brecciated in places	10

Number 1 of this section corresponds to the magnesian beds below number 7 in the preceding section. Following up the stream a short distance number 3 is about 20 feet thick, with about ten feet of brecciated limestone between it and the magnesian limestone below.

In a railroad cut one and one-half miles south of Croton station the sequence shown is:

XVI. Croton Section.

		FEET.
8.	Drift	30
7.	Sandstone, light brown; stratification irregular..15 to	20
6.	Limestone, brecciated, fragments fine-grained, bluish and white; breaks with conchoidal fracture; nodular chert abundant	10
5.	Limestone, brecciated fragments coarser than above, large pieces of magnesian limestone included	20
4.	Limestone; thin but very persistent layer of pure, lightcolored, fine-grained stone; breaks with conchoidal fracture, weathers white; 2 to 4 inches	1/3
3.	Limestone, brecciated; coarse, incoherent, breccia; magesian limestone and sandstone predominating like No. 5	15
2.	Concealed; blue clay and fragmentary limestone exposed at top	20
1.	Shale, with geodes in bed of branch one-fourth mile north of point where above was taken	3

The base of the section is about fifteen feet above the Des Moines river. The portion concealed represents the horizon of the Warsaw formation. The beds from 3 to 6 inclusive belong to the Saint Louis, while the sandstone above is the basal member of the Coal Measures. In the bluffs near Croton it is well developed and sufficiently indurated to admit of quarrying. It has been taken out to some extent on the right bank of the branch below the station. Twenty-five feet of the brecciated rock underlie the sandstone. Following up the branch for one-half mile or more, the upper portion of the brecciated limestone is seen to be replaced by hard, white, granular or oolitic limestone, cross-bedded and ripple-marked. The ripple marks at some points are very broad and deep, measuring five inches from crest to crest and from one to one and one-half inches in depth.

OTHER SECTIONS.

Besides the sections which have been described as occurring along the three principal streams and which are representative of almost continuous exposures along the water-courses, there are several others in the interior of the county which are readily correlated with those along the margins and which deserve mention. On West Sugar creek outcrops of the indurated rocks are infrequent. The most important one perhaps is on a small branch two miles south of Donnellson (Tp. 69 N., R. VI W., Sec. 5, SW. ¼).

XX. Donnellson Section.

		FEET.
4.	Concealed	75
3.	Limestone, white, granular, ripple-marked (exposed)	10
2.	Limestone, brecciated	10
1.	Limestone, brown, magnesian, somewhat sandy, cherty; locally called "sandstone"	5

In passing up East Sugar creek the first exposure of rock occurs near the railroad bridge about two miles northwest of Viele at which place about five feet of the brown magnesian limestone belonging to the lower part of the Saint Louis formation crops out. One mile above this point is another exposure of the same bed at the level of the water in the creek near an old mill. The exposure shows about six or eight feet of brown calcareous sandstone; it has been quarried to some extent. The strata have an apparent southward dip considerably greater than the slope of the creek bed. Two miles northwest of this locality the white limestone of the Saint Louis is quarried on the Graner land. The magnesian beds lie below, with some brecciated limestone between; while a drill-hole showed blue shale below the whole.

XXI. Section at the Graner Quarry.

		FEET.
10.	Concealed	10
9.	Limestone, white, granular or sandy in texture, cross-bedded	5
8.	Limestone, in heavier ledges; surface of beds beautifully ripple-marked	3
7.	Limestone, more impure than preceding; otherwise similar	2
6.	Limestone, very fine-grained and pure; burns excellently for lime	1
5.	Limestone, granular, white like 8 and 9; separated from 6 by clay parting five inches in thickness.	6
4.	Limestone, brecciated 8 to	10
3.	Limestone, brown, magnesian	8
2.	Shale, blue, argillaceous; no geodes (Warsaw) 10 to	12
1.	Shale, with goedes (exposed)	20

On Little Sugar creek, south of the Graner house, the same beds are evidently exposed for a distance of a mile or more, but show considerable variation in character. They are more or less disturbed and are available for quarrying at only a few points. Moreover, the sandy character is much less marked while the bedding is quite uneven.

On the East branch, about two miles northeast of the Graner quarry, rock escarpments extend along the creek for a distance of a mile or more (Tp. 68 N., R. V W., Sec. 20, NE. qr.).

XXII. Sugar Creek Section; East Branch.

		FEET.
6.	Concealed	5
5.	Limestone, hard, bluish-white; breaking with conchoidal fracture	3
4.	Sandstone, light brown, soft, saccharoidal	10
3.	Limestone, fine, white, chert-like	1
2.	Limestone, soft, or calcareous sandstone grading downward into next	10
1.	Limestone, brecciated, roughly stratified	10

All of this section from 2 to 5 inclusive, evidently represents the white limestone division of the Saint Louis, though the incoherent character of 2 is a phase not observed elsewhere. The brecciated rock which is here quite compact and firmly cemented has the appearance, at one point, of having been channelled and the excavation filled with a breccia of similar but loose and incoherent materials, with a considerable proportion of clay.

About a quarter of a mile down the stream lower beds appear (Tp. 68 N., R. V W., Sec. 20, NE. qr.).

XXIII. Sugar Creek Section, East Branch.

		FEET.
6.	Concealed	6
5.	Limestone, quite regularly bedded	3
4.	Limestone, brecciated	12 to 15
3.	Limestone, brown, magnesian, in massive undulating beds	8 to 10
2.	Shale, arenaceous and marly, containing fragments of chert	3 to 6
1.	Shale, blue, arenaceous above (exposed)	2

The brown, magnesian limestone (3) sometimes incloses lenticular layers of light colored limestone breccia between the beds. Along the line of juncture between 3 and 4 fragments of the light colored limestone are sometimes inclosed in the latter, while fragments of brown, magnesian limestone mingle with the white in the breccia. The layers of 3 show quite regular bands due to staining from iron oxide. On the main creek directly west of this locality is a similarly stained rock evidently belonging to the same formation.

North of Franklin about two and one-half miles there is a bold escarpment of brecciated limestone about fifty feet high presenting much the same character as the formation seen at Croton.

A mile and a half northwest of this, on Big creek, the beds are more regularly stratified; while a seam of coal appears above (Tp. 68 N., R. VI W., Sec. 15, NW. qr., NE. ¼).

XXIV. East Sugar Creek Section; Big Creek.

		FEET.
7.	Concealed	8
6.	Coal; has been worked here, drift now abandoned; about	2
5.	Fire clay	2
4.	Sandstone, soft, quartzose	5
3.	Limestone, white, rather hard and coarse in texture; contains *Bellerophon gibsoni* White, *Productus semireticulatrus*, *Zaphrentis pellaensis*, Worthen, Allorisma	2
2.	Shale, somewhat calcareous, lamminated	1
1.	Limestone, granular cross-bedded, irregularly srati-fied and somewhat brecciated in places; includes a bed of rough silicious rock, also one of clay and chert; the base of the limestone is light colored and contains much nodular chert	26

Numbers 4 to 6 inclusive belong to the Coal Measures; the remainder of the section represents the white concretionary limestone of the Saint Louis.

On Lost creek there are a number of exposures of small extent. In the southeast quarter of section four, Washington township (Tp. 68 N., R. IV W.), the Keokuk limestone appears at short intervals along the creek, sometimes having an exposure of eight to ten feet. In the southwest quarter of section three, ten inches of dark blue, sub-crystalline limestone, bearing *Spirifera logani*, *Spirifera keokuk*, a Productus and a zaphrentis, overlie six feet of cherty shale and earthy limestone. This is evidently very near the line of division between the Burlington and Keokuk limestones. It probably represents the top of the Montrose cherts. For a distance of about two miles below this point no exposures occur. Near the church in the northeast quarter of section eleven, five feet of Burlington limestone overlain by eight feet of white chert interbedded with brown limestone appear at the side of the creek. Below this point, for a distance of over a mile, the Burlington limestone may be seen in the ravines.

GEOLOGICAL FORMATIONS.

The general sequence and arrangement of the strata exposed in Lee county have been given in the table of formations. The lithological characters of the different members may be inferred from the descriptions of the typical vertical sections which have been selected for special mention as furnishing indices to an accurate correlation of beds in all parts of the district. Considered in its entirety each of the geological formations represented exhibits a somewhat different aspect than when shown in the details in the more or less disconnected sections. The range of formations is not very great since all the indurated rocks belong to one system—the Carboniferous.

Mississippian, or Lower Carboniferous, Series.

The oldest rocks exposed at the surface of Lee county are known as the Lower Carboniferous, or Mississippian, limestones. They have been termed also the Mountain limestones, and the Subcarboniferous, both of which names are now regarded as inapplicable. Lower Carboniferous has been used widely of late to designate the rocks in question, but there are serious objections to the use of this term. More recently the title Mississippian series has come into use in designating the great sequence of limestones lying at the base of the Coal Measures. The word is a revival, with a slight terminal modification, of an old term employed years ago. It is very appropriate for the group of strata to which it applies as it is typically developed along the great stream for which it was christened.

In the Mississippi valley there are recognized four well marked subdivisions of the Lower Carboniferous, or Mississippian. One of these, the uppermost, is not present in Iowa. This absent member is the Kaskaskia limestone which is well exposed below the mouth of the Missouri river. It is a three-fold division made up of the Aux Vases sandstone, the Kaskaskia limestone proper and the Chester shales.

KINDERHOOK SHALE.

Although this member of the Lower Carboniferous is such an important formation in Des Moines county, immediately to the north, and in northeastern Missouri to the south, it lies almost entirely below the river level in Lee. It has only been recognized in a single place on the Skunk river near the Chicago, Burlington and Kansas City railroad bridge over that stream. In the bed of Spring creek a mile north of the Lee county line and one-half mile west of Patterson station the uppermost beds of the Kinderhook are well exposed.

IV. Section on Spring Creek, west of Patterson Station.

		FEET.
5.	Limestone, heavily bedded, encrinital (Lower Burlington; exposed)	10
4.	Sandstone, yellow, fine-grained	4
3.	Oolite, gray, massive; highly fossiliferous	3
2.	Shale, blue, argillaceous	1
1.	Shale, sandy (exposed to creek level)	1

From this point the Kinderhook is carried down in a shallow syncline which reaches its greatest depth near

Keokuk where it is about 130 feet below the low water mark; then rising rapidly it appears again above the river at Hannibal, Missouri.

AUGUSTA LIMESTONE.

The Augusta limestone comprises a very considerable portion of the surface rocks of Lee county. It forms the greater part of the vertical extent of the bluffs on all the streams bordering the district; but in the interior it is largely overlain by the Saint Louis limestone and Coal Measure shales. The term Augusta has been recently proposed for all those formations which in southeastern Iowa and the adjoining portions of Illinois and Missouri were formerly referred to under five distinct names. The term, therefore, is intended to be applied to the formations which have been known as the Lower and Upper Burlington limestones, the Keokuk limestone, the Geode bed and the typical Warsaw shale. The original localities of all of these formations are in Lee and Des Moines counties.

Lower Burlington Limestone.—In Lee county this rock has a surface exposure over only a small area, on the banks of the Skunk river in the northeastern part of the county, north of Weber and a few miles east of the town of Augusta. The beds comprise chiefly coarse-grained, encrinital limestones, usually firmly cemented, intensely white in certain layers but elsewhere brown or reddish on exposed surfaces. Many of the beds are made up almost entirely of disconnected skeletal plates of crinoids and other animals related to the starfishes and sea urchins. These organic hard parts are firmly cemented together by means of calcareous material. In the upper portion of the Lower Burlington there are sillicious shales and cherty limestones which have been regarded as the layers separating the lower from the upper division. The distinguishing characters between the Upper and Lower Burlington limestones are chiefly faunal rather than lithological or physical differences, so that ordinarily the two divisions are not readily separated except by an examination of the fossils contained. Occurring only as a narrow strip for a short distance at the base of the Skunk bluffs the formation is not so important in Lee county as a few miles farther north. The economic value of this limerock will not therefore ever be very great on account of the occurrence of equally good beds of similar character immediately over it.

Upper Burlington Limestone.—Though usually very similar in general aspect to the lower member, the Upper Burlington may be often distinguished from it by its thinner bedding and greater abundance of chert in irregular nodules and thin bands. The more massive character of the lower beds is perhaps the only casual mark of distinction which is of value in discriminating between the two. The Upper Burlington is perhaps best exposed in the bed of the Skunk river at Augusta. Here for several hundred yards below the old mill dam the water breaks into ripples forming in places rapids of considerable size. The same rocks are also well exposed in the river banks for some distance both above and below the dam. A good section is found at the south end of the wagon bridge near by.

The flinty beds of the Upper Burlington are now called the Montrose cherts. They have recently been found to have less than one-third the thickness which has been commonly attributed to them, or only about thirty feet. The beds are well exposed along the Mississippi river from Montrose to Keokuk. Between these points they constitute the bed of the river causing the obstruction to navigation known as the Des Moines rapids. The slope of the strata is very nearly the same as that of the river and hence the upper surface of the formation lies from five to fifteen feet above the water level for the entire distance. A short distance directly north of the Augusta bridge, in Des Moines county, there is an old quarry face showing the entire thickness of the cherts, with the Burlington limestone below and the Keokuk above. Thin layers of limestone are intercalated in the chert beds, the whole being rather thinly bedded as compared with the layers associated. Opposite the town on the south side of the river the same chert beds are found near the middle of the bluffs extending for a considerable distance, both up and down the stream. Other outcrops appear on Lost creek below Denmark.

Keokuk Limestone. Though this formation has its typical development in Lee county the area of its surface exposure is relatively small. It occupies the larger part of Denmark township together with a portion of Washington. In addition it is exposed by erosion in the Mississippi gorge and its tributaries between Montrose and Keokuk and forms the base of the abrupt escarpment which constitutes such a marked feature in the topography of the region. At the city of Keokuk it is well shown in numerous places, the best exposures being along Soap creek and in the west bluff from the foot of the canal to the mouth of the Des Moines river (see plate XXIX).

Along the Des Moines river the rocks lie somewhat above the water level all the way from Sand Prairie to Farmington, but as a rule are not very well exposed.

QUARRY AT McGAVIC MILL; KEOKUK.

For the most part the formation consists of twenty-five to forty feet of coarse-grained, bluish, often crinoidal limestone. Nodular chert is quite prevalent throughout. Some beds are somewhat argillaceous, and this with the presence of chert renders many of the layers unfit for use as a quarry rock. Some ledges, however, are well adapted for building purposes. The best of these layers is known as the "white ledge," which is rather extensively quarried especially at and around the city of Keokuk. The beds are much more massive towards the base and the partings are very thin, usually reduced to mere films; but towards the top the bedding becomes thinner, the separating clays more prominent and the layers assume a somewhat shaly character.

Geode Bed.—The shales immediately overlying the blue Keokuk limestone have a maximum thickness of perhaps forty feet. The lower half is made up largely of indurated calcareous shales with some chert and a few thin bands of limestone. The shales graduate rapidly into the massive limestone below. The upper half is much freer from calcareous material, is somewhat gritty and breaks down under the influence of the weather much more readily than the lower portion. The name of the formation was originally given to it on account of the existence of numerous globular, silicious and calcareous concretions known as "geodes." These are commonly hollow shells lined within by beautiful crystals of quartz or calcite which are studded often with single crystals of various metallic sulphides, among which are sphalerite chalcopyrite, millerite, galena and pyrite. Often the interior is composed of mammillary and botryoidal chalcedony. Sometimes the geodes are filled with liquid bitumen and occasionally with water. The geodes are characteristic of the formation only in the southeastern part of Iowa and the adjoining portions of Missouri and Illinois.

Warsaw Beds.—Above the geode bed comes the Warsaw formation, as originally defined by Hall. As developed in the vicinity of Keokuk, which is on the opposite side of the Mississippi river from the typical locality, it consists of (1), a bluff magnesian limestone at the base in a massive layer often ten to twelve feet in thickness; (2) a median member made up largely of blue, arenaceous shales, with intercalated limestones in thin bands; and (3), at the top, a buff sandy limestone locally called "sandstone." By Hall the Warsaw was put in with the Keokuk; by White it was placed with the Saint Louis. Since the appearance of the publications of these writers the "Warsaw" has been claimed to be recognized in many localities and much confusion has arisen as to its proper limits and position. In southeastern Iowa this difficulty has been thought to be due to the assumption that the three members already mentioned belong to the same formation; and Gordon is inclined to the opinion, as will be shown farther on, that the "sandstone" is more closely related to the Saint Louis and should be regarded as the basal member of that formation. On the other hand the limestone and shales are manifestly very closely related to the Keokuk both lithologically and faunally. If, however, the title Warsaw is to be retained for any member, or formation, of the Lower Carboniferous series it can at best be applied only as a matter of convenience in local stratigraphy, since beyond the immediate vicinity of Keokuk where it was first recognized the typical Warsaw is not known. It appears to thin out quite rapidly to the north and evidently does not extend a very great distance in that direction beyond the limits of Lee county.

At the town of Warsaw, five miles below Keokuk, and across the river in Illinois, the formation consists of ten feet of magnesian limestone overlain by thirty feet of blue argillaceous shale, above which is the sandy limestone. At Keokuk the formation is essentially the same though reduced in thickness fully one-third, the lower division being only five or six and the median about twenty feet thick.

Saint Louis Limestone.—There is comprised under this term some of the most important rock formations found in Lee county. The area over which they constitute the surface beneath the drift exceeds that of any other one of the members of the Lower Carboniferous. Numerous exposures of the Saint Louis beds occur on the small tributaries in West Point and Franklin townships. They also appear in the bluffs below Montrose and on the Des Moines above Sand Prairie. They are known on West Sugar creek at a single locality only, near Donnellson. Rocks of Saint Louis age occupy probably one-third of the areal mileage of the county.

In its normal development, in this region, the formation consists, according to Gordon, of ten to twenty feet of magnesian, often somewhat sandy limestone and blue calcareous sandstone below — the upper part of the typical Warsaw of Hall — and a somewhat greater thickness of white, fine, or granular limestone above. This succession, however, appears only at rare intervals as brecciation has taken place to a greater or less extent along the horizon separating the two divisions, and in some cases the process has gone so far as to involve both sections. So universal and prominent is the brecciated character of these beds in southeastern Iowa that it has to a large degree obscured the true relations of these deposits and has been the occasion of much misapprehension as to the real characters of the Saint Louis in Iowa. While the brecciated character is one that has been impressed, in part at least, upon rocks already formed and hence cannot be considered as a distinct formation, it is equally evident that it may have had its origin in the conditions which existed during the deposition of these beds. In its minor development it uniformly occurs at the horizon between the magnesian and the white limestone. In consideration of these facts it is here treated as a distinct subdivision though its probable secondary character is not overlooked. The lower member consists of bluish-gray and dove-colored magnesian limestone, generally in thick concretionary beds, which on weathering usually assume a characteristic brown color. The limestone becomes arenaceous in places and sometimes passes almost completely into sandstone. This is the case at the Sonora quarries opposite Nashville, and below Belfast. At Nassau bluff, below Keokuk, the formation is represented by eight feet of calcareous sandstone in which the quartz appears in large white, more or less angular grains. This pebbly character is also marked at a number of other places. On weathering, the sandstone becomes brown like the limestone. The formation is well exhibited on the Des Moines river above its mouth where at various points, it shows alternations of the arenaceous and limestone phases.

On Mumm creek, west of Belfast, both phases are shown within the distance of less than one-fourth of a mile. A limited outcrop of the same beds also appears on West Sugar creek, near Donnellson, and there are good exposures at numerous places on East Sugar creek.

Heretofore the arenaceous beds have been considered as underlying the magnesian limestone and as constituting the upper member of the Warsaw division. Gordon is of the opinion that the recognition of the continuity of the arenaceous beds and the magnesian limestone removes the difficulty usually attending the classification of the Warsaw and explains satisfactorily the conflicting statements regarding it. The sandstone occurring on the Des Moines river, opposite Keosauqua in Van Buren county, where it overlies the brecciated limestone and evidently belongs to that division, was identified by White with the upper member of the original Warsaw; while the magnesian division was correlated with the Warsaw limestone and shales. Two distinct formations were thus confounded. In both Lee and Van Buren counties the two phases are readily traced almost directly into each other; while in many and separate localities, each is found to overlie blue, argillaceous shales which bear no geodes and which are of variable thickness, very evidently representing the middle Warsaw. In a thin zone at the top of the shales and below the sandstone or magnesian limestone as the case may be, there are found large quartz grains sometimes almost pebbly in character, while from one to three feet of the succeeding deposit is composed of clay and broken fragments of chert indiscriminately mingled and grading upward into magnesian limestone, where this is the overlying bed, in which irregular silicious masses are abundant at the base. The slight disturbances shown at this horizon have been observed at various places and would seem to indicate a slight degree of unconformity. White has asserted the existence elsewhere of unconformable relations between the Saint Louis and Keokuk divisions, and it may be that the slight discordance here noted is a phase of an erosion interval exhibited in a more marked degree in other districts. An instructive outcrop of the formation occurs at the Sonora quarries on the Illinois side of the Mississippi river opposite Nashville. The beds are exposed for several hundred feet along the bluff and have been quarried extensively. At the south end of the quarry, ten to fifteen feet of the sandstone in massive beds underlies the breccciated limestone, as at Keokuk. Towards the north the brecciated limestone thins out, allowing the shales and sandstone of the Coal Measures to rest directly upon the Sonora sandstone which becomes more magnesian and in some places shaley as shown by the following section:

V. *Sonora Quarry Section.*

	FEET.
7. Loess	10
6. Clay and sand	4 to 8
5. Shale, and sandstone, with a few inches of coal in disconnected basins	10 to 15
4. Sandstone, blue	4
3. Limestone, bluish, magnesian and arenaceous; banded with yellow, the whole weathering brown; arenaceous layers cross-bedded	15
2. Shale, arenaceous, graduating horizontally into sandstone	4
1. Limestone, magnesian, resembling 3, but less arenaceous and more vesicular and cavernous	4

All below 5 belong to the lower member of the Saint Louis and show an increase in thickness of nearly twenty feet within a distance of less than one-fourth of a mile. In some cases this formation becomes involved in the disturbance characterizing the brecciated limestone and thus loses its local individuality. This is well shown in the bluff below Croton.

The brecciated character is a very pronounced feature of the Saint Louis everywhere in southeastern Iowa. It exhibits considerable lithological variation. The changes are from a mixture of limestone and sometimes sandstone fragments loosely imbedded in clay or firmly cemented by calcareous material, to a more or less quartzose sandstone. The latter phase has been observed in Van Buren county opposite Keosauqua. In Lee county it was seen at only one locality, on East Sugar creek. In general the division consists of ten to twenty feet of a fine white limestone breccia mostly in small fragments and firmly cemented together by calcareous matter similar in appearance to the limestone fragments themselves. Locally it assumes an increased thickness up to seventy-five feet, but loses its consolidated character and contains much clay in which fragments of the lower blue limestone and sandstone predominate below, while above the fragments are prevailingly white in color. In some cases the clay constitutes a large proportion of the mass but more often the limestone predominates and shows a somewhat rude and coarse stratification of the component fragments interstratified with thin undulating layers of limestone which adapt themselves to the irregularities and inequalities of the mass upon which they rest.

Occupying a position normally above the lower member of the Saint Louis, but usually separated from it by the brecciated division is a fine-grained, hard, white or gray limestone which breaks with a conchoidal fracture and bears a close resemblance to lithographic stone. In some cases it becomes granular or sandy in texture and then shows the cross-bedding and ripple marks of a littoral deposit. This character is especially pronounced in Lee county and is seen to good advantage at the Graner quarry and elsewhere on East Sugar creek; also near Donnellson and in the vicinity of Belfast, Croton and

Keokuk (figure 16). It lies immediately upon the brecciated limestone, in some places filling the irregularities in that stratum and is in its origin quite similar to that formation. However, it is evident from the manner in which the upper part of the brecciated and the fine-grained and granular varieties graduate into one another and also from their occurrence in the same stratigraphical horizon, that they are closely related in their mode of origin and constitute essentially the same formation.

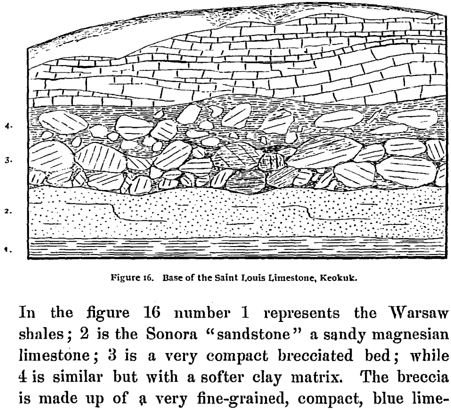


Figure 16. Base of the Saint Louis Limestone, Keokuk.

In the figure 16 number 1 represents the Warsaw shales; 2 is the Sonora "sandstone" a sandy magnesian limestone; 3 is a very compact brecciated bed; while 4 is similar but with a softer clay matrix. The breccia is made up of a very fine-grained, compact, blue limestone, which breaks with a conchoidal fracture. The fragments are angular and vary in size from a few inches to several feet. The interstices are filled with a clayey, calcareous material which is usually much softer than the limestone, and in weathering allows the limestone boulders to project far beyond the matrix. Above the brecciated portion of this limestone the strata are laid down very irregularly, but upward rapidly pass into evenly bedded layers.

The thickness of the white limestone rarely exceeds twenty feet and more commonly not more than ten or twelve feet.

The most generally distributed fossil of the Saint Louis group is the coral *Lithostrotion canadense*, Castlenau. The remains of this organism are frequently found in the beds of the streams of Lee county, having been dislodged through the disintegration of the limestone. The fossil being completely silicified easily resists the agencies which have disintegrated the beds in which it occurs. In southeastern Iowa this form appears to be confined to the magnesian limestone and the brecciated beds. In the latter case they may have been derived originally from the magnesian limestone. Besides Lithostrotion the magnesian layers often contain abundant impressions of a Fenestella, *Spirifera keokuk* and *Productus semireticulatus*. They seem to be confined principally to the basal portion and are arranged in bands along which the rock is decidedly more magnesian than in other portions. The presence of the fossils may have exerted some influence in the segregation of the magnesia along these planes; or, on the other hand, the presence of magnesia may have preserved the fossils better here than in adjacent portions where this element is much less pronounced. The latter explanation seems to be favored (1) by the gradual transition from the fossiliferous to the non-fossiliferous portions and (2) by the finely vesicular character of the beds where no other evidence of the fossils can be detected and which evidently is due to the remains of polyozoans (Fenestella) whose organic character has been almost entirely obliterated.

The clays of the brecciated limestone sometimes carry fossil forms, while the upper white limestone is usually marked by an abundance of well preserved organic remains.

The fine-grained limestones which have a conchoidal fracture, usually yield an abundance of *Spirifera keokuk*, Hall, *Rhynchonella ottumwa*, White, and *Productus semireticulatus*, Sowerby. At one locality, on Sugar creek, a bed somewhat intermediate in texture between the granular and fine-grained limestones yielded numerous specimens of *Bellerophon gibsoni*, White, associated with Allorisma, *Zaphrentis pellaensis*, Worthen, and *Productus semireticulatus*, Sowerby.

Upper Carboniferous.

Lower Coal Measures.—These deposits occur principally in three disconnected areas, two of which seem to belong to the main eastward extension of the rocks of this horizon on the west and northwest; while the third is an isolated basin dissected by East Sugar creek and occurs in the interior of the county. There are besides several small areas in the southern part of the district. As elsewhere along the eastern border of the formation in Iowa the Coal Measures occur in basin-like depressions in the Saint Louis limestone, to which circumstance some of the smaller outliers doubtless owe their preservation. Along the Des Moines river the exact limits of the area covered by this formation have not been definitely made out, as the only exposures occur in the immediate vicinity of the stream. At Croton about fifteen feet of the basal sandstone caps the bluffs, while farther north and west, near Farmington, coal has been mined just outside the county limits.

In lithological characters the Coal Measures differ very much from the other formations with which they are associated. Instead of being made up chiefly of limestone or calcareous shales, as is the case of nearly all of the other strata of the region, the coal-bearing strata are composed almost entirely of soft clay-shales and friable sandstones. In contradistinction to the shales occurring with the limestones the former deposits are as a rule much darker in color, even black, though often light-colored clays are present, especially immediately beneath the coal beds where the white fire-clays are found. In other parts of the Iowa coal field the shales vary greatly in color from pure white to black, yellow, drab, blue and red. Often all of these are intermingled forming what are termed variegated shales. Most of these shales carry more or less fine grit which frequently becomes so abundant as to form sandy shales or even shaly sandstones. In Lee county the Coal Measure shales are largely blue or drab in color; and these beds form by far the greater part of the formation. They occur in considerable thickness and are of wide geographical extent. Difficulty, however, is encountered in attempting to trace the different layers for any considerable distance on account of their tendency to break down readily into plastic clays in which all traces of stratification are lost at once.

The sandstones of the Coal Measures are commonly fine-grained, rather friable, and yellow or brown in color. Occasionally very fine white sandrock occurs; but these beds are usually quite limited in extent and are only a few feet in thickness. The sandstones as a rule show marked cross bedding which is made more pronounced in weathering (figure 17 represents the base of the sandstone shown in plate xxx).

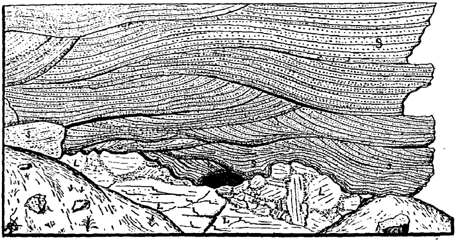


Figure 17. Cross-bedding in Coal Measure Sandstone above the Line of Unconformity.

More specifically the Coal Measures as exhibited in Lee consist of a basal member of coarse, brown, quartzose sandstone somewhat micaceous in places, which is replaced locally, in whole or in part, by brown sandy and dark argillaceous shales, the latter underlain by a bed of coal. The transition from sandstone to shale is often abrupt as is seen in the bluffs above Rand park at Keokuk, where the sandstone is reduced to a few feet in thickness, the shale with a thin bed of coal replacing the upper portion of the bed as shown by the accompanying diagram. Number 1 is the white

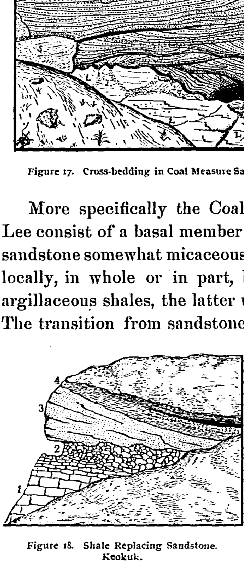


Figure 18. Shale Replacing Sandstone. Keokuk.

COAL MEASURES RESTING UNCONFORMABLY ON SAINT LOUIS LIMESTONE; KEOKUK.

Saint Louis limestone; 2 the brecciated bed; 3 the Coal Measure sandstones; and 4 the shale with a thin bed of coal. A photograph of the line of unconformity between numbers 2 and 3, the Lower Carboniferous and Coal Measures is represented in plate xxx.

The irregular character of the upper surface of the Lower Carboniferous (numbers 1 and 2) is also seen at the Sonora quarry. (Figure 19.)

Usually no other Coal Measure rocks have been found overlying the thicker deposits of sandstone; but in the basins the coal is usually overlain by black fissile layers or

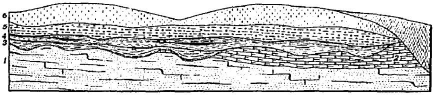


Figure 19. Unconformity of Coal Measures and Saint Louis Limestone. Sonora Quarry.

arenaceous shales. The sandstone frequently extends under the coal and the light colored shales though diminished in thickness are usually more or less sandy.

Few fossils have been observed in the coal-bearing strata of the county. The following species were obtained from the shale overlying the coal at Keokuk:

Athyris argentea, Shepard.
Productus longispinus, Sowerby.
Streptorhynchus crassus, Meek & Hayden.
Lophophyllum proliferum, McChesney.

The coal beds of Lee county are somewhat limited as compared with the districts lying to the west. Deposits of considerable value have been worked to some extent and others of equal or greater importance doubtless still await development. In thickness the coal seams vary from one and one-half to three feet. A detailed description of the coal and its workings will be found in another place.

Pleistocene Deposits.

Within Lee county there are no deposits which represent the long period of time intervening between the deposition of the Lower Coal Measures and the beginning of the ice age. If later Coal Measure, Mesozoic or Tertiary strata were laid down over the region they were entirely removed by erosive agencies before glacial times. It is quite evident that the rocks of the Coal Measures at least were deposited in considerable thickness over this part of the state and were connected with the now separated Carboniferous fields of Iowa and Illinois. Something of a measure of the enormous erosion to which the rocks of the region have been subjected is seen in the extensive buried river channels which are described farther on. Upon the rock surface thus gashed and trenched, rest the clays and silts of the Pleistocene period, filling up the depressions and raising the whole surface to a nearly uniform level. The even plain thus formed has a general southward slope, with a secondary inclination toward the Mississippi river. Upon this even plain subsequent drainage has effected various changes but it has not yet destroyed the general relief of the original slightly tilted surface.

The superficial deposits of southeastern Iowa may be classed as (1) Lower Till, (2) Loess and (3) Terrace deposits.

LOWER TILL.

The Lower Till of the region comprises an inferior division of blue boulder clay, varying from a few feet to two hundred feet in thickness; and a superior portion comprising thirty to seventy-five feet of yellow clay.

Blue Boulder Clay.—This deposit consists of blue clay filled with boulders of various kinds, those of crystalline rocks predominating, though limestone masses also occur. The boulders are generally rounded or subangular and often striated; those with sharp edges showing little if any abrasion are not rare. On the higher levels where the indurated rocks lie near the surface, this deposit is thin or absent. It constitutes the larger part of the filling of the preglacial depressions, however, and exhibits a thickness of fully two hundred feet in the old channel of the Mississippi. In this channel a bed of sand was found in the Mount Clara well, below the blue clay which may represent an old terrace deposit. Beds of sand occur at intervals in the clay in irregular deposits which often constitute the source of water supply of wells on the upper levels.

At Fort Madison bluffs composed entirely of drift capped by loess rise directly from the water's edge. The blue clay constitutes about sixty feet of the nearly vertical embankment, and imbedded in it are numerous fragments of wood. Deep wells also sometimes show considerable quantities of vegetal matter, chiefly wood, enclosed in this deposit. Pieces of the wood taken from the clay were submitted by Mr. C. H. Gordon to Prof. D. P. Penhallow, of McGill University, for identification. He replied that "the material included two genera and probably three species. The best preserved specimens proved to be of the genus Larix (Larches) and from the close specific agreement with *L. americanus*, as well as the recent age of the deposits in which it was found I have no hesitancy in referring them to that species. The second is an undoubted Taxus though it differs from any modern Taxus with which I am acquainted, in having a number of very small resin passages, and fusiform rays. Otherwise it agrees almost exactly with our modern *Taxus canadensis*, to which I would provisionally refer it in the hope that better material at some future time may serve to clear up the points in doubt. The third is, I think, also a Taxus, but of this I cannot be certain. It clearly differs specifically from the former and the best we can do is to refer it provisionally to that genus."

At Keokuk along the bluff between Main street and the mouth of Soap creek a bed of boulders with some sand and clay rests upon the shales of the Geode bed. The deposit is about fifteen feet thick and the top is sixty-five to seventy feet above the river. Resting upon it is a loess-like deposit. The boulders comprising the bed are of all sizes up to two feet in diameter and are cemented together in places forming a somewhat incoherent conglomerate. The relations of this deposit are as yet imperfectly understood but it is thought to represent a much later stage in Pleistocene history than that of the blue clay. A similar accumulation has been found at one or two other points within the county.

Yellow Boulder Clay.—Above the blue clay is a yellow deposit of somewhat similar character lithologically which also contains rounded and striated boulders. In neighboring places this clay shows faint traces of stratification though no indications of this character were observed within the limits of Lee county. Its differentiation from the lower division is marked chiefly by its color and the character of its boulders which are prevailingly limestones and chert though crystalline rocks are also common. The limestones are often smoothed and striated, all the marks

DRIFT DEPOSITS AT KEOKUK.

appearing fresh and distinct. At the "Yellow Banks" on the Des Moines river, twenty-five feet of sand are seen resting upon the blue clay and over this fifteen feet of silty clay, dark above and overlain by eight feet of yellow clay which in turn is capped by a thin veneer of loess. The sand varies in places to a fine gravel and along the east bank of West Sugar creek near the mouth of the stream it passes into a coarse incoherent sandstone. There is a sharp line of demarkation between the blue clay and the "sandstone" and along the juncture iron charged waters ooze out and fall into the creek below. Whether the relations of this sand bed are with the yellow clay or whether the arenaceous layer represents an independent stage intermediate between the two clay deposits is not clear though some considerations seem to favor the latter view. Generally the yellow clay contains much sand as is well shown along the Chicago, Santa Fe and California railroad where it cuts through the main divide. The surface of the clay is usually highly oxidized and often a line of pebbles marks its line of separation from the overlying loess. The clays are usually cut vertically by sheets of lime from one-fourth to three-fourths of an inch in thicknes. Hollow concretionary nodules of lime are abundant in some places but rare in others. They vary in size from one-half to one inch in diameter and when broken show cracks and crevices on the inside, apparently due to shrinkage. These nodules are typical "loess kindchen" which have long been held to be distinctive of the loess. In southeastern Iowa and northeastern Missouri, however, they are abundant in places in the upper part of the yellow clay and are but sparingly distributed in the loess itself. This may therefore indicate a genetic relationship between the two formations.

LOESS.

This deposit consists principally of a fine, ash-colored silt. It is distributed quite uniformly over the entire area under consideration, varying in thickness from a foot or two up to fifteen feet. Over the greater portion of the district the material does not average more than four to six feet. Along the line of the Chicago, Santa Fe and California railway in the vicinity of New Boston it has a development of fifteen feet. The lower portion is more friable than the upper, and in some cases appears to be somewhat marly at the base. At Keokuk the boulder accumulation already referred to is overlain by stratified white and ferruginous sand grading upward into typical loess. (See plate XXXI.) The thickness of the silt and stratified sand is about thirty feet.

On Soap creek there is an interesting exposure, showing the following:

Section on Soap Creek at Seventh Street, Keokuk.

	FEET.
6. Loess, fine, ash-colored, retaining a vertical face in excavations for a long time	14
5. Sand, coarse, red, mixed with clay; bands of chert fragments near the middle quite continuous along the face of the exposure	6
4. Sand, fine white, banded with thin layers of red sand quite firmly cemented by iron oxide	4
3. Sand, fine, yellow, more compact	3½
2. Clay, yellow and blue, containing boulders	2
1. Boulders, sand and gravel, resting upon the geode bed below	5

The deposits represented by the above section have generally been referred to the loess formation though some doubt has been entertained as to the correctness of this reference. In the study of similar depositions along the Missouri river Todd has considered that much of what has heretofore been regarded loess is actually a high terrace formation; and facts gathered in Lee county seem to confirm this conclusion, though additional study is needed to settle the question definitely. This statement, however, applies only to those deposits adjacent to the Mississippi and its tributaries; as no doubt exists as to the blanket of loess which is found in the interior of the county. The iron stained sands exhibited in the section (4 and 5) are sometimes developed in such force as to give the bluffs a characteristic redness.

TERRACE FORMATIONS.

Well marked terraces are found in the alluvial plains flanking the Mississippi river above Montrose and the Des Moines below Sand Prairie. Above the first named place these structures rise successively from the river level to a height of about fifty feet. They consist of ridges of water-worn sand, sometimes marked by the whitened, decomposing shells of mussels, like those living in the neighboring streams.

At Fort Madison, the bluff already mentioned as composed entirely of superficial deposits has a bed of sand apparently resting, as shown by excavation, on the blue clay at an elevation of fifty feet above low water-level. This evidently corresponds to the highest terrace observed in the alluvial plain below and is correlated with it. Cut terraces are well shown along the same river bank between Montrose and Keokuk.

GEOLOGICAL STRUCTURE.

GENERAL RELATIONS OF STRATA.

Although the geological structure of Lee county is comparatively simple as regards deformation there are some very decided stratigraphical complications arising from irregularities of deposition. With two exceptions all of the various beds lie conformably upon one another, in regular sequence. For the most part the inclination of the strata is slight, usually so little as not to be perceptible. The general dip is southward; on an average about ten feet to the mile. The total declination across the county is therefore something over two hundred feet. But notwithstanding the fact that the geological structure on the whole is not very complex there are considerations to be taken into account which are of the greatest importance economically and at the same time of extreme interest scientifically.

GEOLOGICAL CROSS-SECTIONS.

Mississippi River Section.—The description of the lithological characters of the different vertical sections along the Mississippi river has already been given. While the strata have a general dip to the southward the inclination is not uniform. Toward the northern end of the section the slope is much greater than anywhere else and the constant lowering of the successive beds in passing down the stream is quite noticeable. The Keokuk limestone which occupies the very summit of the bluffs near the Skunk river comes down to the water-level at Fort Madison; that is, it falls nearly one hundred and fifty feet in a distance of seven or eight miles. From Fort Madison to Keokuk the dip closely appproaches horizontal, the general slope being very nearly the same as that of the river. This arrangement is shown in the rather detailed section along the Mississippi river represented in figure 2, plate XXVII. The inclination of the beds to the south in Lee and Des Moines counties is met, in northeastern Missouri, by a similar slope in the opposite direction. A broad shallow syncline is the result. The maximum depression is in the neighborhood of the city of Keokuk, for which reason it is known as the Keokuk syncline (figure 20). The economic importance of the recognition of the synclinal depression will be at once apparent when it is remembered that the particular structure represented by it is one of the leading factors in the securing of successful flows of artesian water.

Skunk River Section.—Measurements along this stream, where the outcrop of the various strata may be readily traced, show that there is a considerable inclination of the beds to the west. The Upper Burlington layers which cap the hills at the east in Des Moines county are brought to the water-level at Augusta, the distance being not over four or five miles. This would seem to indicate a dip to the west of about ten or twelve feet for this short distance. But in taking into consideration the average inclination for the entire distance from the mouth of the river to where it

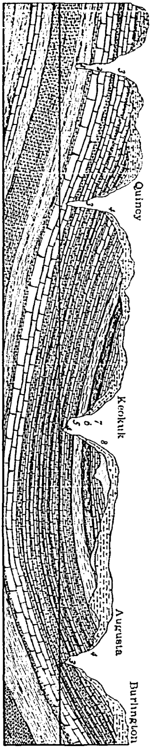


Figure 20. The Keokuk Syncline.

enters Henry county the actual slope is not more than eight feet to the mile. This, however, is made more pronounced by the fall of the stream of about four feet per mile, in the opposite direction; making in all an apparent dip of about twelve feet in the same distance.

Des Moines River Section.—As in the Skunk river section the direction of the Des Moines gorge is nearly at right angles to that of the Mississippi. The general dip is very slight indeed and directly opposite to the course of the stream. The gradual rise in the river bed in passing westward brings the different layers successively to water-level sooner than would otherwise be the case.

DEFORMATION OF STRATA.

Deformation or the warping of the rock layers on account of the working of dynamic agencies analogous to those which act in raising mountains are nowhere very marked within the limits of the district. The larger folds, the principal expression of which is represented by the Keokuk syncline (figure 20), are very broad with comparatively small amplitudes. By reference to the geological cross-sections the details are readily made out. The greatest inclination observable is in the Mississippi section which runs northeast and southwest. Dips in the other two principal cross-sections are relatively slight so that the inference may be drawn that the trend of the trough is nearly northwest and southeast with a veering to the south.

The minor undulations cannot be traced very far from the points of first observation. For the most part they are unimportant.

UNCONFORMITIES.

The most marked irregularties in the relationships of the different strata are several well marked unconformities. Nearly all the stratified rocks exposed in Lee county represent an uninterrupted sequence of deposition. A notable exception is in the case of the Saint Louis limestone and Coal Measures.

Coal Measures and Saint Louis Limestone.—The pronounced discordance in sedimentation between these two formations in southeastern Iowa is shown at various localities. In the bluff at Keokuk, above Rand park, the unconformable relations are especially well exhibited. The basal sandstone of the Coal Measures is a coarse, brownish sandrock resting immediately upon a very uneven surface of the brecciated limestone of the Saint Louis. At the bottom the sandstone presents marked irregularities in bedding as is shown in figure 17. Towards the top the stratification becomes more even and regular.

A still better exposure showing the phenomena is seen at the Sonora quarries, opposite Nashville. It is represented in figure 19.

The Saint Louis limestone in southeastern Iowa has been shown to have great irregularities in its surface. In some cases this is evidenced by the appearance of Coal Measure rocks below the level of the limestone in adjacent exposures. This irregularity is manifestly due to erosion, coupled with the structural peculiarities of the brecciated limestone. This fact has sometimes given rise to a popular misapprehension as to the relations of the two formations, and has caused a fruitless search for coal deposits in positions where they could not possibly occur.

Drift and Indurated Rocks.—It is well known that the mantle of glacial débris which spreads over all Iowa, hiding the hard stratified rocks from view, has everywhere unconformable relations with the underlying strata. Illustrations of the phenomenon are so common that they attract but little attention. In Lee county there are some features which are especially interesting in this connection and they therefore demand more than passing mention. In the long interval succeeding the close of the Carboniferous, the area, of which Lee is only a small part, was elevated above sea-level for a considerable period of time, as is evidenced by the extensive denudation and channeling which has taken place in the rock surface. It has already been intimated that the Coal Measure rocks and possibly other later formations originally extended over the whole of this region. As to the thickness of the beds removed, and hence the extent of the general denudation there can be only a rough surmise; but that it was considerable is quite manifest.

Among the most noteworthy features to call attention to is the existence of drainage valleys and the general character of the ancient land surface. Though the data with reference to the channels beneath the drift is still far from complete, sufficient evidence has been gathered to indicate the existence of at least two profound gorges representing the former locations of the Mississippi and Des Moines rivers, with traces of other lesser channels which were in all likelihood tributary to these. The great development of glacial material along the west bank of the Mississippi above and below Fort Madison was long ago noticed. The location here of an old channel of the Mississippi was first made known some years ago by Major G. K. Warren, and more recently the position of the same buried channel was discovered and determined independently by Mr. C. H. Gordon, whose results agreed in all essential respects with the earlier work. From data gathered by him the previous observations were not only confirmed but the extent and depth of the valley was calculated closely. The location of the former course is indicated upon the accompanying sketch (figure 21).

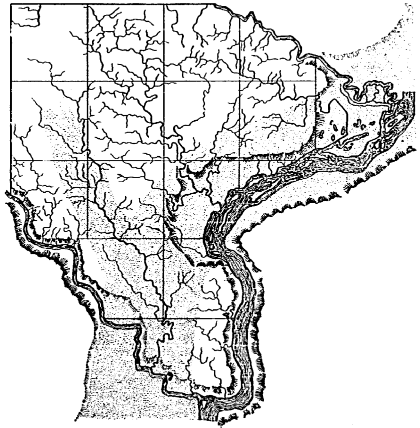


Figure 21. Preglacial Channel of the Mississippi River.

Between the mouth of the Skunk river and Montrose the old channel coincides with the present valley of the river which has been partly re-excavated along the eastern margin of the older valley. From Montrose it sweeps with a broad westward bend to the Des Moines river which crosses it below Sand Prairie. The comparatively narrow rocky gorge within which the river now flows from Montrose to Keokuk is itself suggestive of its more recent origin than the broad valleys above and below bordered for the most part by drift-covered slopes. Along the western bank, above Montrose, rock exposures are only seen on Lost creek, about one and a half miles west of Wever; on East Sugar creek, west of Viele, at the crossing of the Burlington and Kansas City railroad, and in the northwestern part of Charleston township well back from the bluff on Painter creek. These points are taken to indicate the limits of the channel here. Westward from Keokuk the indurated rocks disappear just above the railroad bridge over the Des Moines and do not again appear in the bluffs until Sand Prairie is reached. A further surface indication of the existence of the channel between Montrose and Sand Prairie is seen in the crescentic alluvial plains found at these points, the former of which is a result of the efforts of the Mississippi river to recover its old channel; and the latter apparently due to the agency of the Des Moines.

Several deep wells put down recently at Fort Madison all agree in indicating a great thickness of clay and sand below the present river level. The thickness of this deposit varies from 175 to 190 feet according to the location of the well, and when reduced to sea-level shows the rock bed to lie at an elevation above tide of 365 to 380 feet. A few miles southwest of Fort Madison, at Mount Clara, where the elevation of the surface is 679 feet, a boring put down showed the rock bottom to be 364 feet above tide level. As the extent of the channel indicates an advance stage in base leveling, the slope of the river bed from Fort Madison to Mount Clara should be slight, and this seems to be borne out by the figures except in the case of the well at the paper mill which shows an elevation of 379 feet for the rock bottom. At Montrose, which is only two miles northeast of Mount Clara, the low water mark of the river is 500 feet above tide. The bottom of the old course, therefore, is 136 feet below present low water level, or about 130 feet below the bottom of the new channel.

The width of the ancient channel is about six miles, which is about the size of the present rock-gorge which the stream now follows in the revived course above Fort Madison. The river in preglacial times probably did not exceed its present dimensions at least very greatly, and after cutting down its channel in its early history, its subsequent efforts were directed to widening the valley in which it alternated from side to side until it reached the limits indicated upon the map. The accompanying cross-section from Sonora to Argyle (plate XXVIII, figure 2) illustrates the relative sizes and positions of the two channels.

COAL.

Lying on the extreme eastern margin of the western interior coal field, Lee can never be expected to rank among the important coal producing counties of Iowa. At the same time the coal deposits, though necessarily limited, are sufficiently large to be of considerable commercial value; and supplies for local demands and even shipment may be furnished. For many years mining has been carried on in a rather desultory manner; and the veins still continue to be worked from time to time. The principal places where coal is now known to exist in workable thickness are in the northern part of the county near the center of Pleasant Ridge township and in the northeastern portion of Franklin township; also in the extreme southern part of the district a short distance both north and west of the city of Keokuk.

Pleasant Ridge Township.— Coal Measure rocks cover the greater part of the northern two-thirds of this township. They form a portion of the area which extends northward through southern Henry county. The chief openings in this district are those which have been made on Sutton creek, about five miles northwest of Denmark and a couple of miles from the Skunk river (Tp. 69 N., R. V W., sec. 16, NE. qr., NE. ¼). The coal is obtained both by drifting and stripping. Formerly considerable quantities were mined, the output going chiefly to West Point and the surrounding country. Among the old openings the Norris mine was perhaps the best known. At the present time none of the places are worked systematically, the local supplies being obtained chiefly by desultory stripping along the creek bottoms where the coal is two and one-half feet or more in thickness.

Two miles to the eastward (sec. 14, NE. qr., NW. ¼) coal has been obtained for years to supply local demands, but none of the openings are now operated. An outcrop near the road shows the following section:

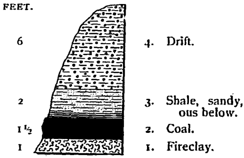


Figure 22. Outcrop northwest of Denmark.

Along the creek near by, sandstone, shales and the Saint Louis limestone are exposed at a somewhat lower level. The coal bed has a very appreciable dip to the west and probably thickens in that direction. The probability of a basin of considerable extent is also shown by the fact that coal has been taken out just west of the township line and a short distance east of the village of Saint Paul.

Marion Township.—There are in this township two areas of Coal Measure deposits which are separated from each other by a broad belt of older rocks. The principal opening is the Stevenson mine a short distance east of Saint Paul (Tp. 69 N., R. VI W., sec. 14, SE. qr., SE. $\frac{1}{4}$). Like many of the other mines of the county it is only operated at irregular intervals, usually during the winter. About a mile directly south a thin seam crops out in the bed of a small ravine. Overlying it are several feet of black shale and light-colored clay. Three miles southwest of Saint Paul (sec. 33, SW. qr., SW. $\frac{1}{4}$) is a small shaft which has supplied considerable coal for local use.

Franklin Township.—About four-fifths of Franklin township is occupied by the Coal Measures; and coal has been mined at a number of places. The most extensive mining in the county has been done here and the thickest seam so far found in this region has been opened.

Two miles from West Point coal has been obtained in small quantities for many years. Above the road leading directly west from the town recent washouts have exposed a vein of coal varying from one to two feet or more in thickness, and underlain by a good fire-clay (Tp. 68 N., R. VI W., sec. 1, NE. qr., NW. $\frac{1}{4}$). One and one-half miles south, in the valley of a small branch, are the abandoned workings of a mine which formerly was operated to satisfy local demands.

Three miles to the west, on Sugar creek, or about five miles from West Point and one mile northeast of Denver postoffice there are several openings. The most important mine is the old Hardwick (Tp. 68 N., R. VI W., sec. 4, NE. qr., NE. ¼). It was formerly worked by means of a shaft, which is now abandoned; and the coal is now reached by a drift in a ravine. Coal was at one time taken out of this mine in sufficient quantities to afford abundant local supplies. The vein dips to the south and west and is said to be from three to three and one-half feet in thickness. The relation of the shaft to the drift is indicated in the accompanying cut (figure 23).

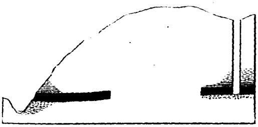


Figure 23. Relations of Drift and Shaft Openings at Old Hardwick Mine.

The details of the section at the mouth of the opening of the drift are:

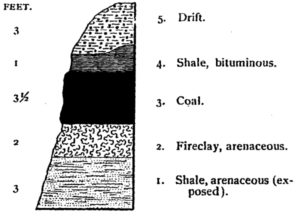


Figure 24. Coal Bed at Old Hardwick Mine. Near West Point.

A mile directly south of the Hardwick mine several openings have been made at various times on a tributary of Sugar creek (sec. 10, NW. qr., NW. $\frac{1}{4}$), where the following section was measured, the lower half being the the Saint Louis limestone.

Section, Northeast of Donnelson.

		FEET.
8.	Drift	10
7.	Coal	2
6.	Fire clay	2
5.	Sandstone, soft, quartzose	5
4.	Limestone, coarse, irregular, fossiliferous	2
3.	Shale, calcareous	1
2.	Limestone, fine and shaly	3
1.	Limestone, sandy, thinly bedded (exposed)	8

Coal is said to occur also to the north in section 3, (northwest quarter) and directly southward in section 15 (southwest quarter).

Van Buren Township.—Although the Coal Measures are known to occupy fully one-half of the surface of the district no mining has been carried on. On the opposite side of the Des Moines river, in Missouri, several mines were formerly in active operation. In Van Buren county, within half a mile of the Lee boundary, coal is also being taken out in considerable quantities and the same seam doubtless extends eastward into Lee county.

Jackson Township.—In the vicinity of Keokuk the principal places yielding coal are below the city, above Nassau slough.

A section near one of the openings is as follows:

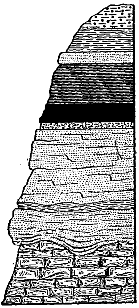


Figure 25. Section at Top of Bluff on Mississippi River at Nassau Slough. Below Keokuk.

		FEET.
8.	Drift	2
7.	Shale, blue, argillaceous (exposed)	2
6.	Sandstone, ferruginous, irregularly bedded.	1
5.	Shale, dark, fissile, many small concretions.	3½
4.	Coal, thickening slightly northward	1½
3.	Fire clay	½
2.	Sandstone, variable in thickness, with irregular bands of clay shale, resting unconformably upon the next	10
1.	Limestone, gray, compact, brecciated (Saint Louis formation)	5

Below number 1 of the above section the full thicknesses of the Saint Louis limestone, the "Warsaw," the "Geode" bed, and part of the Keokuk limestone are exposed. The coal mined here is of very good quality. It has been worked at different times during the last thirty or forty years. No coal, however, appears to have been taken out during the past three or four years.

North of the city, in the bluffs near Rand park, coal was formerly mined by means of drifts. Very little coal was taken out at this point, and the entry is at present blocked or filled by débris from the fallen roof. The position of the coal bed at Rand park is shown in figure 18.

A short distance away, at the place where the coal was mined at one time, the section is:

		FEET.
6.	Drift	20
5.	Shale, dark colored	6
4.	Coal	1½
3.	Fire clay	½
2.	Sandstone, brown, coarse grained	10
1.	Limestone, brecciated (Saint Louis), exposed	8

Six miles to the north, near Nashville in Montrose township, there is a small isolated basin of Coal Measure sandstone, on the crest of the bluff; but no coal is known to be associated.

BUILDING STONES.

Lee county is well supplied with stone suitable for all ordinary constructional purposes. Nearly the entire county is underlain by the Lower Carboniferous limestones, every member of which affords a good grade of stone. Although the limestones vary greatly in quality and texture in the different parts of the county, those supplied by each geological formation may be readily distinguished from that yielded by every other.

The Burlington beds are made up largely of an encrinital limerock, that is, it is a coarse-grained, somewhat crystalline limestone formed almost entirely from the skeletal remains of crinoids, cemented by fine lime material. In color it varies from a brown to a pure white. It is very durable and may be used for all constructions, including those which are especially exposed to weathering influences. The rock is easily quarried and readily dressed. The thick ledges may be used for dimension work of all kinds.

The Keokuk limestone is, as a rule, a compact, rather hard, often sub-crystalline rock, of an ashen or bluish color. Its fracture is even, sometimes however, approaching conchoidal; although often encrinital it is rarely so markedly sub-crystalline as the Burlington. The more pronounced encrinital parts are usually confined to particular layers and do not make up the bulk of the formation, as in the case of beds immediately beneath. The quarry rock of the upper part of the Keokuk, often called the Warsaw, is chiefly a magnesian limestone, containing some sand and fine pebbles. It is generally called "sandstone." The principal quarries in it are at Sonora, on the east side of the Mississippi, and it consequently goes under the name of Sonora sandstone. It is a massive layer six to twelve feet in thickness, bluish or yellowish when first taken out, but after exposure to the weather for a time turns to a buff or brown. It is very durable. Buildings in Keokuk erected of it nearly half a century ago have still the tool marks preserved nearly as fresh as the day when made. For dimension work it is largely used; and wherever dressed stone is required. The Westminister Presbyterian church, several large residences and other buildings have been constructed of this stone; besides the sills and caps of a large number of other structures. It has also been used for bridge piers, dam locks and other works of a similar character, where great durability is required.

The Saint Louis white limestone differs from all the other quarry rocks of the county in being a fine-grained compact limestone breaking with a very marked conchoidal fracture. Usually the color is bluish or gray. Some layers are very similar to lithographic stone and have been used for this purpose to some extent.

The sandstones are more or less ferruginous, coarse-grained and massive. They are rather soft, but usually sufficiently indurated to be a fairly good grade of stone when carefully selected. The sandstones are all Coal Measure deposits. The so-called Sonora "sandstone," as already remarked, is in reality a buff limestone with siliceous grains scattered through it.

Jackson Township.—By far the greatest amount of quarrying in the county is carried on in and about the city of Keokuk. The principal places where quarries have been opened are along the Mississippi river at the base of the bluff, along Soap creek in the western part of the city, and in the northern part of the city above Rand park.

The blue limestone of the Keokuk affords the greater part of the quarry work, but the Warsaw beds of Hall and the Saint Louis also furnish considerable material. The Coal Measures supply a small amount of soft sandstone. A considerable quantity of stone is shipped away both by river and by rail. The transportation facilities are exceptionally good; for in addition to the waterway, several lines of railroad enable the output to be distributed in all directions. The Chicago, Rock Island and Pacific, the St. Louis, Keokuk and Northwestern, the Keokuk and Western, the Keokuk and Northwestern (a part of the Burlington system), and the Toledo, Peoria and Western (a branch of the Wabash system), all afford means of reaching good markets.

In the eastern part of the city of Keokuk small openings have been made for a distance of two or three miles along the river bluff. The principal quarries are, however, below the Union railroad station.

Near the Chicago, Rock Island and Pacific freight depot, on the corner of Timea and Water streets, is the

McManus and Cameron quarry, which has been opened in the Keokuk limestone. The rock is used chiefly to supply local demands, though some stone is shipped west into Iowa and Missouri for a distance of fifty to seventy miles. The local supplies are about equally divided between macadam and building material; some broken stone for riprap along the river is also furnished.

A short distance below is the quarry of Kelley Brothers, near the St. Louis, Keokuk and Northwestern freight depot. The stone is used chiefly for building purposes and macadam, though during the past two or three years the quarry has not been worked much.

Still farther west, beyond the mouth of Soap creek, and between H and G streets, is the new city quarry, which has been opened scarcely a year. The stone is used principally for macadam, for foundation walls and the construction of street gutters. During the first ten months of the present year about 5,000 yards of macadam were taken out. Ten quarrymen and five teamsters are employed.

Near by is the Coyle quarry. Much of the rock taken out is for macadam, though most of what is known as the "white ledge" is used for building purposes.

In the vicinity of the planing mill, and a short distance beyond the Coyle place, is the newly opened Harris quarry, employing for eight months in the year from two to twenty-five men. The rock is loaded directly on the cars and shipped chiefly to points west along the Chicago, Burlington and Quincy system.

Still farther westward, in Nassau addition, and a short distance west of the Rand lumber yard, is the Tigue quarry, which is one of the oldest openings in the vicinity. It has been in operation for more than thirty years. The section shows:

		FEET.
4.	Drift	8
3.	Limestone, thinly bedded, with considerable calcareous shale	6
2.	Limestone, more massive than 3	9
1.	Limestone, rather sandy, with shale partings (exposed to railroad track)	14

This is near the location of the old McGavic mill. A complete section of the bluff at this point is given as one of the standard sections for Lee county.

A short distance to the west, within half a mile of the railroad bridge crossing the Des Moines river, is the "sandstone" quarry of Tigue & Son. The stone is the massive Warsaw magnesian limestone, which contains some grit in the form of fine grains and small rounded pebbles of white quartz. The output is almost entirely for bridgework and sills.

In the western part of the city of Keokuk, along Soap creek for a distance of fully one mile, quarries have been opened at a number of points, the principal openings being near the Seventh street bridge. The section of the rock exposure near the mouth of Soap creek has already been given.

Below Seventh street is the Conroy quarry, situated on the east side of the creek. The output is chiefly macadam and material for foundations. A short distance above, near the corner of Eighth and Cedar streets, is the McManus and Tucker quarry. The stone is used chiefly for foundations. From fifteen to twenty car loads are shipped annually over the Chicago, Rock Island and Pacific railroad. The section at this point is as follows, number 1 being used chiefly for dimension work:

		FEET.
5.	Shale, disintegrating	2
4.	Shale, calcareous, bluish, with thin limestone bands.	6
3.	Limestone, heavily bedded, rather coarse-grained, dark, somewhat encrinital, with some chert	4
2.	Shale, drab, with thin bands of limestone	3
1.	Limestone, heavily bedded, generally sub-crystalline (exposed)	8

On the opposite side of the creek is the Coyle quarry, which works in practically the same layers as shown in the McManus and Tucker section. Only about three or four feet of lower limestone is taken out, the chief supply being from the central encrinital limerock.

There are other small quarries along Soap creek which are worked in a desultory manner for local supplies of foundation stone.

In the northern part of the city of Keokuk, near Rand park, several small openings have been made in the Saint Louis limestone, which at this point supplies a rude flagging that is used largely for sidewalks and street crossings. The stone splits readily in layers two to five or six inches in thickness and slabs several feet square may be readily obtained. The vertical extent of the bed is about fifteen feet. The principal place from which stone is taken out is at the Fowler quarries, which are located on both sides of a small, deep ravine near the crest of the bluff, about three-fourths of a mile directly northwest of the park. The section shows:

		FEET.
5.	Limestone, gray, flag-like, in layers 2 to 5 inches thick, irregularly bedded	10
4.	Limestone, compact, fine-grained, brecciated, with much green clay between the fragments	6
3.	Limestone, very hard and compact, brecciated, but finely cemented	2
2.	Limestone, buff, massive, sandy and somewhat magnesian	6
1.	Shale, blue (exposed)	2

Three miles above the city, near the mouth of Price creek, is the McManus and Cameron "sandstone" quarry. The rock is the seven-foot ledge of the sandy, magnesian limestone which occurs at the top of Hall's Warsaw. The opening has only recently been made; and the rock is used chiefly for caps and sills and the foundations of the better class of buildings. Near the quarry the section is:

		FEET.
5.	Drift	10
4.	Shale, calcareous	3
3.	Limestone, gray, somewhat arenaceous at the top	15
2.	Limestone, dark blue, with some chert	4
1.	Limestone, gray (exposed)	2

Des Moines Township.—In the eastern part of the township there are no exposures of rock suitable for building stone. Along the Des Moines river the first outcrop met with is in the vicinity of Sand Prairie. A mile west of the station the Saint Louis limestone crops out in several of the ravines opening into the Des Moines valley, and from these stone is sometimes taken out for local use. One-half mile above Hillsdale is the Deamude quarry, which is worked chiefly for the Chicago, Santa Fé and California railroad. The section shown is:

		FEET.
6.	Clay, yellow above, gray below	6
5.	Limestone, brecciated in pockets of green clay, sometimes rudely and coarsely stratified	30
4.	Limestone, blue, encrinital	3
3.	Shale, blue, calcareous	3
2.	Sandstone, blue, calcareous, with discontinuous beds of blue shale, the principal quarry rock	8
1.	Shale, blue	15

The stone is used largely for bridge work; the rubble and small sizes are made into material for concrete. From fifteen to twenty men are employed; and the Chapman steam drill is used.

In the same vicinity is another quarry which has been opened by the Chicago, Rock Island and Pacific railroad. In the northwestern part of the township, a short distance below Belfast, is the McEwer quarry (Tp. 66 N., R. VII

W., sec. 1, SW. qr.). The stone is the same as the Deamude quarry farther south and is used largely for bridge building by the railroad.

Montrose Township.—Six miles north of Keokuk, near Ballinger station, a quarry has been recently opened by McManus and Tucker in the Warsaw magnesian limestone. The stone dresses readily and is used for dimension work of all kinds. It has been taken for the penitentary at Fort Madison, the building of the Canning Company and the high school. A dozen men are employed part of the time.

In the southern part of the town of Montrose a small quarry has been recently opened by Wardlow and Moor. The rock is used chiefly for foundation walls and well linings. The section of the quarry face shows:

	FEET.
4. Drift	4
3. Limestone, gray, coarse-grained, fossiliferous, thinly bedded at the top	4
2. Chert, in thin layers	1
1. Limestone, dark-colored, with hard shale parting (exposed)	2.

Many of the creeks in the vicinity have ledges of good stone exposed in their beds, and these outcrops are quarried in a desultory manner to supply local demands. Indeed nearly all the smaller streams entering the Mississippi river show rock ledges from which stone has been taken out in small quantities at various times for foundation and retaining walls and for the construction of the Des Moines canal.

Jefferson Township.—A large part of Jefferson township is occupied by an old channel of the Mississippi river so that only the extreme western and northern borders may be expected to furnish supplies of building stone. At the present time only two quarries are in operation. These are on Sugar creek, two miles above Viele station, in the northwestern part of the district. They are situated on opposite sides of the stream a short distance above the railroad bridge. On the west side of the creek is the Wemmer quarry (Tp. 69 W., R. V W., sec. 5, NE. qr., SW. ¼), which has been in operation in a small way more or less continuously for sixteen years. The exposed ledge is about twelve feet in height, rather thinly bedded above, but heavily bedded below, the layers being from two to three feet in thickness. The stone hardens greatly on exposure to the weather. The output is used chiefly in the surrounding country for foundation and retaining walls. The Applegate opening is in the same beds a few hundred yards to the westward on the west side of the creek; the stone is used in the same way as that from the other quarry.

Charleston Township.—The surface of this district being largely prairie upland, with no large water courses passing through it, and deeply covered by drift materials, there are few exposures of bed-rock. The principal place from which stone is obtained is from the Donnell quarry, which is situated about a mile southwest of Donnellson, on a small branch opening into Sugar creek (Tp. 67 W., R. VI W., sec. 5, SW. qr., SE. ¼.) The output is entirely local. The upper layers are used for walls and the lower ones for other building purposes. The section shows:

	FEET.
3. Drift	3
2. Limestone, broken	3
1. Limestone, yellowish, arenaceous, massive (exposed)	5

Elsewhere along the creek a white oolitic limestone is exposed. It is rather thinly bedded and may be taken out in large flag-like plates. It probably represents the Saint Louis limestone so well exposed in other parts of the county. In the eastern part of the township are a number of places from which stone is removed from time to time as needed n the immediate neighborhoods. On Panther creek (Tp. 67 W., R. VI W., sec. 13, NW. qr., NE. ¼) the Saint Louis beds form outcrops of considerable local importance.

Van Buren Township.— Little quarrying is now being done in the district. Thirty years ago in the days of slack water navigation there was an opening made half a mile northeast of Croton, where a massive yellow sandstone belonging to the Lower Coal Measures was taken out and used largely for the dams and locks in the Des Moines river. This stone is used scarcely at all now. There are also outcrops on Lick and Mumm creeks which often afford supplies for local use, but at none of these localities is quarrying carried on regularly. On the latter stream is the Harlan quarry. Near the mouth of Monk creek is also an opening furnishing stone to Belfast and the vicinity.

Franklin Township.— A considerable portion of the township being covered by Coal Measures, sandstones are exposed at various points. Over the rest of the district, however, limestones prevail. In the southwest the quarry rock is supplied from south of Donnellson; and in the southeast from the Graner place, in West Point township.

In the vicinity of Franklin there are a number of small quarries which afford all the stone needed for local use. The principal points are north of the town with two to the south. All are in the white, granular ledge of the Saint Louis limestone. One mile east of the town is the Edwin

Graner quarry (Tp. 68 W., R. VI W., sec. 25, NE. qr., NE. ¼) which has recently been opened. Flagging is the chief output. The church at Franklin has the area around it paved with this stone. One mile directly north of the Graner place is the Pardel quarry. Most of the stone taken out is dressed, and some of it has been sent to Fort Madison. The church at Saint Paul has also been constructed of it. Two and one-half miles directly north of Franklin on a branch of Sugar creek is a bluff 40 to 50 feet high which is made up chiefly of white limestone. One and one-half miles farther to the northwest (sec. 10, NW. qr., NE. ¼) near an old coal drift the following sequence of strata is shown:

		FEET.
16.	Drift	10
15.	Shale, black	2
14.	Coal (about)	2
13.	Fire clay (about)	1
12.	Sandstone, yellow	5
11.	Limestone	2
10.	Shale, laminated, calcareous	1
9	Limestone, yellow, magnesian and somewhat argillaceous	3
8.	Limestone, oolitic, in flag-like layers	8
7.	Limestone, white, concretionary	2
6.	Limestone, oolitic, more massive than number eight	6
5.	Limestone, somewhat irregularly bedded	5
4.	Shale	1
3.	Limestone, oolitic, irregular and flag-like	2
2.	Limestone, argillaceous	2
1.	Limestone, nodular and brecciated (exposed)	3

Some of the layers are utilized for foundation and retaining walls. At several other points on the same stream quarrying has been carried on in a small way.

West Point Township.—The available stone for building purposes in the West Point district is almost entirely from the Saint Louis limestone. The principal openings now in operation are in the western part of the township.

Two miles northeast of Franklin is the Kiener quarry (Tp. 68 N., R. V W., sec. 18, NE. qr., NE. ¼) where a white limestone of fair quality is taken out to supply local demands. One and one-half miles south of the last mentioned location and about the same distance directly east of Franklin the Graner quarry has been opened in the bluffs of Sugar creek (Tp. 68 N., R. V W., sec. 30, NW. qr., NW. ¼). The face of the quarry displays the following layers:

	FEET.
10. Drift	10
9. Limestone, white, granular, oolitic, evenly textured, more or less distinctly cross-bedded	8
8. Limestone, sub-crystalline	2
7. Limestone, blue, concretionary	1
6. Shale, blue	½
5. Limestone, granular, oolitic	6
4. Limestone, brecciated	10
3. Limestone, brown, arenaceous	8
2. Shale, blue	10
1. Shale, blue, with geodes	20

Beds 5, 7, and 8 dress well and are used in making tombstones. Number 3 is used for all kinds of rough masonry and for bases for monuments. All the layers are used for manufacturing lime, but number 7 is the best for this purpose.

Three-fourths of a mile to the south on Little Sugar creek (sec. 30, SW. qr., SW. ¼) a fine white sandstone is exposed near the top of the bluff and quarries have been opened in it. The stone hardens on exposure and forms a moderately good constructional material. Below the sandstone a good limestone crops out which is similar to the best layers of the Graner opening. The Judy quarry, from which stone has been quarried for more than thirty years, is about midway between Viele and Franklin in the northeast quarter of the southwest quarter of section thirty-two. The rock is a brown arenaceous limestone which has been used for all kinds of foundations and bridge work. Lime was formerly burned at this point, the stone used coming from layers above the present quarry ledges. There are numerous other places where extensive quarries might be opened, all of which would have good transportation facilities.

Washington Township.—The chief outcrops of building stone occur in the northeastern part. On Lost creek, a short distance west of Wever station, considerable rock has been removed for constructional purposes. The Lange quarry is the principal opening; and it is located near the Lost Creek church Tp. 68 W., R. IV W., sec. 12, NW. qr., SE. $\frac{1}{4}$). The output is entirely local and is chiefly utilized in foundation walls. One-half mile west is the Hayes quarry and three miles farther upstream (sec. 4, NE. qr., NW. $\frac{1}{4}$) is the Eoff place, which has been opened for nearly twenty years. Other small openings have also been worked from time to time along Lost creek.

Green Bay Township.—The greater portion of the district being occupied by alluvial flood plains little building stone is to be expected. Only one opening is now being worked. This is the O'Neil quarry, which is located one mile north of Wever and a short distance west of the St. Louis, Keokuk & Northwestern railroad bridge over Skunk river (Tp. 69 N., R. III W., sec. 32, SE. qr., NE. $\frac{1}{4}$). The quarry is in the Lower Burlington limestone. The section presents:

		FEET.
7.	Drift	3
6.	Limestone, light buff, encrinital	3
5.	Limestone, sandy, soft	1½
4.	Limestone, brown	1
3.	Limestone, light brown with band of chert	1
2.	Limestone, brown	3
1.	Hidden to water level	30

Denmark Township.— Along the Skunk river, which forms the entire northern boundary of the township, an abundance of good building stone is easily accessible. The Burlington, Keokuk and Saint Louis limestones are all present in force. In South Augusta considerable stone is removed from the bed of the river, which at this place passes over rapids. Also in the ravines of the neighborhood numerous small openings have been made. On the north side of the river are several quarries. Directly north of the town of Denmark stone has been obtained for foundation walls in the crest of the bluff (Tp. 69 W., R. IV W., sec. 17, NW. qr., NE. ¼) and elsewhere along a small ravine some distance from the river.

Pleasant Ridge Township.— Several quarries are in operation, the principal ones being the Klopfenstein and the Bascomb, the former being situated two miles northwest of Denmark (Tp. 69 N., R. V W., sec. 13, NW. qr., SW. ¼). The rock quarried is chiefly the oolitic bed of the Saint Louis limestone. It has a workable thickness of about twelve feet. There are over twenty feet of ordinary limestone also worked. The second quarry, the Bascomb, is in the northern part of the township (section 3, southwest quarter). It is also in the white Saint Louis limestone, and supplies local demands. Other small openings in the northwestern part of the district are the Kennedy (section 16) and the Balm (section 14).

Marion Township.— In the southeastern corner of the district is the old Jarret quarry (Tp. 69 N., R. VI W., sec. 36, NW. qr., NW ¼). The rock is a nodular somewhat cherty limestone, rather regular in bedding but not very uniform in texture. Farther up Sugar creek is the Pilot Grove quarry from which bridging, flagging and foundation stone are taken out. The section is:

		FEET.
6.	Drift	6
5.	Limestone, thinly bedded, with some chert and clay partings	5
4.	Limestone, gray, compact	2
3.	Shale, bluish, calcareous	½
2.	Limestone, bluish gray, brecciated	5½
1.	Limestone, brown, fine-grained, arenaceous (exposed)	2

CLAY DEPOSITS.

CHARACTER AND DISTRIBUTION.

For a district in which the bedrock is so prevailingly calcareous, Lee county is well supplied with clays suitable for all of the ordinary uses to which that material may be put. Aside from the superficial deposits which mantle the entire district several of the geological formations furnish a good grade of clay. Principal among these are the Coal Measures; though the Warsaw beds have recently been brought into use successfully, and it is expected that the Kinderhook shales, which are utilized so extenively farther north at Burlington, will soon be drawn upon.

Kinderhook Shales.—The lowest geological formation which may be profitably used for the manufacture of clay products is probably the Kinderhook. The shales of this division are so well adapted to the making of a high grade of paving brick that they will doubtless come into extensive use for this purpose. These beds, which are some seventy-five feet above the water level of the Mississippi river at Burlington a few miles beyond the northern boundary of the county, and at Hannibal, forty miles to the south, have their nearest surface exposure in the vicinity of the mouth of the Skunk river. There they may be encountered near the water level, but from this point southward they get to be lower and lower until, in the southern part of the country, they are fully 150 feet beneath the river level, and on the bluffs, 250 to 325 feet beneath the surface. The Hubinger Brick Company at Keokuk are, at the present time, sinking a shaft for the purpose of utilizing these shales at their plant in the western part of the city, and it is expected that they will obtain suitable material in the neighborhood of 300 feet. So far as is known this is the first attempt to work the Kinderhook shales in Lee county.

Warsaw Shale.—Although well exposed in many places in the county, the only point where these shales are utilized for clay products is in Keokuk, at the Hubinger Brick Works. As a rule these shales are too calcareous for the manufacture of good brick and the presence of numerous thin bands and nodules of limerock interferes with their usage for this purpose without special treatment. At the Hubinger place these difficulties are readily overcome. The last mentioned interference is removed by running the material through a disintegrator, and the first by the proper mixture of the ground clay with other varieties. In different places the Warshaw shales vary very considerably in lithological characters, in some localities the clayey portions predominating, in others the calcareous parts. With proper care in selection of sites a large part of the Warsaw shales might be readily utilized for brickmaking purposes.

Coal Measures.—The shales of the Coal Measures occupy considerable areas in Lee county. They are well distributed, and, although chiefly belonging to Carboniferous outliers, extensive pockets of clay shale occur in one-half of the townships. In many places coal sufficient to burn the materials might be taken out with the clay. In other localities but thin seams of coal are present, yet an abundance of good clays often exists even where there are no coal veins. The drab and yellow shales are well adapted for the manufacture of brick. The clays underlying the coal are suitable for making refractory products and, when properly mixed with other clays, for paving brick. Some of these light colored clays, when sufficiently free from grit, are excellent for pottery ware, and are widely used in other parts of the state. On the whole the Coal Measure shales are the most valuable beds in the county for supplying raw materials for the making of all kinds of ordinary clay products. The northern and western borders of the county and the northcentral portion are well supplied with these deposits. Several areas sufficiently large to supply the surrounding region for centuries exist in the vicinity of Keokuk, one north of Rand park and the other above Nassau slough.

Till.— The drift or superficial deposits of the county belong to what has been commonly called the lower till. It is composed of two rather distinct subdivisions; the basal part, known as the blue boulder clay, and the upper portion, which is known as the yellow boulder clay. The lower member, though much thicker, is as a rule seldom well exposed at the surface, and is rarely utilized for making clay goods. It will never be an important formation from which to obtain clay for commercial purposes, for the reason that the yellow boulder clay everywhere overlies it and is much more accessible. The "yellow" boulder clay is yellowish or light brownish to gray in color, with bands or lenticular masses of coarse sand and occasionally pebbles and boulders of crystalline rocks. Frequently calcareous concretions are present. Owing to these characters, most of the clay cannot be used to good advantage in making even the ordinary clay products.

Loess.—This is the fine siliceous material which is found capping the bluffs everywhere in southeastern Iowa. Though differing somewhat from similar deposits in other parts of the state in some of its physical characters it preserves on the whole its characteristic brownish to ashen color, homogeneous texture and fine silty structure. The material just as it comes from the excavation is not very well adapted to making brick and must be mixed with other clays or receive special treatment to destroy a distinct jointed structure which it possesses.

Alluvium.—For ordinary brick the alluvium has been utilized to some extent in various localities. Its distribution is chiefly along the Des Moines, Mississippi and Skunk rivers, though narrow bands are also present on some of the larger creeks.

For the manufacture of ordinary building brick the loess, till and alluvial clays are used. These are found everywhere in the county but usually only a rough sand-rolled brick is made. Certain of the loess deposits would doubtless afford a good material for a high grade of pressed facing brick.

The paving bricks at present are made from the Warsaw shale and at but a single point. The Kinderhook shale will probably soon afford an unsurpassed quality of material for pavers although reached at only one point, at Keokuk. It will doubtless be a long time before other shafts are put down for this purpose. The Coal Measure shales which are so abundant in many parts of the county will yield unlimited quantities of the best clays for paving brick and in the future these deposits will also be drawn upon for road material.

Pressed and ornamental brick are now made only from the Warsaw shales. The Coal Measure clays and portions of the loess are manifestly superior for general purposes though a very excellent product is made from this Warsaw shale at Keokuk. Fire brick, furnace linings and all ordinary refractory articles may be readily manufactured from the Coal Measure clays which lie immediately beneath the coal seams or highly bituminous shales. Pottery clays are yet only known in Lee county in the Coal Measures. At Donnellson they have been used for some years.

CLAY INDUSTRIES.

Keokuk.—The Hubinger Brick Company has the largest and most complete plant in the county. It is situated in the valley of Soap creek near the cemetery in the western part of the city of Keokuk. It has been in operation three years, and was erected especially for the purpose of manufacturing pavers and high grade building brick. The Keokuk and Northwestern railroad, a branch of the Burlington system, affords good shipping facilities, the output being loaded directly upon the cars as it is taken from the kilns. Several varieties of clay are used, the chief one being from the Warsaw beds. Surface clay is also utilized. As already mentioned an effort is being made to mine the Kinderhook shales and for this purpose a large shaft is now being put down in order to reach them. It is thought that it will be necessary to sink about 300 feet in order to secure the proper material. Two-thirds of this distance has already been passed through. In addition to the Warsaw shales now used, a loess-like material is obtained on the slopes near the plant; this is used chiefly in combinations. The raw material is very thoroughly treated. It first goes through a Potts disintegrator, from which it passes into a dry-pan and then through a twelve-mesh revolving screen of the

Williams pattern. The finely sifted material is then elevated to an Andrus dry press or a Frey-Sheckler double dye, automatic, end-cut, stiff mud machine. The compact mud blocks are loaded on small cars and run into a four tunnel Chicago Ironclad dryer where they are left twelve hours. Two Raymond Columbian steam power represses are also in use. There are now five Eudally downdraft kilns in operation. They have a combined capacity of 800 000 brick. For the dry pressed brick seven days are consumed in water-smoking and seven days for properly burning. For the stiff mud bricks twelve days are necessary. A large variety of light colored and red building brick are made and a good line of pavers.

In the northern part of Keokuk is the Spaan brick yard. The output consists entirely of sand-rolled brick. These are made from an ashen silt or bleached loess. Only the upper fourteen inches is used.

The Worley yard is on Concert avenue, between Eighteenth and Nineteenth streets. Rarely more than a couple of kilns are burned each season. The clay used is the humus bearing silt, similar to that used at the Spaan place. The burnt product is used chiefly in the building of sidewalks.

Fort Madison.—There are several brick yards in this neighborhood, all using drift materials. One of the oldest yards is the Reichelt in the southwest quarter of section thirty-four of Washington township. It has been in operation for about thirty-four years. The clay used is the upland loess of the region and is taken out to a depth of three feet. Below this depth it assumes a jointed character and cannot be used to advantage. A Penfield plunger was formerly used, but this has been replaced by a stiff mud machine patented by the present operator of the yard. A Carnell & Co. hand repress is sometimes called into service. The kiln is a down draft rectangular pattern of the Reichelt patent, and has a capacity of 60 000 brick.

The Stillern yard is about one and one-half miles north of the town on the prairie upland. Previous to 1893 sand-rolled brick were made. Since that time a home made stiff mud machine has been in operation and a Miller hand press. The clay is the upland silt, or loess, and is taken to a depth of two feet. A short distance to the north is the Meyerthalen yard where brick have been made by hand for upwards of two score years. The material used is similar to that at the Stillern place. It is prepared by continually spading—an old style foreign method.

On the margin of the flood plain of the Mississippi is located the Hausmann yard. For several seasons hand made brick were turned out. Subsequently a Frey-Scheckler machine was used. At the present time an "Ohio No. 2" of the Freese & Co. pattern is in operation. Two grades of clay are used. One is the upland loess and the other the alluvial clay at the foot of the bluff. The former is dug to a depth of five feet; the latter may be used to a greater depth. Two and one-half miles north-west of the business part of the town is the Wigginjost yard. Upland silt to a depth of twenty inches is used. The soaked clay is spaded and respaded before being moulded. Near the northwest limits of the town, on the West Point road, is the Bartell yard. Sand-rolled brick are made from the upland bleached loess.

Donnellson.—At the west edge of town a small yard was opened in 1891. The brick were hand made from prairie soil and were used in building the school house.

At the junction of the two lines of railway was the new Pottery where all the common varieties of stone and earthenware were manufactured. The raw material was taken from the Coal Measures about three miles north of the place. The ware was a little grity but otherwise very good. The pottery has recently been moved to Farmington, a few miles to the west, in Van Buren county.

SANDS.

Sands suitable for building purposes are derived chiefly from the stream beds. The Skunk, Mississippi or Des Moines supplies at almost any point an abundance of good sharp river sand capable of uniting mortar in strong bond. On the smaller streams the sand is obtained from the bars which appear at low water. Along the Mississippi the sand which is dredged from the channel appears to be more satisfactory and is used in preference to that which may be obtained on the bars.

In the drift there are frequently lenticular beds of sand which might be readily utilized for building purposes. They are scattered widely over the entire region. Another source of sand is the soft sandstone of the Coal Measures which occupy a considerable portion of the county. These sandstones in places are quite incoherent or readily disintegrate on exposure to the weather, and often furnish a clean, sharp-grained material equal to the best river sand. Certain beds of the Coal Measure sands are pure white and are practically devoid of iron and other impurities and could probably be used for manufacturing the ordinary grades of glassware. Sands for moulding purposes in iron foundries are generally obtained from the drift beds the material found there being finer and more homogeneous than the river sands.

ROAD MATERIALS.

The subject of good highways has been agitated as much perhaps in Lee county as any other place in Iowa. There are probably few counties in the state which are possessed of superior materials for the betterment of the principal roads. As the matter of cost enters largely into the consideration of improvement, the use of materials is necessarily limited to a few kinds. In the cities and large towns macadam has been used almost exclusively heretofore, but its extension to country roads has been very limited. Vitrified brick, however, are now being successfully used for paving streets, and in the larger places elsewhere they are replacing everything else.

For the country highways there are in Lee county at least three kinds of material of wide distribution which may be made readily available. These are stone for macadam, gravel and burnt clay. The first of these may be found in nearly every part of the district. All of the limestone formations afford good ledges. The cost of preparation, of breaking the large blocks into sizes small enough for placing on the roads, is considerable, and hence this material could be used only on the leading and much traveled routes. Roads thus improved and properly cared for from time to time last indefinitely, and the cost of repairs is very slight if done in the right way. The location of suitable ledges is such that the transportation of material is reduced to a minimum.

The gravel beds are widely scattered. The rivers and larger creeks afford abundant material, as does also the drift. The distances over which it would be necessary to move the material would be greater than in the case of the stone for macadam; but for two or three miles in each direction considerable stretches of roadway might be covered.

Burnt clay is a material which has not come into use very extensively for roadways. Railways are using it largely in some places in preference to gravel and stone for ballast. Driveways to residences are frequently covered with it as it beats down, hardens and does not cut up or become muddy. This use might be widely extended. In the areas having coal the highly bituminous and other shales, mixed with poor grades of coal, could be readily used in road improvement. At the larger mines the "dumps" afford large quantities of clay shale already thoroughly burnt and the roads for several miles in either direction could be soon covered with the best of materials at merely the cost of hauling.

The materials for good roads are, therefore, abundant in Lee county and readily accessible on every hand. It remains for local enterprise to use them.

CEMENTS.

From time to time hydraulic rock has been reported from the southeastern part of the state. It has usually been associated with the coal bearing strata. Probably the dark gray calcareous band frequently found over coal seams is commonly referred to; but even if this were a high grade material for the manufacture of cement, the layers are seldom more than a foot or so in thickness and hence the cost of quarrying would be too great to render it profitable. An abundance of good clays is present in close proximity to the pure white Saint Louis limestones, and with coal also profusely at hand, paying plants might be erected at several points.

LIME.

Material suitable for the manufacture of quick lime is abundant in the greater part of the county. The Burlington limestone affords a fairly good grade of limerock and has been burned at a number of places a short distance north of the Skunk river. On the south side of that stream the same stone has also been burned at several points. The Keokuk limestone furnishes good ledges for lime and has been utilized at a number of points for many years. Keokuk and Montrose are the principal places. Most of the lime which has been burned in the county has been derived from the white Saint Louis limestone. At Keokuk and the vicinity, east of Franklin and northwest of Denmark, kilns have been erected and considerable lime manufactured during the many years they have been in operation. By the judicious selection and use of the magnesian limerocks a very superior article might be readily made, as dolomitic stones, those containing both magnesia and lime, are commonly regarded as making a better bond in mortars than when pure lime is used.

MINERALS.

Besides the deposits which are now being utilized there are a number of other minerals which are not mined at the present time. Some of these are found only sparingly or in quantities too small to be of value as commercial products, yet possess considerable worth as mineralogical specimens, and as such frequently command good prices on account of their beauty, rarity or scientific interest. Many minerals, particularly the metallic substances attract much popular attention, but occur in too limited amounts to pay for working them, yet they annually cause a great waste of time, energy and money in luring persons with the hope of hidden wealth. Some minerals not now attracting attention may in the near future develop into sufficiently important deposits to call forth both brawn and gold.

Copper.—Small masses of native copper have been picked up at various points, but it is not to be expected that this is any proof of the presence of copper in paying quantities; as the masses are derived from the drift and hence have been transported by ice from the copper regions of the north.

Gold.—Native gold being one of the most universally distributed of minerals occurs in the drift in small quantities where it has been concentrated through a natural process very similar to panning. The small deposits, though frequently arousing considerable local excitement, need not be taken anywhere in Lee county as an indication of quantities of commercial importance.

Silver.—Although this metal probably does not exist in commercial quantities in this part of the country, it is reported that certain layers of the limestone below the city of Keokuk have yielded so much as four or five ounces to the ton upon careful assaying.

Sphalerite.—Zinc blende or the sulphide of zinc, one of the commonest of zinc ores, is rather widely distributed in small quantities, sometimes occupying small cracks and crevices in the rocks, sometimes lining small cavities left by the remains of fossils or often occurring in geodes. In the latter place it is found in thin well crystallized masses associated with calcite and quartz. Some of the crystals found measure an inch along the edges which are quite sharp and well defined.

Pyrite.—Aside from the regular masses of iron pyrites the common sulphide of iron occurs abundantly in certain layers. Small pyrite crystals are abundantly scattered through many of the limestones and shales. In the bitumi-

MILLERITE ON CALCITE; KEOKUK.

nous shales of the coal deposits large quantities of this mineral are disseminated in fine particles, and also in irregular concretionary masses. Frequently pyrite is found replacing the calcite shells of fossils. Many of the geodes contain abundant crystals, usually small but with bright glistening faces and sharp edges. They often stud the interior of calcite and quartz lined grottos, sometimes sparingly, at other times forming almost a complete lining. Occasionally cubes are also found attached to the edges of calcite and quartz crystals.

Millerite.—The sulphide of nickel has been known to occur in very minute quantities in geodes. Recently it has been discovered in larger quantities in small cavities in the upper part of the Keokuk limestone at Keokuk and Fort Madison. As mineralogical specimens some of these are perhaps the finest ever discovered. The mineral occurs in fine yellowish filaments, penetrating crystals of clear calcite after the manner of the *fleches d'amour* or rutile needles in quartz; also in tufts of closely appressed needles. The cavities in which the mineral occurs vary from one upwards to twenty or more inches. These hollows have large thickly set rhombohedrons of calcite projecting in towards the center. The faces are brightly reflecting and the edges sharpely cut. In some of the calcites are found beautiful clusters of tufts having closely arranged brass colored needles of millerite protruding from the center of attachment in all directions to a distance of one and one-half to two inches. In some of the examples the tufts are made up of hundreds of fine filaments, often so close together that the needles of the different clusters are interwoven so as to form a dense matted mass. Often a perfectly transparent calcite has a tuft of long matted millerite completely enclosed; or a part of the tuft may be embedded in the lime crystal, the extremities of the needles projecting outside. Masses of the calcite thickly covered with the nickel bearing needles sometimes weigh over fifty pounds. The millerite at Fort Madison occurs in a similar way, the needles sometimes adhering to one another and forming bundles, often several ounces in weight.

Calcopyrite.— This mineral is found sparingly in small but very perfect crystals, in certain geodes occurring at Keokuk. It occurs enclosed in calcite, the crystal forms being the tetrahedron with the corners truncated. The crystallographic planes are brightly reflecting and the edges are clearly cut. Perfectly formed crystals from one-quarter to one-half of an inch in size are found frequently.

Quartz.— Though this mineral is rather widely distributed, the most interesting occurrences in Lee county are in connection with the geodes. The geodes are found scattered through a shale lying immediately above the Keokuk limestone, and the layers containing these are widely known locally as the "geode bed." The geodes are miniature grottos, lined usually with quartz crystals. In size they vary from a few inches up to two feet or more. They are usually more or less spherical bodies composed of shells of calcedonic quartz. Lining the inside of these shells are quartz crystals showing a large development of the prism, terminated by the fundamental pyramid. Often the quartz crystals are doubly terminated. Frequently large crystals of calcite rest on the quartz and the whole is frequently studded with small crystals of various metallic sulphides. Some of the geodes, instead of being lined with quartz crystals, have on the interior chalcedony in the form of botryoidal masses. Though as a rule the geodes are hollow, many of these are perfectly filled. The quartz geodes are generally confined to the lower part of the bed, while the calcite geodes occur most abundantly in the upper part. Usually the quartz is limpid, though some times milk-white, rose-colored or reddish.

Rutile.—In certain geodes there have recently been found some very minute yet very perfect crystals of a mineral which appears to have all the characteristics of rutile.

Limonite.—This is found sparingly in many localities as a pseudomorph after pyrite. Small quantites of the massive form are also found.

Calcite.—This occurs abundantly in the rocks of Lee county, filling narrow veins and crevices and lining small caverns. Beautiful crystals are abundant. In many of the quartz geodes, usually in those found near the top of the bed containing these bodies, single crystals of the calcite, showing perfect crystallographic faces, occur resting immediately upon the quartz points. Sometimes a single lime crystal will nearly fill the entire cavity. In the Keokuk limestone there are often small cavities which are lined with beautiful crystals of this mineral. The aggregates are arranged around a cavity just as in the geodes, but there is no quartz lining, the calcite being attached directly to the limestone. Among the most interesting crystal forms found is the fundamental rhombohedron which occurs abundantly. A very large series of rhombohedrons and scalenohedrons has been obtained among the Keokuk calcites. Beautiful specimens showing vicinal planes are also of frequent occurrence. The majority of all these crystals lining the limestone cavities are as perfectly transparent as Iceland spar.

Aragonite.—This form of lime, identical in chemical composition with calcite, but differing only in the system of crystallization, is occasionally found in geodes.

Dolomite.—Crystal forms showing the various planes occur in the magnesian limestones. The finest crystals, however, are met with in the geodes.

Kaolin.—A fine, snow white powder frequently found in the bottom of geodes appears to be the hydrous silicate of aluminium.

SOILS.

It is hardly necessary to direct special attention to the soils. For the most part those of Lee county are rich. The uplands are covered everywhere with a black loam-like humus to a depth of two or three feet. Although derived almost entirely from the drift, there are but few places and these quite limited, where the tenacious and untractable "gumbo" occurs.

Along the stream the alluvial bottoms are somewhat more sandy than the soils of the uplands, but seldom so arenaceous as to interfere with cultivation.

WATERS.

The waters may be divided into three classes: the surface, the artesian and the mineral. On the whole the county is well supplied with flowing streams. Over four-fifths of its boundary is made up of the largest streams in the state and into these flow several smaller courses which rarely run dry. Everywhere, it may be said, wells of moderate depth yield an abundant and never failing supply of good wholesome water. This is the case whether on the uplands or in the alluvial valleys. Springs of good water also occur in nearly every township. Some of these nearly fail during protracted periods when there is small rainfall, but others are never failing.

The artesian waters of the district are of particular interest. In the southeastern half at least and probably in all of the county the conditions are favorable for water supplies of this kind. The Keokuk syncline or trough underlies many square miles and the pressure is sufficiently great to produce flowing wells at most points at least. Depths of from 800 to 1000 feet usually reach the water bearing stratum. At Keokuk several wells have been put down at the top of the bluff and large reservoirs have been built to contain the overflow. The strata passed through by one of the principal wells — the Hubinger — are given in section number III in connection with the general geology.

The so called mineral springs which occur in various parts are similar to those which occur abundantly throughout the coal fields. But usually in Lee county they are too small to supply more than local demands for a water containing various sulphates.

The following is the record of the well put down by the Fort Madison Paper Company. The surface at the well is twenty-one and one-half feet above the water level of the river, which is 502 feet above sea level.

	THICKNESS.	DEPTH.
5. Black loam, quicksand and blue clay, not separated in the record, doubtless largely the last	145	145
4. Limestone	35	180
3. Shale, blue and white	250	430
2. Limestone	180	610
1. Sandstone (water-bearing)	77	687

The Atlee well which is about twenty-five feet above this, shows 190 feet of clay and alluvium, while the Hospital well, at nearly the same elevation, shows 185 feet. At the Paper Mill the rock surface is found at 379 feet above sea level, while the Atlee well and the Hospital well agree very nearly in placing it at about 365 feet.

At Mount Clara, which is situated at the summit of the divide, west of Montrose, a well put down on the Beck place shows the following arrangement:

		THICKNESS.	DEPTH.
12.	Clay	250	250
11.	Sand	55	305
10.	Limestone, white	25	330
9.	Shale, white	8	338
8.	Limestone	5	343
7.	Shale	325	668
6.	Limestone	115	783
5.	Limestone	10	793
4.	Limestone, flinty	25	818
3.	Limestone	40	858
2.	Limestone, hard	5	863
1.	Samples carried away by water	76	939

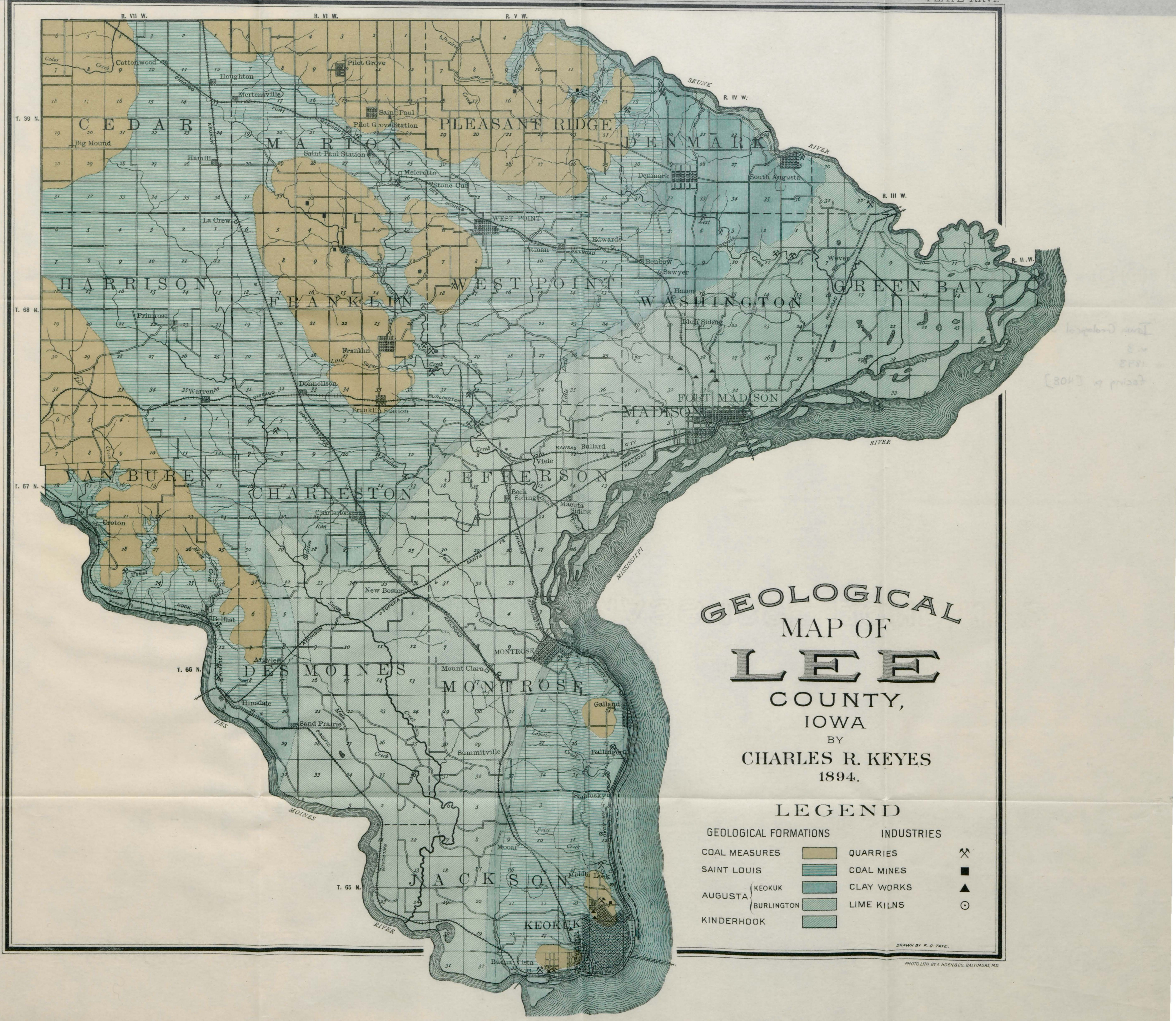
ACKNOWLEDGMENTS.

For much that is of value in the foregoing account, and for detailed mapping in different parts of the district, special acknowledgements are due to Mr. C. H. Gordon, now of Chicago University, who formerly resided at Keokuk. During that period he spent considerable time studying the local geology. In connection with his work on a neighboring county, he recently spent several weeks in Lee connecting his own work with what he had previously done, visiting certain parts of the district which needed further investigation, and settling doubtful points. His notes are

so full and excellent that they have been followed quite closely, in places.

Mr. Arthur J. Jones, of Iowa College, spent some days in connection with the work on building stones, and Mr. E. H. Lonsdale, who has charge of the work on clays, visited all the principal clay deposits while getting together material for his report on the subject. The notes of both have been freely referred to in the preparation of the sections on these subjects.

Mr. L. A. Cox, of Keokuk, has rendered timely assistance, and Mr. J. C. Hubinger, of the same place, has given aid freely. Dr. H. Morgridge, and Mr. Atlee, of Ft. Madison, furnished the records of the deep wells at that place.


GEOLOGICAL MAP OF LEE COUNTY, IOWA
BY
CHARLES R. KEYES
1894.
LEGEND
GEOLOGICAL FORMATIONS
COAL MEASURES
SAINT LOUIS
AUGUSTA { KEOKUK
BURLINGTON
KINDERHOOK
INDUSTRIES
QUARRIES
COAL MINES
CLAY WORKS
LIME KILNS
CEDAR
MARION
PLEASANT RIDGE
DENMARK
HARRISON
FRANKLIN
WEST POINT
WASHINGTON
GREEN BAY
MADISON
FORT MADISON
VAN BUREN
CHARLESTON
JEFFERSON
DES MOINES
MONTROSE
JACKSON
KEOKUK
MISSISSIPPI
DES MOINES RIVER
SKUNK RIVER
DRAWN BY F. C. TATE.
PHOTO LITH. BY A. HOEN & CO. BALTIMORE, MD.

GEOLOGY OF DES MOINES COUNTY.

BY

CHARLES ROLLIN KEYES.

ECONOMIC GEOLOGY OF DES MOINES COUNTY.

BY CHARLES ROLLIN KEYES.

CONTENTS.

PAGE

INTRODUCTION.

SITUATION AND EXTENT.

Des Moines lies on the eastern boundary of the state and is the second county above the south state line. Its areal extent is about 415 square miles. In outline it is roughly quadrangular, the Mississippi and Skunk rivers forming the irregular eastern and southern boundaries. The former stream separates the district from the state of Illinois and the latter from Lee county. Louisa county adjoins Des Moines on the north and Henry on the west.

PREVIOUS WORK.

It is very remarkable that, widely as the region under consideration is celebrated geologically, little or nothing has heretofore been done to set forth its economic resources. The rocks which are typically developed at the city of Burlington, where they were first described, and which are known everywhere under the name of Burlington limestones, stretch out over an area of more than one thousand square miles. The peculiar construction of the Burlington limestones, made up as they are of the skeletal remains of marine organisms closely related to the modern star fishes and sea urchins, makes the formation one of unusual interest. Burlington crinoids are known throughout the world as objects of surpassing beauty. They are sought for and highly prized everywhere. In consequence, a great deal of attention has been directed to the consideration of the fossils in the rocks, rather than the rocks themselves. Everything, therefore, which has been written concerning Des Moines county, with the exception perhaps of Worthen's short account, consists of descriptions of fossils, with only occasional incidental explanations of the local geological features.

PHYSIOGRAPHY.

SURFACE RELIEF.

As in Lee county, the surface of Des Moines forms an upland plateau having a slight inclination to the southeast. Interiorly the elevated plain is gently undulating, but much more rolling than in Lee county, on account of the character of the streams and the nature of the strata traversed by them. The eastern and southern margins of the plateau are abruptly cut off by steep declivities reaching in many places to the water's edge of the bounding streams.

The escarpment along the Mississippi river rises to a height of 150 to 200 feet above the flood plain of that stream. It is very much steeper in Des Moines county than either to the north or to the south. This is probably largely due to the character of the rocks, and the peculiar association and arrangement of the various beds. The massive, heavily bedded limestones forming the top of the bluff are underlain by much softer strata in the form of shales, which often occupy fully one-half of the vertical height of the section. The shales, disintegrating much more rapidly than the harder limestones, leave the latter standing out in bold perpendicular walls or overhanging cliffs. Along the Skunk river, the bluffs are not so rugged, but approach the lowlands in much more gentle slopes. Here the strata are more uniform, the shales in passing southward having dipped beneath the river level.

As is so characteristic of the county farther southward in Iowa, the general plateau border is dissected by small ravines and gorges, in which the minor water courses run. As they approach the escarpment the streams break into cascades. In passing back towards the interior the water courses quickly enter broad, shallow valleys.

INDIAN SPRING; NEAR BURLINGTON.

While the elevated plain which forms the greater part of the county has a surface gently undulatory, there is noticeable, in the center of it, a broad, shallow depression, occupied by the dentritic drainage system of the Flint river. The general plateau is thus subdivided into two smaller plains separated from each other by a shallow basin. Together they represent the original plateau surface.

The profile across the county, running westward from Burlington along the line of the Chicago, Burlington & Quincy railroad, indicates the more salient features in the topography of the district. The general uniformity of level is well expressed in the plateau surface, continuing to the very verge of the Mississippi escarpment. (Figure 26.) Another profile, constructed at right angles to the last, and extending from Burlington to the north county line along the course of the Burlington, Cedar Rapids & Northern railroad, expresses similar relations between the plateau surface and the escarpment, the latter here being represented by the bluffs along Flint river, though this feature is not noticeable in the profile, since the railroad follows down the valley of a stream. (Figure 27.)

The character of the relief of the region in the vicinity of the Mississippi escarpment is well exhibited in the neighborhood of Burlington. The area may be taken as

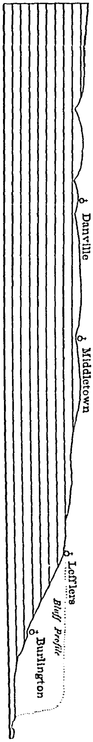


Figure 26. Profile west from Burlington, along C., B. & Q. Railroad.

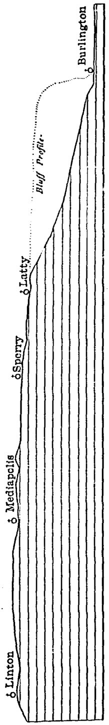


Figure 27. Profile north from Burlington, along B., C. R. & N. Railroad.

typical of the entire district. It is represented in the accompanying map (figure 34), constructed from street and railroad elevations and from lines run with level and rod. The highest portions to the west merge into the general level of the upland plateau; to the east they abruptly terminate in the precipitous bluffs bordering the Mississippi. The minor waterways, as Hawkeye creek and its tributaries, have trenched short, steeply inclined V-shaped courses. Flint river, in the northern part of the area mapped, presents the same features. For a number of miles, however, it has corraded its bed down nearly to the level of the water in the Mississippi, yet its lateral erosion has been slight, as is shown by the high mural bluffs on either side.

The highest place in the county is a few miles from Mediapolis, which has an elevation of 780 feet above sea level. The lowest point is at the mouth of the Skunk river, which is in the neighborhood of 499 feet above tide.

The lowland plains or river bottoms are comparatively unimportant, save in two places. The flood plain of the Mississippi, which is usually from eight to ten miles in width, is almost entirely on the east side of the stream. The river for fully one-half of its extent in Des Moines county hugs the west shore and leaves for much of the distance no space whatever between the water and the nearly precipitious bluff. The profile of the Mississippi gorge at Burlington is shown in figure 28. In the northern part of the county the flood plain of the Mississippi is for a short distance three or four miles in width, but it rapidly contracts to less than a mile, and finally, a short distance above Burlington, to practically nothing. In the southern portion of the county, at the mouth of the Skunk river, the flood plain of the west side of the great water course abruptly widens out for a short distance.

The flood plains along the Skunk river are quite narrow, being for most of the distance that the stream traverses Des Moines county, nowhere much more than a quarter of a mile in width.

Along Flint river the alluvial plains are also very narrow. Immediately above its mouth the stream for several miles flows in a narrow gorge; but farther on the valley widens out and narrow flood plains occur for some distance.

In the subjoined table the elevations above the sea level are given for all important places in the county.

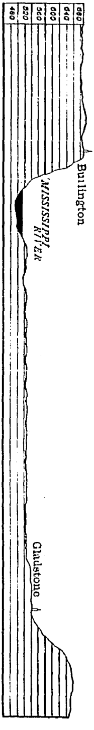


Figure 28. Gorge of the Mississippi River at Burlington.

Table of Altitudes in Des Moines County,

LOCALITY.	ELEVATION.	AUTHORITY.
Burlington—		
Low water.	511	Miss. Riv. Com.
High water.	527	Miss. Riv. Com.
Union depot.	533	Miss. Riv. Com.
Danville.	549	C., B. & Q. Ry.
Latty.	757	B., C. R. & N. Ry.
Linton.	771	B., C. R. & N. Ry.
Mediapolis.	779	B., C. R. & N. Ry.
Middletown.	727	C., B. & Q. Ry.
Patterson.	549	C., B. & Q. Ry.
Sperry.	757	B., C. R. & N. Ry.
West Burlington.	689	C., B. & Q. Ry.
Yarmouth.	696	B. & NW. Ry.

DRAINAGE.

Des Moines county is well drained. The Mississippi river, though passing along the entire eastern border of the district, drains directly but little of the region; most of the surface water being carried off by means of small streams before reaching the larger water course. The greater part of the rainfall which finds its way ultimately to the Mississippi is carried thither by two streams, the Skunk and the Flint.

Mississippi River.—As already stated, this stream traverses the entire eastern side of the county, flowing south, with a slight western deflection opposite Oquawka. Though meandering through broad alluvial flood plains, it flows along the southern half of its course in the county on the western margin of the gorge. In the northern part of the district numerous bayous and sloughs, which have at all times more or less direct communication with the river, occupy almost the entire flood plain. In times of high water the lowland plain from one side of the gorge to the other is covered by an unbroken expanse of water and the river is then from six to nine miles wide. The

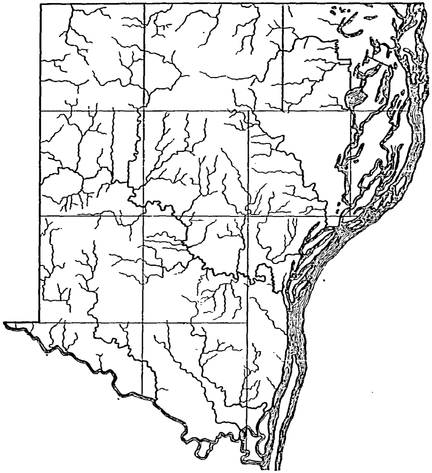


Figure 29. Drainage of Des Moines County.

drainage of the county, which goes directly into the Mississippi, is confined to that from small creeks which dash over the escarpment in foaming cascades. The principal creeks are Swank, Dolbree, Hawkeye, and Spring; Flint river and its tributaries coming in about midway between the north and south lines of the county.

Skunk River.— This stream, forming the southern boundary of the county, receives a number of small creeks. It drains about one-sixth of the total area of the district.

Everywhere except where it begins to meander through the flood plains of the Mississippi it flows in a narrow valley. The principal creeks flowing into it are Long and Bush.

Flint River drains about two-fifths of the county; and the entire central depression formed by its basin is a rather marked feature in the topography of the region. It rises in Henry county and flows southeastward, entering the Mississippi a short distance above the city of Burlington.

STRATIGRAPHY.

General Geological Relations.

Des Moines county lies entirely within the belt of Lower Carboniferous strata, which extends in almost unbroken continuity from the Minnesota line southward into Alabama and New Mexico. For the most part the rocks are massive limestones, though at the base there is a thick shaly member which, however, is not exposed except along the base of the Mississippi escarpment. In the southwestern part of the county several small outliers of Coal Measures exist.

Over all the stratified rocks a mantle of glacial drift is spread, greatly softening the effects of previous erosion. Only in a few places beyond the immediate neighborhood of the Mississippi bluff has the action of post-glacial waters cut through the drift sheet and exposed to view the indurated rocks.

The superposition of the various geological formations which outcrop within the limits of the county is indicated in the subjoined table:

Classification of Geological Formations.

GROUP.	SYSTEM.	SERIES.	STAGE.	FORMATION.
Cenozoic.	Pleistocene.		Drift.	Terrace. Loess. Till.
Paleozoic.	Carboniferous.	Coal Measures.	Des Moines.	Sandstone and shale.
		Mississippian.	St. Louis.	Brecciated and white limestone.
			Augusta.	Keokuk limestone. Montrose cherts. Upper Burlington limestone. Lower Burlington limestone.
			Kinderhook.	Shale and sandstone.

GENERAL SECTION.

The maximum vertical measurement of all the geological formations in Des Moines county taken together is approximately 560 feet. The greatest thickness shown in any one place is at Burlington, where outcrops sixty to one hundred and twenty-five feet are not infrequent. Of the general section numbers, 1 to 11 are best exposed perhaps in the neighborhood of Burlington (section I); 11 to 13 are well shown in the vicinity of Augusta (section II); numbers 13 to 15 are found outcropping in the extreme southwestern corner of the county (section III), as are also 17 and 18 (section IV). The quaternary deposits are well shown at many places and especially well along the crest of the Mississippi escarpment (North Hill section).

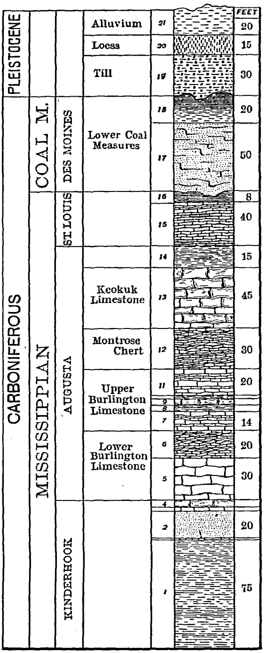


Figure 30. General Section of Geological Formations.

The few sections taken together represent all the strata exposed above the level of the streams in Des Moines county. They may be regarded, therefore, as indices to all the rock beds existing in the district, and all sections wherever found within its limits may be referred directly to them. Their position and close relations with other sections enable all the stratigraphical work of the county to be referred directly to them as starting points and standards for correlation.

STANDARD SECTIONS.

The outcrops showing the lithological details of the lower half of the general section to the best advantage are found in the southern part of the city of Burlington.

On the north end of Prospect hill, west of the railroad bridge across the Mississippi, and in the immediate vicinity the following section is shown:

I. Section at Prospect Hill, Burlington.

		FEET.
11.	Loess	15
10.	Till; yellowish brown clay, with pebbles and small boulders	8
9.	Limestone, white, thinly bedded	10
8.	Chert and silicious shales, with thin, irregular limestone beds, white and red in color	20
7.	Limestone, brown and white, rather heavily bedded, coarse-grained, sub-crystalline; becoming more thinly bedded and cherty above	25
6.	Limestone, buff, soft, sandy locally	5
5.	Limestone, white, oolitic	3
4.	Sandstone, yellowish, soft, fine-grained, highly charged with casts of fossils	6
3.	Limestone, argillaceous, fine-grained, with often an oolitic band or thin bed of purer limerock at base	18
2.	Sandstone, yellowish, soft, friable, clayey	25
1.	Shale, blue, argillaceous, shown by borings to extend 100 feet or more below river level (exposed)	60

The relations of the Upper Burlington and Keokuk limestones with the cherts separating them are shown best perhaps at Augusta (Tp. 69 N., R. IV W., sec. 24).

II. Augusta Section.

		FEET.
4.	Drift	8
3.	Limestone, bluish, encrinital in places, clay partings often highly fossiliferous (Keokuk)	20
2.	Chert, white, thinly bedded, with thin irregular bands of limestone (Montrose)	30
1.	Limestone, white, coarse-grained, encrinital (Upper Burlington), exposed	15

Farther up the Skunk the Saint Louis rocks are found in the top of the bluffs on both sides of the stream. The section on the north bank (Tp. 69 N., R. IV W., sec. 6, SW. qr.) gives the following:

III. Section near Southwestern corner of County.

		FEET.
5.	Drift	10
4.	Limestone, brownish, shaly (exposed)	12
3.	Limestone, buff, somewhat magnesian, rather massive	4
2.	Shale, blue, with thin, discontinuous bands of impure limestone, and containing geodes in the lower part	25
1.	Limestone, blue and gray, with considerable chert, rather heavily bedded (exposed)	30

The Coal Measure deposits of the county are shown to the best advantage a few miles southwest of Danville (Tp. 70 N., R. VI W., sec. 5, NW. qr., NE. $\frac{1}{4}$):

IV. Section Southwest of Danville.

		FEET.	INCHES.
7.	Drift	20	
6.	Shale, light-colored	20	
5.	Shale, bituminous	3	
4.	Coal	1	2
3.	Fire clay	3	6
2.	Shale, brownish gray, gritty	1	6
1.	Shale, light, brownish, sandy in places (exposed)	4	

MISSISSIPPI RIVER SECTIONS.

As has been stated, the Mississippi river has on its west bank a high escarpment, which extends entirely through Des Moines county from the north to the south boundary line. The upper part of the bluff usually forms an almost perpendicular cliff, while the lower portion is commonly covered by a steep talus reaching from one-half to three-fourths the distance to the crest. North of the city of Burlington the strata lie nearly horizontal, but south of that place they dip to the southward bringing the top of the Kinderhook, which is more than seventy feet above the river level, down to the water's edge (figure 31). In this section, number 1 is the Kinderhook; numbers 2 and 3, the Lower Burlington limestone with the overlying cherts; number 4, the Upper Burlington limestone; 5, the Montrose cherts; 6, the Keokuk limestone; 7, the Saint Louis limestone; 8, the Drift, and 9, the Loess. Among the best outcrops along the escarpment in the extreme northern part of the county is one a short distance south of the Louisa county line, near the angle which the bluff makes in changing from its southeastward to its southerly trend (Tp. 72 N., R. II W., sec. 22, SE. qr., NW. $\frac{1}{4}$), and about two and a half miles north of Huron postoffice:

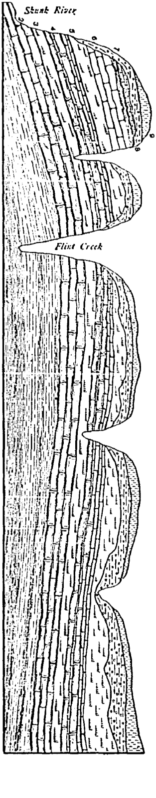


Figure 31. Cross-section along Mississippi River.

V. Section North of Huron.

		FEET.
5.	Limestone, white, somewhat irregularly bedded, containing bands of chert....	16
4.	Limestone, yellow, shaly, arenaceous..	15
3.	Limestone, heavily bedded...........	10
2.	Sandstone, friable, argillaceous........	20
1.	Shale, blue, reported from well near by	4

The sandstone and shale (numbers 1 and 2) are without doubt the upper part of the Kinderhook, while the rest is the lower Burlington, with possibly the lowest part of the upper division.

A short distance southwest of Huron, near the mouth of Dolbee creek (Tp. 72 N., R. II W., sec. 23, SW. qr., SE. ¼), is shown:

VI. Dolbee Creek Section.

		FEET.
5.	Drift	4
4.	Limestone, largely encrinital, white, irregularly bedded	16
3.	Limestone, rather evenly bedded, with a few chert bands	14
2.	Limestone, yellowish, earthy and sandy	8
1.	Limestone, heavily bedded (exposed)	12

Farther south, about five miles from Kingston (Tp. 71 N., R. II W., sec. 35, NW. qr.), on Oak creek, a high salient appears as the stream opens into the valley of the Mississippi river.

VII. Section on Oak Creek.

		FEET.
5.	Loess	8
4.	Drift	6
3.	Limestone, buff and white, heavily bedded below, passing into silicious shales above (Lower Burlington)	35
2.	Shale, buff, sandy, forming incoherent sandstone in places	10
1.	Shale, bluish (exposed)	20

The last two numbers belong to the Kinderhook. The exposure is somewhat obscured by debris and the oolitic bed, which is so well defined at Burlington, is not seen. A short distance to the north, however, this layer is well exhibited with all its characteristic fossils. At the last named place the Lower Burlington is only eight or ten feet thick at the edge of the escarpment.

In the north part of the city of Burlington, on what is known as North Hill (Tp. 70 N., R. II W., sec 29), similar outcrops are exhibited in the bluff.

From this point to Prospect Hill, two miles directly south, the exposures are well shown and present, practically the same features throughout. (See section I).

From North Hill nearly to the mouth of the Skunk river there is an almost continuous exposure, owing to the fact that the Mississippi sweeps westward cutting its right bank and enabling every little rill to make a clean vertical section of one hundred feet or more. The Kinderhook gradually gets lower and lower until at the Skunk river it passes beneath the water level. On Spring creek, west of Patterson station (Tp. 69 N., R. III W., sec. 25, SE. qr., NE. ¼), the upper portion of the Kinderhook is exposed in the bed of the creek.

VIII. Section on Spring Creek, west of Patterson Station.

		FEET.
5.	Limestone, heavily bedded, encrinital (Lower Burlington) exposed	10
4.	Sandstone, yellow, fine-grained	4
3.	Oolite, gray, massive, highly fossiliferous	3
2.	Shale, blue, argillaceous	1
1.	Shale, sandy (exposed to creek level)	1

SKUNK RIVER SECTIONS.

The cross-section which follows the course of Skunk river is almost at right angles to the Mississippi river section. The direction is nearly transverse to the trend of the slight deformations which exist (figure 32).

The Patterson section (VIII) has already been described. In passing westward the bluffs are comparatively gentle

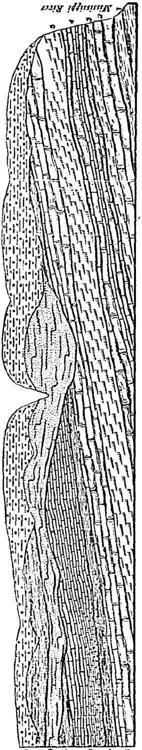


Figure 32. Cross-section along Skunk River.

for a distance of three miles and the exposures are rather limited. A couple of miles east of the town of Augusta the outcrops show both divisions of the Burlington limestone. In this section the numbers represent the following formations: 1 is the Kinderhook; 2 and 3 the Lower Burlington and overlying cherts; 4 the Upper Burlington limestone; 5 the Montrose cherts; 6 the Keokuk; 7 the Warsaw shales; 8 the Saint Louis limestone; 9 the Saint Louis marls; 10 and 11 the Coal Measures.

To the west the strata dip gradually bringing the Upper Burlington down nearly to the water's level at Augusta. The outcrop showing the Montrose cherts is repesented in section II. West of Augusta the steep bluffs on the north side of the river continue to exhibit good sections at short intervals to the west county line. Section III may be regarded as characteristic of the exposures found in the extreme southwestern corner of the county.

FLINT RIVER SECTIONS.

The Flint river furnishes a series of sections which extend in a line about midway between those of the

Mississippi and Skunk rivers. For a distance of several miles from its mouth Flint river flows through a narrow canyon-like gorge. From the Mississippi escarpment, at the point where the North Hill section is shown (section VIII), the wall of rock is almost unbroken, in many places overhanging. At the place known as the Starr Cave (Tp. 70 N., R. II W., sec. 19, NW. qr., NW. ¼) the formations are shown in detail on account of the perpendicular exposures from the water's edge to the top of the bluffs. (Plate XXXIV.)

About a mile farther up the stream (Tp. 70 N., R. III W., sec. 24, SW. qr., NW. ¼) the Upper Burlington is shown with the following section:

X. Section above Mouth of Knotty Creek.

		FEET.
3.	Drift	10
2.	Limestone, white, encrinital (Upper Burlington)	10
1.	Limestone, buff, cherty and sandy (exposed)	12

Four miles beyond (Tp. 70 N., R. III W., sec. 9, NE. qr., NW. ¼) an old quarry, north of Big Hollow, gives good exposures of Burlington limestone:

XI. Section near Big Hollow.

		FEET.
4.	Loess	6
3.	Drift	4
2.	Limestone, cherty	2
1.	Limestone, white, well bedded and containing characteristic fossils	8

In the southwestern part of Franklin township along Little Flint creek are several good though rather limited sections which appear to belong to the Keokuk limestone. One of these, five miles directly north of Middletown (Tp. 71 N., R. III W., sec. 31, NW. qr., SW. ¼), shows six to eight feet of blue shale overlain by several feet of massive bluish limestone. On Cedar creek, a branch of the Flint, there are several good quarry faces exhibited about a mile east of Pleasant Grove (Tp. 71 N., R. IV W., sec. 12, SE. qr., NW. ¼):

XII. Pleasant Grove Section.

		FEET.
10.	Loess	4
9.	Drift	6
8.	Limestone, yellowish, heavily bedded	6
7.	Limestone, thinly bedded, brittle	2
6.	Limestone, heavily bedded, white	6
5.	Shale, yellow, sandy	2
4.	Limestone, gray, unevenly bedded	4
3.	Chert	1
2.	Shale, yellowish, sandy	2
1.	Limestone, thinly bedded (exposed)	3

GEOLOGICAL FORMATIONS.

The stratified rocks which everywhere underlie the drift mantle in Des Moines county belong entirely to the Carboniferous age. Although both of the two great subdivisions of this age are present, they are very unequally represented. The lower division, or Mississippian series, which over nearly all of the county has no indurated rocks resting on it, is made up, at least above the water level of the streams, almost wholly of limestones. The upper division, or Coal Measures, covers only a small area, in the extreme southwestern corner of the district. The lithological characters of the various formations at the different localities may be readily made out from the descriptive notes which accompany the geological sections already given. The broad relations which the different beds have to one another, and the unity of the individual members which go to make up the general sequence of strata are best understood when the different members are treated separately.

Mississippian Series (Lower Carboniferous),

The oldest rocks exposed at the surface in Des Moines county belong to the Lower Carboniferous or, as it has been more appropriately termed of late years, the Mississippian series. As already intimated, the most prominent members of the formation are heavy limestones. Aside from the great economic value of the rocks, the series as exhibited in Des Moines county is of special interest, historically, to the geologist. The strata along the Mississippi river in the vicinity of Burlington have become classic in American geological literature. Wherever these rocks are known the Burlington limestone is a familiar term. It was at the city of Burlington that they were first studied carefully and described in detail. This place, consequently, becomes the typical locality; and with the section at this point all beds of this age in other regions must be compared.

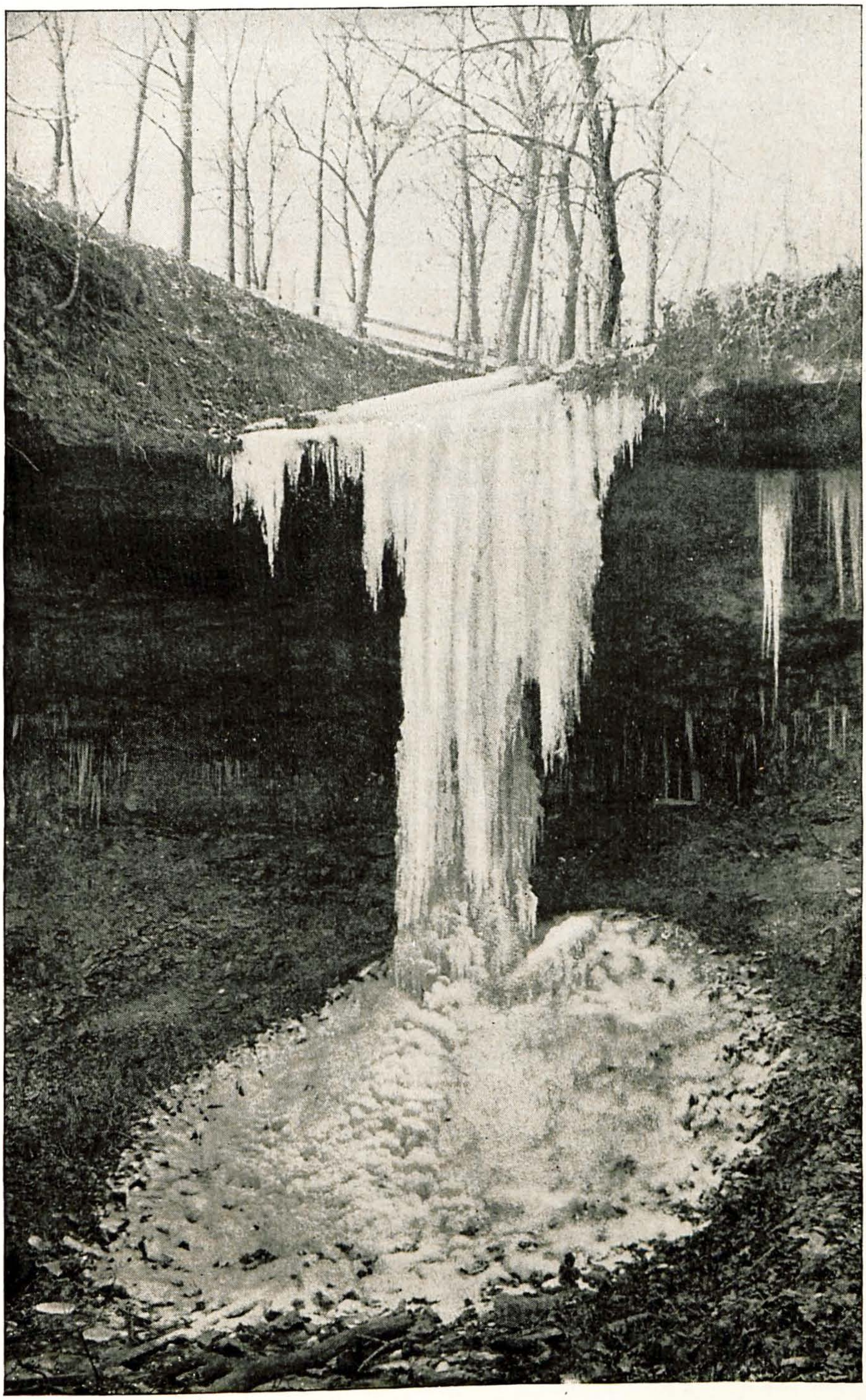
There are four major divisions of this series, of which three only are present in southeastern Iowa, the uppermost, or Kaskaskia, being absent. This missing member is not found in the Mississippi basin north of the Missouri river. Over this northern area its position is marked by an erosion interval which has left very striking evidences of its duration and extent. The three subdivisions present are the Kinderhook, Augusta, and Saint Louis. The first or lower is a thick shale; the other two are limestones, separated by shale.

KINDERHOOK SHALES.

The shales of the Kinderhook attain a maximum thickness in Des Moines county of about 150 feet, of which perhaps one-half or seventy to eighty feet are exposed above the level of the water in the Mississippi river. In this region these beds assume greater importance than anywhere else within the limits of Iowa.

On account of the peculiarities of erosion and the presence of a thick, massive limestone formation above it and very much harder than the basal shales, the Kinderhook beds do not present very extensive outcrops in the south-eastern part of the state. Being the lowest of the geological formations appearing above the water level and as slight changes in the dip occur, the shales have no exposures in the uplands. Their natural outcrops are thus confined to a narrow belt at the bottom of the Mississippi escarpment, extending in a few places a short distance up some of the larger creeks which cut deeply through the bluff. This narrow belt is practically continuous along the entire eastern border of the county, the vertical height being from a few to about seventy-five feet.

As just stated the greatest thickness of the Kinderhook in Des Moines county above the water level in the Mississippi river is in the neighborhood of seventy-five feet. Borings, however, indicate that at least fifty, and possibly as much as one hundred feet of similar strata are present beneath this level. This would make the probable thickness of the Kinderhook beds at Burlington about one hundred and fifty feet. This is considerably greater than any observed thickness of these beds farther north. It is over twenty-five feet greater than the vertical measurements of the beds at Louisiana, Missouri, including the Louisiana limestone which has usually been put in the Kinderhook, but about the exact age of which there is now some doubt; and double the thickness of the Hannibal shales which are exposed so well in their full development at both Louisiana and Hannibal and which are thought to be practically the exact equivalent of the blue



KINDERHOOK AND AUGUSTA; "CASCADE," BURLINGTON.

shales as disclosed in the base of the Burlington section. No comparisons of thickness with the Kinderhook sections lying to the north of the district under consideration can be instituted for the reason that the rocks of this age in other parts of the state are largely limestones so far as has been observed and their exact equivalency with the shales at Burlington has not therefore been as yet determined.

The formation consists largely of compact, rather massive clayey shale at the base, with sandy shale at the top. The best exposure, one showing great variation in lithological details, is the Prospect Hill section, at Burlington (section 1). It consists of:

		FEET.
6.	Limestone, buff, soft, sandy locally	5
5.	Limestone, white, oolitic	3
4.	Sandstone, yellowish, soft, fine-grained, highly charged with casts of fossils	6
3.	Limestone, argillaceous, fine-grained, with often an oolitic band or thin bed of impure limerock at base	18
2.	Sandstone, yellowish, soft, friable, clayey	25
1.	Shale, blue, argillaceous, shown by borings to extend 100 feet or more below river level (exposed)	60

The uppermost member (number 6) is somewhat earthy and apparently contains much magnesia. It doubtless represents a zone of rapid transition between two beds having very diverse lithological features. Its position and textural characters are very similar to the Chouteau limestone of Missouri, which attains a maximum thickness of upwards of one hundred feet. It rapidly becomes thinner northward. The most northerly exposures of it in that state are at Louisiana and Hannibal, Missouri, where it is from ten to fifteen feet thick. In view of these facts it is not unlikely that this layer (number 6) may be eventually regarded as the extreme northern attenuated extension of the Chouteau limestone of the region farther south. This stratum differs very materially from that immediately overlying it, being practically devoid of crinoid remains which go to make up so large a part of the Burlington limestone. Ordinarily this layer is too soft to be of use as a quarry rock, but in many of the quarries in which the layers immediately over it are worked it greatly facilitates the removal of the harder stone.

The oolitic bed (number 5) has a somewhat variable thickness, the limits being between one and four feet, the average about three feet. In most places this rock is quite massive and compact, forming apparently an excellent dimension stone when first quarried, but its use must be guarded and the selection made with the greatest care. The bed is well exposed at many places in the neighborhood of Burlington. It is shown in the Starr Cave cliff and along the Mississippi escarpment above and below the mouth of Flint creek; and on Spring creek west of Patterson station. The fossils which especially characterize the oolite are *Aviculopecten circulus*, Shumard; *Straparollus obtusus*, Hall, and *Murchisonia prolixa*, White & Whitfield. On the whole the fossils of the oolitic bed are predominantly gasteropods and lamellibranchs.

The fine-grained yellow sandstone (number 4) is remarkable chiefly on account of the prolific fauna it contains. Both in species and individuals the numbers are very great. It was from this bed that nearly all of the Kinderhook fossils which were described from Burlington by Winchell, White, and Whitfield were obtained. The great abundance of small lamellibranchs, gasteropods and peculiar brachiopods is particularly noteworthy. Economically the sandstone is of small value. It is too friable for a quarry stone, but in breaking down forms a good building sand. Certain parts of it would also doubtless serve admirably as a moulding sand.

The fine-grained, fragmentary, calcareous member (number 3) is usually quite impure, and in most places would more properly perhaps be called a massive calcareous shale. Frequently some fine sand is present and often a rather large percentage of argillaceous material. At the base there is often exposed a thin layer of compact gray, or oolitic limestone or sometimes both. This band is characterized by an abundance of fossils of which a small Chonetes is the commonest. The thickness of this band varies from four to ten inches.

The soft sandstone (number 2) usually contains a considerable amount of clayey material and passes downward into an argillaceous shale. The upper part is considerably coarser than the lower portion. It forms a soft, friable layer which disintegrates rapidly upon exposure; and is one of the principal beds which allows the harder overlying strata to jut out over the lower portions along the escarpment of the Mississippi river.

The most important member, both geologically and economically, of the Kinderhook in Iowa is the basal shale, as shown in Des Moines county. It is a thick, compact massive bed, largely free from grit or layers of coarser material. It is well adapted for making brick and is so utilized extensively. Attention is called to its use in this industry elsewhere. It is capable of furnishing inexhaustible supplies of material for the manufacture of clay goods.

The remarks just made in regard to the Prospect Hill section apply equally as well to most of the Kinderhook wherever exposed in the district. Towards the north, however, there is a tendency for the sand to become more and more abundant and to occupy an ever increasing proportion of the formation. At the same time the arenaceous beds become harder and firmer, and finally assume the characters of a fairly good quarry rock.

Correlation of the Kinderhook.— The beds of this age in Des Moines county cannot be exactly paralleled with the strata found anywhere else which pass under the same name. Farther south, in Missouri, the Kinderhook is readily separated into three well-marked divisions called the Louisiana limestone, the Hannibal shales and the Chouteau limestone, the latter being at the top. The relations of the Missouri to the Iowa sections cannot be made out by directly tracing the various beds from place to place since a shallow syncline carries the Kinderhook down below the river level between Hannibal and the mouth of the Skunk river.

The section of the Kinderhook at Louisiana shows:

		FEET.
4.	Limestone, buff, fine-grained, somewhat earthy and magnesian	18
3.	Shale, brown, sandy	12
2.	Shale, clayey, bluish or greenish	60
1.	Limestone, buff, compact, thinly bedded	50

This, with the Hannibal section, which is practically the same, is the nearest outcrop on the south with which the Burlington exposure may be compared. The green shales at the Missouri locality are manifestly the equivalents of the basal blue shale at Burlington, in great part at least. The buff, sandy shale above the clay shale at Louisiana perhaps has its representative at Burlington in all the Kinderhook section between the basal blue shale and the oolitic and buff limestone at the top. Although somewhat thicker and presenting a greater variety of lithological characters than at Louisiana the more northern locality could not be expected to exhibit exactly the same features. That sediments of this description should have a greater development toward the old shore than farther seaward would be expected. Furthermore, the Chouteau limestone which forms a superior member of the Kinderhook in Missouri, and which south of the Missouri river attains a maximum thickness of one hundred feet, thins out rapidly to the north. At Louisiana not more than ten to fifteen feet of the buff, earthy limestone immediately beneath the Burlington beds can be referred to it. On the north side of the Keokuk syncline it appears to be entirely unrepresented unless the few feet of buff, impure limerock and perhaps also the oolitic bed can be placed with it.

The lower member of the Kinderhook, the Louisiana limestone, which is so well developed in northeastern Missouri does not appear above the water level in Des Moines county, if represented at all. It is believed to have thinned out completely before reaching so far northward. In sinking a deep well at Keokuk there was encountered at the base of the Kinderhook shales only ten feet of compact, fragmentary limerock which could in any way be referred to the Louisiana limestone. This being the case, then, it would have been reduced four-fifths of its thickness in a distance of sixty miles.

As regards the correlation of the Kinderhook rocks of southeastern Iowa with those of other parts of the state little can be said at the present time. In the central and north-central parts of the region the strata which have been referred to the Kinderhook are heavily bedded limestones. The yellow sandstones of Muscatine county, fifty miles north of Burlington, which have been usually paralleled with the strata having similar lithological characters in Des Moines county have been found to have no relationship whatever, but to contain a typical Devonian fauna. The fossils of the Muscatine region formed the chief grounds, probably, for regarding the Burlington sandstones also as Devonian as was argued by Hall and subsequent writers.

Useful Deposits.—The materials of economic importance which occur in the county will be described in detail in another place. It is pertinent here to allude in a general way to the useful deposits which are to be especially looked for in the Kinderhook beds. First in importance are the basal shales. Special emphasis is to be put upon the value of these beds in Des Moines county as a brick material, and particularly in the manufacture of pavers. The extensive plant now in active operation at the "Cascade," two miles below Burlington, has for several years been turning out a superior grade of vitrified brick for paving purposes. This is at a single point only. For a distance of more than twenty miles along the Mississippi escarpment the situation is just as favorable for the erection of plants for similar purposes; and for at least half of the distance shipping facilities by both rail and water are exceptionally good.

The oolite bed may be used for building purposes, but great care must be taken in the selection of the stone. Lime of good quality has been burned from this layer. Building sand may be obtained from the upper arenaceous member of the Kinderhook where this bed has been exposed to atmospheric influences for a long period. Certain of the clayey shales in connection with particular parts of the highly calcareous shales appear to furnish suitable constituents for the manufacture of hydraulic cement. The chief drawback, however, will be the securing of the proper fuel, cheap enough to warrant the profitable burning of the materials.

AUGUSTA LIMESTONES.

The term Augusta has been recently applied to all the formations which have heretofore been embraced under the Burlington and Keokuk groups. It is taken from the village of Augusta, about seven miles southwest of the city of Burlington in the southern part of Des Moines county, where both of the limestones and the separating cherts are exposed in the bluffs of the Skunk river. The Augusta includes:

6. Warsaw shales (in part).
5. Geode shales.
4. Keokuk limestone.
3. Montrose cherts.
2. Upper Burlington limestone.
1. Lower Burlington limestone.

The typical outcrop of the Augusta is shown in section II already given. The reasons for uniting these formations are numerous. Lithologically the rocks are very similar and are especially characterised by being made up in large part of the skeletal hard parts of crinoids or stemmed feather-stars. They have thus long been called crinoidal or encrinital limestones. The fossils contained are very similar throughout the vertical extent of the rocks and show a gradual though notable evolution or development from the bottom to the top. The changes which the organisms of the time underwent as they progressed from the beginning to the end of the period of deposition are best shown in the most characteristic and most abundant form of life — the crinoids. The same phenomena are shown especially well in other zoological groups, but not quite so conspicuously. These fossils form perhaps the best example known of the evolution of life during past geological ages. In many cases all the different lines of separation may be readily made out and easily followed, with a wealth of material to draw from. Nowhere else in the Mississippi basin is a limited group of strata so strongly linked together by biological ties.

In southeastern Iowa the geological limits of the formation are unusually well defined. A thick shale and an accumulation of shore deposits abruptly terminates it below, while above there is not only a very decided change in lithological characters but also what appears to be a very marked physical break in the continuity of deposition.

Lower Burlington Limestone.—The lower portion of the limestone series as exposed at Burlington was the first part of the Augusta rocks to receive careful attention. It occupies about fifty feet of vertical height if the twenty feet of silicious and calcareous shales at the top are also taken into consideration. The limestone proper is a coarse-grained, encrinital rock, pure white to brown or red in color. It is rather heavily bedded, especially at the base. The so-called crystalline appearance is due to the fractured and separated plates and stem-joints of crinoids which are scattered or disseminated through the beds like pebbles, often so abundantly that it gives at first glance the appearance of gravel. During disintegration, the plates accumulated in beds, the fine material being carried off by running water.

The partings are usually quite thin. Almost the entire section is sufficiently compact and massive to be used as quarry rock. Normally the stone is gray, but portions of

BURLINGTON LIMESTONE OVERHANGING KINDERHOOK SHALES; FLINT RIVER AT STARRS CAVE.

it are intensely white. The characteristic brownish color or reddish hue is imparted to it by percolating waters which enter the crevices and circulate along the bedding planes. By carrying away much of the lime in solution the water forms caverns and cavities which are often of considerable extent. In Iowa the cavernous character of the Burlington is not so pronounced as farther south, in Missouri and especially in the southwestern part of that state. The Lower Burlington beds present some peculiarities in texture which are not met with in such a marked degree in other parts of the Mississippian series.

The conspicuous encrinital character so commonly ascribed to the Augusta limestone is far more pronounced in the Lower Burlington than elsewhere. Crinoidal life at the time of deposition must have been prolific beyond all conception. The organisms made up almost wholly of hard, thick plates composed of carbonate of lime, furnished an abundance of material for the accumulation of extensive beds. An idea of the immense quantity of crinoidal hard parts making up some layers may be obtained when it is remembered that the average crinoid is composed of from thirty to fifty thousand plates of all sizes, and that the remains of half a dozen individuals would occupy the space of about a pint. These plates or ossicles were fastened together by ligaments, which readily decayed when the animal died, allowing the structure to fall to pieces in a confused mass of loose pieces. Only under the most favorable circumstances were the hard parts preserved entire, with the plates in place. The disjointed skeletal remains of the stemmed echinoderms or feather stars form great beds of what has been often called a crinoidal breccia. This agglomeration varies greatly in the degree of consolidation; sometimes it is very hard and compact, sometimes very open in texture and full of interstices with scarcely any finer cementing material. Broken and shattered calyces, parts of arms and sections of stalks are mingled with the mass of separated plates. Elsewhere thick, compact beds alternate with thin friable layers. Occasionally in the thin, sandy partings there are preserved the remains of the forms, each plate in its original position, and as perfect as when the animals were entombed.

The species which characterize the Lower Burlington are widely distributed geographically. From Iowa to New Mexico they are so near alike that it is impossible to tell from just what part of the country a particular individual comes, so uniform were the conditions of existence. The fossils, particularly the crinoids, are distinguished in a general way from those from other parts of the Augusta by a notable delicacy and lightness of construction and fine, graceful ornamentation. With a few exceptions the crinoids may be told at once by these features.

The upper part of the Lower Burlington is made up of brown and white silicious shales, with much chert in nodules and irregular bands, and some limestone. Ecomomically the shales are of small value.

Upper Burlington Limestone.—The upper division of the Burlington is distinguished from the lower section chiefly by being thinner bedded, containing more chert, and having clay shale layers intercalated. The grain is noticeably coarser and the texture more open. The color is an intense white, which is rendered all the more conspicuous by the alternating bands of brown silicious material.

The most typical section of the Upper Burlington is shown in the Miller quarry, south of Burlington, above the "Cascade."

Section at the Miller Quarry.

		Feet.
8.	Loess	12
7.	Drift	3
6.	Limestone and chert	8
5.	Limestone, brown and white, banded with chert, thinly bedded	6
4.	Limestone, gray and white, heavily bedded	10
3.	Shale, blue argillaceous, fossiliferous	2
2.	Limestone, heavily bedded, white	5
1.	Shale, blue (exposed)	4

The two shale beds form a marked feature in the section. They have not been recognized elsewhere in such thickness. They are fossiliferous, carrying an extensive fauna very different from that of the limestone.

The Upper Burlington limestone forms the surface rock over fully one-fourth of the entire county, occupying a broad belt immediately west of the Mississippi escarpment. On account of its position nearly all of the quarrying done in the district is in the upper division of the Burlington. Throughout the region of its occurrence the water courses cut into it exposing good ledges and making the rock very easy of access. Although the Lower Burlington affords beds more massive and much thicker, the layers of the upper division are usually of sufficient thickness for all ordinary constructional purposes. Moreover, the lower section being so much lower and only exposed in the bluff sides, it is not so accessible; and only at a few points can it be worked to advantage.

The upper member of the Burlington has been regarded as a distinct subdivision chiefly on account of the fossils it contains. Being preeminently a crinoidal limestone the crinoids form the most prominent group of organisms whose remains are preserved. On the whole they represent a stage of development intermediate between those of the Lower Burlington and the Keokuk. The species have neither the delicacy, frailness and small size of the earlier forms, nor the massive construction, coarseness and exaggerated features of the later organisms of the same group. The most characteristic species are: *Batocrinus rotundus* (Shumard), *Batocrinus christyi* (Shumard), *Eretmocrinus verneuilianus* (Shumard), *Dorycrinus cornigerous* (Hall), *Actinocrinus verrucosus* (Hall), *Strotocrinus regalis* (Hall), *Granatocrinus norwoodi* (Shumard), and *Schizoblastus sayi* (Shumard). Wherever the Upper Burlington is exposed these species are almost always present; and it is rarely that some of them cannot be recognized after a little search. They are the most widely distributed geographically of any species occurring in all of the Augusta rocks. On account of the wide dispersion and great abundance of the fossils named, the Upper Burlington is readily recognized even when it is not possible to make out clearly the associated beds. The horizon thus becomes an important one for purposes of correlation in sections widely separated, and for determining rocks which occur either above or below.

Towards the top, the upper Burlington becomes more and more cherty and finally passes into beds in which flinty nodules and bands predominate, and which have been called the Montrose cherts.

The chief value of the formation is as a quarry rock. As already remarked most of the quarries at present in operation in Des Moines county are opened in the Upper division of the Burlington limestone. The easy access to the stone and the excellent facilities for transportation both by rail and water should cause a very much larger development of the quarry industry in this region. A superior grade of lime is afforded by the burning of the white layers, but at the present time little is being done in this line. Farther south, in Missouri, the cherts of this formation are used largely for scouring purposes, the nodules being ground to flour-like powder and put in certain grades of soap and polishing preparations.

Montrose Cherts.—The Upper Burlington cherts were formerly thought to have a thickness of from fifty to one hundred feet. Recently well exposed sections show clearly that twenty-five or thirty feet must be regarded as a more accurate measurement. Though a comparatively unimportant bed itself, it has come into considerable prominence on account of forming the extensive obstruction to navigation in the Mississippi river, which has long been known as the Des Moines rapids and which extends from Montrose to Keokuk. In Lee county the cherts extend along nearly the entire eastern border of the district. In Des Moines county they are best exposed along the Skunk river, the most instructive outcrops being in the neighborhood of Augusta. The details are given in section II. With the general rise of the strata towards the north the chert beds are brought more and more to the surface where they have suffered great erosion. At Burlington only the lower part is preserved in isolated places. Few fossils are found in the cherty layers.

Keokuk Limestone.—The third great division of the Augusta is not so important a number as it is farther south in Lee county; yet it probably underlies fully one-fourth of the areal mileage of the district. The rocks occupy a considerable part of the southwestern portion of the county, but are overlain over a large area by the Saint Louis limestone and Coal Measures. The surface distribution would therefore be more accurately a broad strip of territory trending southeast and northwest. Portions of

Pleasant Grove, Danville, Flint River and Union townships would thus be covered by these rocks. The valley of the Skunk river above Augusta also forms a narrow tongue brought out through erosion. In Lee county much larger areas are occupied by the Keokuk limestone and still further southward in northeastern Missouri the greater part of several counties is underlain by this rock. To the west of Des Moines county, however, the Keokuk is only exposed in the beds of the water courses.

In lithological characters the Keokuk limestone may be distinguished from the Burlington beds by its general blue color, its less crystalline texture, and its greater compactness. The great profusion of crinoidal remains which is so marked in the Burlington is largely absent in the Keokuk, or is confined to thin beds of limited extent. Consequently, when the two members appear in the same section the differences are quite marked. Below, the Keokuk is rather heavily bedded. Above, it becomes more thinly bedded and gradually acquires more and more argillaceous material in the partings until these form well defined shale bands. A considerable amount of chert is present in nodules and irregular nodular bands. In many places the flinty material is so abundant that it practically destroys the stone for quarry purposes.

The shales overlying the Keokuk limestone are not so important in Des Moines county as elsewhere in southeastern Iowa. They are exposed to advantage in only a few places. The geodes which are so characteristic of the lower part and which have caused that portion of the section to be called the "geode bed" are not so abundant, and may be absent altogether.

The chief use of the Keokuk must be as a quarry rock, but it will be a long time before the facilities for transportation will be such as to enable it to compete successfully with the other limerocks of the county. The same may be said of it as a lime-burning stone.

SAINT LOUIS LIMESTONE.

The chief exposures of this formation are in the extreme southwestern corner of the county where it underlies an area of perhaps thirty square miles. It covers most of the uplands of Augusta township and probably nearly one-half of Danville township. A small area also occurs in the western part of Union township. The outcrops are principally on Long and Cedar creeks and on the Skunk river. The beds comprise, (1) white clay or marl at the top, (2) gray, flag-like limestone, (3) brown, arenaceous limestone, (4) concretionary and brecciated limestone. A massive magnesian layer like the member forming the top of Hall's Warsaw beds in Lee county has been reported at the base of the beds above mentioned.

The white marly clay is quite plastic and carries an abundance of fossils. It has been observed at only one point, which is about one mile directly north of the town of Augusta on a small stream emptying into Long creek. This clay is in all respects identical with a similar clay or shale which is found at the top of the Saint Louis in many other parts of the state. The fossils so characteristic of this bed as well as the white limestone are: *Rhynchonella ottumwa*, White; *Spirifera keokuk*, var., Hall; *Productus marginocinctus*, Prout; *Zaphrentis pellaensis*, Worthen, and *Athyris subquadrata*, Hall.

The gray, coarse-grained limestone is regularly bedded, and occurs in thin, flag-like layers from two to five inches in thickness. It is quite compact and without fossils. The best outcrops are on Cedar creek, and on Long creek north of Augusta. A quarry opened three miles northwest of that town in the bank of Long creek (Tp. 69 N., R. IV. W., sec. 10, NE. qr., NE. $\frac{1}{4}$) discloses a face of eight feet of this stone.

The brown sandy limestone is rather unimportant and is exposed in but few places. On Cedar creek a layer apparently belonging to this member crops out near the base of the bluffs.

The brecciated limestone is in all respects similar to the same rock as it occurs elsewhere in southeastern Iowa. It is composed of a very fine-grained, compact limestone, light blue or ash gray in color and breaking with a well-marked conchoidal fracture. The fragments are all more or less angular, rarely rounded or water worn. In size they vary from the smallest particles to plates and irregular blocks several feet in length. These fragments are closely compacted and the interstices filled with a hard, greenish clayey material somewhat calcareous and weathering much more readily than the limestone.

As a quarry rock and as a material for quicklime the Saint Louis offers good supplies. Some of the layers are capable of furnishing a superior grade of stone for dimension work. The clays associated with the Saint Louis limestones are for the most part too calcareous for brick or pottery.

Upper Carboniferous or Coal Measures.

DES MOINES FORMATION.

The Lower Coal Measures form a comparatively unimportant part of the beds which are exposed in Des Moines county. The entire areal mileage of these rocks in the district probably does not exceed half a dozen square miles. In all, there are only a few isolated areas, confined entirely to the extreme southwestern corner of the county. Des Moines county forms a portion of a comparatively narrow belt which borders the Mississippi river from the mouth of the Missouri northward and which is underlain by rock older than the coal bearing strata of the Continental Interior. This zone of more ancient rocks separates the Iowa-Missouri coal field from that of Illinois. The present conditions are probably the result of slight deformations which originated during the latter part of Lower Carboniferous times and of subsequent erosion. The Coal Measures have thus been almost entirely removed. The isolated areas remaining consequently partake of the character of outliers.

Recently the extent of the Coal Measure outliers in Des Moines county has been found to be much greater than has been heretofore supposed. Instead of the single small deposit a few feet in thickness which has long been known to exist on Cedar creek in Danville township several other and much more extensive areas have been discovered, the largest being a short distance northwest of Augusta. These outliers are in the upland plain about three miles from the river, and manifestly form a part of a much larger area whose limits have been lately determined on the south side of the Skunk river in Lee county. The Augusta outliers comprise buff or brown more or less ferruginous sandstones, usually rather fine-grained, homogeneous, and massive, but frequently becoming coarse and even pebbly. The beds attain a thickness of from twenty to fifty and even one hundred feet. The base of the sandstone has nowhere been observed and its exact relation to the underlying Saint Louis and Augusta limestones has not been determined. A few miles to the southward beds of coal two to four feet in thickness are associated with similar deposits; and it is not improbable that workable seams will yet come to light in connection with these sandstones. It is quite likely also that the areal extent is much greater than has yet been determined.

The outlier on Cedar creek in Danville township, shows very little sandstone, only a few feet at the base of the exposure. The greater part of the outcrop (section IV) is composed of clayey shales, the lower part being light colored shale or fire clay and the upper a dark drab bituminous shale. Between the two a thin seam of coal exists. It has a thickness of a foot or more.

Although occupying so small an area in Des Moines county the Coal Measures are more or less important economically. The sandstones furnish a fair grade of building stone. The shales supply, on weathering, a plastic clay which may be used in the manufacture of earthenware. A good quality of brick, both paving and building, may be also made from the clays. While some coal is known to be present it is not to be expected that it occurs in sufficient quantities to create an extensive mining industry; yet it is not improbable that eventually small pockets will be found of sufficient importance and size to supply local demands.

Pleistocene.

GENERAL CHARACTER OF SURFACE DEPOSITS.

The surface deposits which cover the indurated rocks so effectively everywhere except in the immediate vicinity of the water courses belong largely to the first glacial epoch. The accumulations comprise (1) the Lower Till, and (2) the Loess, with some alluvium in the river bottoms. The terrace formations are unimportant and find expression only in a few limited areas.

The drift deposits have been laid down over an old eroded surface even more profoundly gashed and trenched than that existing at the present time. Evidences of this great erosion are now largely obscured by the depositions which have been subsequently made, yet they are being continually brought to light through natural and artificial excavations. Although the old depressions and channels are largely filled with glacial débris the preglacial expression of the country is not entirely obliterated, and the principal features of the modern surface relief are still largely dependent upon the ancient elevations and depressions. In many cases the water courses have endeavored to regain their old channels, often with more or less success. As a result streams are found with thick drift deposits, sometimes fifty to seventy-five feet, on either side, but which are manifestly reclining on the ancient slopes of the indurated rocks. An excellent example is Hawkeye creek at Burlington. A cross-section of this valley is shown in figure 33.

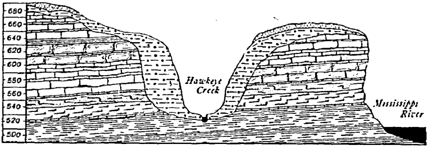


Figure 33. Section across Hawkeye creek at Burlington.

As shown in the section there is an extreme attenuation of the drift deposits over the old elevations and a deep accumulation of débris in the ancient valleys. This is indicated similarly in many other parts of the district.

At Burlington and in the immediate neighborhood numerous excavations and road cuttings disclose the features of the Pleistocene deposits better, perhaps, than anywhere else in the county; and at the same time illustrate just what occurs and what is to be expected in other parts of the district. The area may therefore be taken as typical and as one whose details may be regarded as practically identical with those over most of the county. The topography of the area is represented on the sketch map (figure 34).

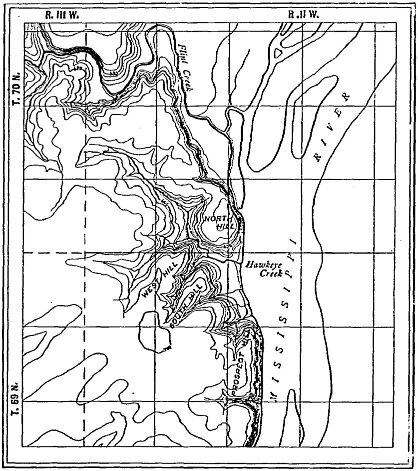


Figure 34. Surface relief of Burlington and vicinity.

The city of Burlington is built upon four "Hills," all of which rise to a height of nearly two hundred feet above low water in the Mississippi river at that place. Perhaps five-sixths of the altitude is formed of Burlington limestone and Kinderhook shales, which along the Mississippi river at Prospect and North Hills, and also in places bordering Flint creek, rise from the water's edge in high, mural escarpments.

North of Hawkeye creek is a nearly insulated plateau, all sides of which are scalloped by steep sided ravines, very deep toward the lower extremities, but interiorly shallowing quickly. The larger ones soon pass into small, shallow drainage basins, which impart to the central portion of the plateau a characteristic, gently undulatory appearance. To the northeastward is a small subsidiary plain of gently undulatory topography, evidently in no way dependent, in its configuration, upon the underlying stratigraphic rocks. It rises thirty or more feet above the broad alluvial flood plain of the Mississippi river and is divided into two parts by Flint creek. Southwestward it passes rather abruptly into the comparatively gentle slopes of the general plateau. It manifestly occupies a preglacial depression, and literally rests upon the irregularly eroded slopes of an ancient water course. A section of this limited auxilliary plain exhibiting all the details of structure forms an exposure continuous for nearly half a mile along Flint creek; and it is practically similar throughout.

Terrace Section Near Mouth of Flint Creek.

	FEET.
7. Loam, coarse, brown, friable, with occasional small pebbles, graduating imperceptibly into 6.......	3
6. Clay, yellowish brown, of a characteristic fissured nature; containing a few small boulders or large pebbles, in places indistinctly laminated..	15
5. Sand and gravel, commingled, irregularly stratified, pebbles up to six inches in diameter, mostly rounded, erratic, but with numerous local angular flint and limestone pieces	10
4. Clay, drab, homogeneous, unctuous................	2
3. Sand, coarse, yellow and white, with a few small erratic pebbles, everywhere quaquaversally stratified	6
2. Sand, very fine, homogeneous (not present along the entire section)............................	1
1. Sand, coarse, yellow and white, with rounded and striated erratic pebbles up to two feet in diameter, and larger local angular fragments of flint and fossiliferous (Burlington) limestone (exposed)..........	12

One mile above, on Flint creek, the coarse yellow sands form a conspicuous feature. A short distance farther north the lower till, with numerous small rounded, erratic boulders up to four feet in diameter, is well exposed in all its characteristic details. It is overlain by six to eight feet of typical loess, containing numerous small loess-kindchen. The deposits here present have an exposed thickness of sixty feet, and are seen to rest against the steep sides of the rather narrow gorge, preglacially eroded by the waters of Flint creek to the depth of more than one hundred and thirty feet. North of Flint creek, and beyond the area represented in the annexed map, the topography in its general aspect is similar to that of the isolated plateau south. On the upper brow of the north slope of

"North Hill" a road cutting discloses the following arrangement:

Bluff Section on North Hill.

		FEET.
3.	Clay, brownish, yellow; free from gravel, and for the most part homogeneous; grading into 2....	5
2.	Loess, typical, ashen, compact, containing numerous loess-kindchen and the following fossils: *Pupa muscorum*, Linn; *Succinea obliqua*, Say; *Patula striatella*, Anth.; *Limnophysa desidiosa*, Say; *Patula perspectiva*, Say; *Helicina occulta*, Say..	8
1.	Till, with an abundance of gravel, and pebbles up to three feet in diameter (exposed)............	20

Over the entire central portions of the northern plateau the distribution of Pleistocene deposits is essentially the same, except that the lower member suffers a considerable attenuation over the more elevated parts, sometimes being reduced to only a few feet in thickness. Upon the removal of the drift materials glacial scorings and striæ on the subjacent Paleozoic strata have been disclosed in various places.

South of Hawkeye creek rises a broad, elevated plain, so level in many places as to be almost devoid of natural drainage. Northeastward it is scalloped by short, deep ravines, but eastward it abruptly terminates with a perpendicular declivity, washed at its base by the Mississippi river, which has evidently separated the plateau from the highland of Henderson county, Illinois. To the south and west this level, elevated plain gradually becomes gently undulatory and finally more broken by the small tributaries of Spring creek. Northwestward it merges into the general elevated plain occupying the greater portion of the county. Near the summit of "South Hill" in a recently opened quarry there is exposed:

South Hill Section.

		FEET.
5.	Clay, brownish; free from pebbles; becoming silty below and graduating insensibly into 4.........	5
4.	Loess, compact, ashen, containing loess-kindschen..	9
3.	Clay, red, tenacious, upper portion containing much gravel, the pebbles small, rounded, mainly erratic, a few local flint and limestone fragments disseminated throughout................	1
2.	Large angular fragments of limestone and flint, the interstices filled with red clay..................	2
1.	Limestone, Upper Burlington, (exposed)..........	20

One-quarter of a mile to the southeast, on the corner of South Fourth and Maple streets, a similar arrangement is shown, superimposed on the Lower Burlington limestone. The Quaternary beds of the two places are manifestly continuous, but the elevation of the latter section is somewhat less than the former, and the several beds are all much thicker, No. 5 of the South Hill section having a thickness of six feet, No. 4 of thirteen feet, and Nos. 4 and 3 together of six feet. One-fourth of a mile southwest of this exposure a road cutting exhibits:

		FEET.
3.	Clay, brownish, silty or loess-like below............	10
2.	Till, typical, lower..................................	25
1.	Limestone, Lower Burlington, (exposed)..........	5

LOWER TILL.

The general characteristics of the drift have already been indicated. The deposit is composed of blue or yellow clay, which contains considerable sand either disseminated, or in thin lenticular beds, and boulders which consist largely of rounded masses of crystalline rocks, together with limestone and some chert fragments. The boulders are rarely angular and are invariably of small size. A few reach a measurement of five or six feet and one, a few miles west of Burlington, is fully fifteen feet across. Good indications of stratification are seldom met with, except when the sand beds are intercalated, and even then the regular bedding lines are not distinct. When the loess overlies the drift a narrow band of small pebbles frequently indicates the line of demarkation between the two. Below, the till gradually mingles with the residuary clays above the limestone; and the zone is marked by a bed, two or three feet in thickness, of dark reddish clay with which is mixed an abundance of chert and some limestone fragments. In many places this appears to be disturbed.

LOESS.

The loess of Des Moines county occurs only over the more elevated areas and always overlies the till. It is usually the characteristic fine ashen or yellowish silt, quite homogeneous and varying in thickness from a few inches to ten or fifteen feet or more. Calcareous nodules, tubules of iron oxide and fossils are more or less abundant. The latter are largely the shells of snails which frequent damp situations. The relations of the loess deposits to the drift is shown in the sections already given (North Hill and South Hill sections).

TERRACES.

Owing to the westward deflection of the Mississippi opposite Oquawka, the river is brought directly against the hard limestone wall which marks its immediate valley. Terraces consequently have an unimportant development. The principal evidences of terrace formation are at the mouth of Flint creek above Burlington, and north of the mouth of the Skunk river. In the northern part of the county low terraces also exist. The terraces at the mouth of the Flint are about thirty feet above the flood plain of the Mississippi. A vertical section of the different beds comprising it is shown in the section at the mouth of Flint creek.

GLACIAL MARKINGS.

Des Moines county has long been known as one of the few localities in Iowa where ice striations have been observed. In fact, the first glacial markings which were reported in southeastern Iowa were those discovered by White in 1858 near Burlington. There is no exact record of White's original location, but it is thought to be two or three miles north of the city. No account of these striations published at the time, though afterward, on several occasions, mention was made of them. The direction was approximately south 15 degrees east. Until very recently nothing additional has been recorded concerning the glacial striæ of this part of the state.

On the west bank of the Mississippi river for the greater part of the distance between the mouths of the Iowa and Des Moines rivers a high escarpment, capped by a massive limestone, borders the stream. In many places the rocks stand out in bold, cliff-like walls, one hundred to two hundred feet high, with a heavy talus at the base. Along much of this exposed scarp the conditions are exceptionally favorable to the recording of ice scorings.

On North Hill, on the brow of the Mississippi bluff, striated surfaces have been reported from time to time, but rarely have they been carefully examined. On one occasion the bearing of the striæ was found to be south 63 degrees east, the magnetic deviation being about 7 degrees. Mr. Frank Leverett has stated more recently that he also has measured the direction of some glacial grooves in the same vicinity. He reported the bearings to be south 65 degrees east.

Observations made a few years ago show that the sharp salient at the Cascade two miles south of the city has been manifestly ice-planed. At the present time no ice markings are visible at this place. A few years ago, however, several large limestone slabs, four to five feet long and two or three feet wide, were removed in quarrying from the top of the salient above the present works of the Granite Brick Company. Some of these flat blocks were beautifully glaciated and polished, showing deep flutings and mouldings.

Special attention may also be called to the recent discoveries of similar phenomena by Mr. F. M. Fultz, of Burlington. A number of localities have been examined by him, at all of which ice-planed surfaces are exceptionally well preserved. One of these localities is near Kingston, another is near West Burlington, and more recently, still others have been reported.

GEOLOGICAL STRUCTURE.

GENERAL ARRANGEMENT.

On the whole the strata of the district are remarkably free from all effects of the great secular movements of the earth's crust which are so pronounced in nearly all portions of the globe, and particularly in mountainous regions. The deformations present are so slight that ordinarily they pass almost unnoticed.

Broadly speaking, the strata are in practically the same position as when originally deposited, preserving an almost horizontal position. There is, however, a gentle dip towards the west or rather southwest, in the southern part, and northward in the northeastern part of the county. The latter slope forms the northern side of the Keokuk syncline, which has its maximum depression about at the mouth of the Des Moines river, and by which the strata are carried downward at least one hundred and fifty feet.

For the most part the indurated beds lie one upon another in regular sequence. But in the southwestern portions of the county there is a noticeable exception in that the Coal Measures rest in marked unconformity upon the underlying rocks, though the irregularities of depositions are not so well defined as a few miles farther west and elsewhere in the state. An unconformity even more pronounced is that between the drift and subjacent strata.

GEOLOGICAL CROSS-SECTIONS.

Mississippi River Section.—The structural arrangement of the strata along the Mississippi river may be made out with considerable ease since the gorge of the great stream, which is in this part of its course so well defined, affords unusually favorable opportunities for careful investigation. The escarpment thus formed on the west bank of the Mississippi is very abrupt, and extends practically continuously along the entire eastern margin of the county.

While at no point is the dip perceptibly great there is, in passing both north and south from Burlington, an impression constantly growing that the beds are nearer and nearer the water level. Measurements carefully made of the altitudes of easily recognized and persistent horizons show that this is really the case, and that the city of

Burlington is very close to the crest of a low anticline, or fold. (Figure 31.) Upstream for some distance the strata appear to vary but little from horizontality. Southward from the city the layers have a more noticeable inclination. The top of the Kinderhook, which at Burlington is some eighty feet above the river level, falls to the surface of the stream at the mouth of the Skunk. This is a drop of eighty feet in a distance of about seven miles or a dip of about eleven feet to the mile. South of the mouth of the Skunk river the slope of the beds continues nearly to the southern boundary of the state where a long rise takes place. This forms what is called the Keokuk syncline, from the city which is near the point of greatest depression.

Skunk River Section.—The strata exposed on this water course show only a single direction of dip—the inclination being upstream. At the eastern end of the section the lowermost beds are the Kinderhook which are exposed but a few feet above water level in the Mississippi and are not seen beyond Spring creek, at which point in the bed of the stream only the uppermost layers are exposed. The Lower Burlington soon passes out of sight and the Upper Burlington limestone is brought down to the bed of Skunk river at the town of Augusta. From a point a short distance beyond to the west county line the bed of the stream is occupied by the Keokuk limestone. Making an allowance of a fall in the Skunk river of four feet to the mile, which is rather high, the total difference in the actual level between the eastern and western extremities of the section, which is about eighteen miles in length, would be about one hundred and thirty feet, or an average inclination of eight feet to the mile. While this amount of inclination is too slight to be distinguished by the eye, an increase of four feet, on account of the slope of the river in the opposite direction makes an apparent dip of about twelve feet which is perceptible in traveling up stream any considerable distance (figure 32).

UNCONFORMITIES.

The lines of unconformity which mark breaks in the deposition of strata are the same in Des Moines county as elsewhere in southeastern Iowa. They are two in number. One is at the top of the Lower Carboniferous and the other is at the base of the Pleistocene, or drift. In all the great sequence of strata, with these two exceptions, deposition has been continuous.

The unconformity between the Lower Carboniferous and the Coal Measures is not so marked a feature as in other parts of the state for the reason that the district lies in the extreme eastern margin of the Western Interior coal field. The only portion of the county where the unconformable relations are to be found is in the extreme southwestern corner. The great thickness of the Coal Measures sandstone—something over one hundred feet in places—seems to indicate clearly that the depressions of erosion which are filled with the sandstone extend not only into the Saint Louis limestone, but also into the Keokuk and perhaps even into the Burlington.

The drift mantle which covers the entire country fills the valleys of an ancient surface as profoundly eroded as the present surface. Its irregular position upon the hard layers is apparent wherever excavations of any extent are made.

BUILDING STONES.

Des Moines county is perhaps as well supplied with good building stone as any similar district in the state. With the excellent railway facilities which it enjoys, transportation in all directions is at hand. Shipment by water is also open and considerable quantities of rock for the government improvements along the Mississippi are continually sent out by boat.

By far the larger proportion of the available rock for constructional purposes is limestone. There is some sandstone of fair quality, but as yet it has not come into general use — owing chiefly to its position at considerable distances from ready transportion. The limestone is of several varieties, the principal and most important being the common white, or encrinital stone. This is coarse-grained, compact, more or less massive and varies in color from pure white to gray, yellowish or brown. It is made up entirely of crystalline hard parts of various organisms, chief among which are the crinoid plates. The mass of animal remains is firmly cemented by fine calcareous material. Fractured surfaces thus show a coarse, crystalline structure, not unlike many marbles. Through these there are all gradations to ordinary earthy limestone. The sub-crystalline varieties withstand weathering admirably and are readily dressed.

All the principal geological formations of the county yield building stone. The Kinderhook, however, supplies comparatively little, the only bed which is worked being the oolite near the top of the formation. It is compact, gray in color and has a thickness of about three feet. For the most part this bed cannot be depended upon to furnish good material which will withstand weathering influences, especially in exposed places. When kept from moisture it will last much longer than otherwise. If carefully selected in the bed it may form a tolerably durable rock. Its massive, homogeneous character and the readiness with which it is dressed has occasioned a somewhat wide use of the rock and it affords such excellent dimension stone and material for dressed trimmings that the temptation to use it is great, notwithstanding its liability to rapid destruction through weathering.

The Lower Burlington limestone, while largely subcrystalline through its encrinital character, has a decided yellowish or brownish hue. Certain of the beds are pure white or gray, but unlike those of the Upper Burlington. The rock being very heavily bedded, compact and easily worked, makes it a very desirable stone for dimension work. Although there are inexhaustable supplies of good building rock its distribution is not so extensive as the Upper Burlington, for the reason that almost everywhere thirty to one hundred feet of other strata overlie it. Consequently quarrying in this bed must be restricted to the base of the bluff along the Mississippi. It has been quite extensively quarried in the city of Burlington. The principal opening, which is probably also the largest quarry in the county, is situated a few miles south of Burlington on the Chicago, Burlington and Kansas City railroad.

The Upper Burlington limestone furnishes by far the greatest portion of the quarry rock in the county. As stated in connection with the discussion of the geological formations, the Upper Burlington limestone occupies fully one-fourth of the surface of the county, stretching out in a broad belt parallel to the Mississippi river and reaching north and south entirely across the district. With few exceptions the quarries of the county are opened in this formation. In texture the rock is commonly a coarse-grained, encrinital limestone, often having the crystalline appearance of marble on broken surfaces. It is commonly a pure white rock varying to gray and sometimes to buff.

It is quite massive, firm and compact, and affords a good material for all kinds of common constructions.

Although the Keokuk limestone occupies a considerable portion of the county, few quarries are opened in it, the only one of much importance being near Augusta. While the rock may be termed an encrinital limestone, this character is not so apparent as in the case of the Burlington stone. There is more earthy calcareous matter and the limestone on the whole is more of an ordinary blue or ash-gray rock with the crystalline portions consisting of isolated plates and hard parts of the organisms disseminated through it.

The Saint Louis limestone is a fine-grained, compact limerock, breaking with conchoidal fracture and usually containing few or no fossils. It is rather thinly bedded and is rarely used, except for foundations and retaining walls.

The Coal Measures supply comparatively little building rock. That which does occur is a medium grained sandstone, rather compact, and buff or brown in color. Beds having a thickness of upwards of one hundred feet are found in the southwestern part of the county. Though too far removed from railroad facilities at present to come into general use it is said to be a very durable rock.

The quarry industry in Des Moines county has not near the development that it should have; and with very little effort could be made many fold more important. Although every township in the county supplies quarry rock for local use, the principal quarries are concentrated in and about the city of Burlington. Most of these are in the upper division of the Burlington limestone though a few, and among them the largest in the district, have been opened in the lower division at the base of the bluff along the Mississippi river.

Burlington Township.—In the west part of the city of Burlington there is a group of quarries near the end of Division street. They have been opened in the valley of the small creek running in a northeasterly direction. One of the principal workings is the Larkin quarry. The face is about twenty feet in height, all of which is in the Upper Burlington. The upper layer shows considerable evidence of erosion, in many places large holes and cavities having been worn out and then filled with drift material. The rock taken out is all used in the city of Burlington, principally for foundations and retaining walls. The following is a section:

Section at Larkin Quarry, Corner of Amelia and Claim Streets.

		FEET.
8.	Loess	3
7.	Drift	6
6.	Limestone, buff, evenly bedded	5
5.	Limestone, yellowish, with considerable chert in the form of nodules and bands	2
4.	Limestone, yellowish, heavily bedded	4
3.	Limestone, white, massive, solid bed	4
2.	Limestone, yellowish, containing much silicious material and many shells of brachiopods	1
1.	Shale, bluish, with flint nodules	4

A block north is the Quell quarry on the north side of Etna street. The section is practically the same as at the Larkin opening, but the bottom of the quarry reaches only to the base of the white limestone. This quarry has been worked along the slope of a small branch for a distance of perhaps thirty rods. Near the west edge the character of the rock changes rapidly and the whole exposure consists of about ten feet of rather brittle, white, thinly bedded limestone.

A short distance farther north on the south side of Division street is the Swan quarry. The white limestone at this point appears to be considerably thicker than in the excavations immediately to the south. On the opposite side of the street is the Muerzenmeyer quarry which is also worked in the same ledges as the others just mentioned. The output of all these quarries is local, being used entirely in the city of Burlington.

Near the center of the city near West Boundary between Division and Angular streets, considerable quarrying has been carried on from time to time. In the ravine directly south of Angular there are a number of deserted quarries. The rock has been removed up to the limits of the ground owned by the quarrymen. On Angular, Maple, Maiden Lane and Division streets considerable quarrying has been carried on by the city in grading, many of the cuts being from twenty-five to thirty feet deep. The rock taken out has been used largely for city improvements.

At the head of Maple street just west of Boundary is located the Hoppmann quarry. This is a small opening in the Upper Burlington giving the following section:

Section at Hoppmann Quarry, Corner of Maple and May Streets.

		FEET.
4.	Loess	6
3.	Drift	2
2.	Limestone, white, thinly bedded, rather brittle	4
1.	Limestone, white, rather heavily bedded (exposed).	6

In another place in what is practically the same quarry the rock has been taken out up to the limits owned. Here the stone appears to be of a somewhat better quality. The quarry is deep and takes in a six-foot ledge of white limestone.

Of the two city quarries which have been opened on Maiden Lane, one is at the intersection of Boundary and the the other at Seventh street. The former is in a white, brittle limestone, rather thinly bedded and of not very good quality. The second cut is about twenty feet deep and passes through a good ledge of white limestone. The section is as follows:

City Quarry, near Maiden Lane and Seventh Streets.

		FEET.
6.	Loess	12
5.	Drift	2
4.	Limestone, white, rather brittle, thinly bedded	3
3.	Limestone, yellowish, heavily bedded	5
2.	Limestone, poorly bedded, with considerable sandy clay and chert	2
1.	Limestone, white, solid bed	6

The rock taken out of number 3 is used largely for curbing and other purposes where dressed stone is required. Number 1, may be taken out in blocks of almost any desired size and is used for heavy masonry and dimension work. Number 4 is used chiefly for macadam. A quarry quite similar to the last was opened some years ago on the corner of Seventh and Division streets but it is now deserted.

On Sixth street south of Division a cut exposes the Upper Burlington resting upon the upper portion of the Lower Burlington.

Road Cutting, Sixth Street, Corner of Division.

		FEET.
8.	Loess	6
7.	Drift	1
6.	Limestone, white, thinly bedded	6
5.	Limestone, white, heavily bedded	3
4.	Limestone, impure, containing considerable clay and chert, with a flint band below	3
3.	Limestone, brownish, with more clay and chert	4
2.	Chert	2
1.	Limestone, yellowish, with numerous bands of chert.	12

Directly east, on the north side of Fifth street, considerable quarrying has also been done. Good sections are still to be seen, but the work of getting out the rock has been abandoned on account of lack of territory.

On Maple street, between Third and Fifth streets, the city has quarried rock in opening the street. On the corner of Third and Maple is the Loftus quarry which is now deserted. It is chiefly in the Lower Burlington and presents at the bottom a heavily bedded limestone eighteen feet in thickness.

Section at Loftus Quarry, Corner Seventh and Maple Streets.

		FEET.
5.	Loess	12
4.	Drift	8
3.	Limestone, somewhat impure, with bands of chert	8
2.	Chert	2
1.	Limestone, buff, heavily bedded	18

Five blocks directly south of the corner of Third and Locust streets is a deserted quarry in the Lower Burlington; and three blocks beyond on South street is a road cutting from which considerable rock has been taken out. A short distance still further south on both sides of a small ravine opening to the eastward, considerable quarrying has been done from time to time, but at present no work is being carried on. One-half a mile southwest of the last named locality is the Miller quarry, which is located in the Upper Burlington limestone. The principal excavation is at the corner of Lynn and Seventh streets.

About two miles south of the Union station on the borders of a small stream called "Cascade," several large quarries are in operation. On the south side of the main creek are two large openings known as the Miller quarries (Tp. 69 N., R. II W., sec. 16, NW. qr., NW. ¼). The quarry face is over fifty feet high and presents an almost complete section of the Upper Burlington.

Section at the Miller Quarry, at Cascade.

		FEET.
8.	Loess	12
7.	Drift	3
6.	Chert and fragmentary limestone, irregularly bedded.	8
5.	Limestone, white, with bands of chert	6
4.	Limestone, white, heavily bedded	10
3.	Shale, argillaceous, blue	2
2.	Limestone, white, solid bed	5
1.	Shale, blue (exposed)	4

On the opposite side of the ravine, to the north, are two other extensive quarries known as the Ervin. (Tp. 69 N., R. II W., sec. 9, SW. qr., SW. ¼). Several small openings also exist a short distance to the west. A third of a mile to the east at the pit of the Granite Brick Company there is from forty to sixty feet of Burlington limestone which must be removed in order to reach the underlying shale. The complete section at this point is something over one hundred feet.

Two miles south of Cascade is the "Picnic Point" quarry. Most of the output is used by the government for improvements along the river. The rock as it is taken out is loaded on barges. The opening is in the Lower Burlington and reaches down to the oolitic bed of Kinderhook.

One of the largest quarries in the county is a mile south of the last named locality (Tp. 69 N., R. II W., sec. 29, NW. qr., SW. ¼). It is known as the Kemper opening. About thirty feet of rock is exposed, entirely of the Lower Burlington. The lower half of the exposure is heavily bedded and furnishes a good grade of material for dimension work. It is shipped to Burlington, Fort Madison, Keokuk and other places. The upper fifteen feet is not of so good quality as the lower and is used chiefly for riprap along the Mississippi river where it is distributed by government boats. A mile to the west, near Patterson station, is a small quarry of similar rock, and a short distance beyond on Spring creek stone is taken out along the edge of the stream.

The quarries thus far mentioned in Burlington township are all south of Hawkeye creek. North of the stream in the northwestern part of Burlington several small quarries have been opened for local use. A number of openings have been made in the brow of North Hill, but most of these are now abandoned. Rock is also taken out for building purposes along Flint river in the neighborhood of Starr cave, but these quarries are of small importance at present. Two miles northeast of the last mentioned localities, on the Burlington, Cedar Rapids and Northern railway small quarries have been opened in the bed of the small stream up whose valley the railroad runs.

Union Township.—The quarrying in Union township is carried on chiefly in the western part on Long creek. For several miles along the stream the outcrops are practically continuous. The principal opening is the Stenstrom quarry (Tp. 69 N., R. III W., sec. 18, NE. qr., NW. ¼). Along the face of the north bluff there is a continuous exposure for fully one quarter of a mile, all of which has been worked more or less in getting out rock. The stone is rather thinly bedded above, the various layers being separated by thin, fragmentary shales, one stratum, however, being two feet in thickness. The stone is a hard, gray variety, with comparatively few organic remains. Lower down the beds are encrinital and assume a sub-crystalline texture. A good grade of building stone is present here, but owing to the lack of proper transportation facilities it cannot have the wide usage it deserves. Most of the section appears to belong to the Keokuk limestone.

One-half mile further down the creek, the Upper Burlington appears in the bed of the stream. A short distance upstream west of the Stenstrom quarry, is a thick sandstone ledge which rises rather abruptly from the creek bed to a height of perhaps one hundred and fifty feet. The sandstone crops out nearly to the summit. A small quarry has been opened a short distance from the west township line. The sandstone here quarried forms a fairly good building rock. It is dark yellow, rather coarse-grained and quite durable. It may be taken out in large angular blocks of almost any required size. There seems to be but little doubt that the rock belongs to the Coal Measures.

In the south part of Union township at various points at the foot of the bluff quarrying in a small way is carried on to supply the respective neighborhoods with material for foundations.

Augusta Township.— The chief quarries are in the immediate vicinity of the town of Augusta, in a small ravine at the west edge of town and directly north of the wagon bridge across Skunk river. A considerable section is exposed showing the Montrose cherts, the underlying Upper Burlington and overlying Keokuk beds (section II). A good deal of rock has also been quarried in the lower beds at this place and in the bluffs on the south side of the stream. Small quantities of rock have also been removed along the bluff between Augusta and the west county line, all of it being from the Keokuk limestone.

Three miles northwest of Augusta on Long creek (Tp. 69 N., R. IV W., sec. 10, NE. qr., NE. ¼), a small quarry has been opened in the Saint Louis limestone. The face of the quarry is not more than eight or ten feet. The rock is a fine-grained, compact, white limestone, rather thinly bedded. It is removed in large flags from two to five inches thick. Half a mile to the eastward the Saint Louis is also exposed for a considerable distance in the creek beds. Farther down the stream it is overlain by a few feet of white marly clay. At the extreme eastern edge of the township, in the valley of the creek, the sandstone which has already been mentioned in Union township is also quarried to some extent.

Danville Township.—In the southwestern corner of the township, three miles from the station of Danville, on Cedar creek, quarrying has been carried on to some extent. The principal opening is the Renner quarry (Tp. 70 N., R. IV W., sec. 30, NW. qr., SE. ¼). The rock is a sandstone and is quarried to a depth of fifteen feet at which level it rests on a bluish limestone. North of this point for a distance of nearly two miles the rock exposures are almost continuous. About one-half mile north of the quarry just mentioned a white massive sandstone crops out along the low bluff twenty to twenty-five feet above the bed of the creek. The rock appears to be somewhat more friable than the yellow sandstone already mentioned. A short distance beyond (section 30, NW. qr., NE. ¼) a small quarry has been opened for local use. The following is the section:

		FEET.
3.	Sandstone, yellow to white, rather heavily bedded..	10
2.	Limestone, compact, fine-grained, bluish...........	9
1.	Shale, bluish......................................	7

In the extreme northeastern corner of the township a little rock has been taken out for local use. The quarry is in the Keokuk limestone.

Flint River Township.—A number of exposures of good quarry rock are found in the Flint river valley. Quarries have, however, been opened in but few places. The principal one is the Loftus (Tp. 70 N., R. III W., sec. 25, NW. qr., SE. ¼). The stone is well adapted for building purposes and some of the layers furnish large blocks suitable for heavy masonry and bridge piers. The opening is entirely in the Upper Burlington.

Section at Loftus Quarry.

		FEET.
6.	Loess	4
5.	Drift	10
4.	Limestone, thinly bedded, with considerable chert	8
3.	Limestone, sub-crystalline, irregular, heavily bedded	10
2.	Limestone, white, solid bed	6
1.	Limestone, dark gray, somewhat irregularly bedded (exposed)	4

The surface of the rock after stripping, is found everywhere to be covered with glacial striations, in a good state of preservation. Lateral polishing is also shown. The drift overlying the quarry rock contains many striated pebbles and boulders.

Pleasant Grove Township.—The principal quarrying done is on Cedar creek, one mile directly east of Pleasant Grove postoffice. The exposures are entirely in the Upper Burlington limestone. Quarrying has been carried on for a distance of a mile and a half or two miles along the stream. Near the south end of the opening (Tp. 71 N., R. IV W., sec. 12, SE. qr., NW. ¼) a more detailed section shows:

		FEET.
9.	Loess and drift	10
8.	Limestone, heavily bedded	6
7.	Limestone, rather brittle and poorly bedded	2
6.	Limestone, white, heavily bedded	6
5.	Shale, yellow, or calcareous sandstone	2
4.	Limestone, gray, irregularly bedded	4
3.	Chert	1
2.	Shale, or yellow sandstone, calcareous	2
1.	Limestone, thinly bedded	3

This exposure furnishes stone for Pleasant Grove, Washington and a large part of Yellow Springs and Franklin townships. Work is not carried on very systematically. The exposures are so numerous, that as soon as a considerable amount of stripping is required the place is abandoned and another opening is made where the drift covering is not so thick.

Franklin Township.—Although most of the quarry rock from this township is obtained along Cedar creek near Pleasant Grove, some desultory quarrying is done at several points. The principal opening, however, is on Flint creek in the southwestern part of the district (Tp. 71 N., R. III W., sec. 32, SW. qr., NW. ¼), where the Upper Burlington yields a good stone for ordinary constructional purposes.

Yellow Springs Township.—A considerable portion of the quarry rock of this township is obtained from Pleasant Grove. One mile and a half southeast of Mediapolis a small quarry for local use has been opened in the Upper Burlington limestone (Tp. 72 N., R. III W., sec. 36, SE. qr., NW. ¼), in the valley of a small creek. The exposure is about eight feet in height. In the northcentral portion of the township the Upper Burlington is also quarried for local use. The principal opening being between Linton and Northfield (Tp. 72 N., R. III W., sec 2, SW. qr., SW. ¼). In the vicinity of Northfield there are also numerous good exposures of rock along the creek west of town. A mile to the north (Tp. 72 N., R. II W., sec. 6, NW. qr., NE. ¼) a quarry has been opened in the Upper Burlington affording a face of about ten feet of gray, rather heavily bedded limestone. The Lower Burlington is also exposed near by.

Huron Township.—A short distance west of the Huron postoffice is the Mississippi escarpment which presents a bold exposure of Upper and Lower Burlington. A quarry has been opened here in the extreme southeastern corner of section 14, in the Lower Burlington. About twelve feet of heavy bedded limestone is used. At various points along the bluff small quarries have been opened, but none are worked systematically.

Benton Township.—No regular quarrying is carried on in this district. The ledges, which are numerous, are quarried at various points for local use.

CLAYS.

DISTRIBUTION.

Although clays suitable for the production of ordinary brick and draintile are fairly well scattered over the county, those grades which will be used the most are not so widely distributed. There are deposits of two geological formations upon which special dependence may be put for supplying good clays. These are the Kinderhook shales and the Lower Coal Measures. A small amount of clay might be taken from the Upper Burlington, but this can rarely be obtained without quarrying from 10 to 30 feet of limerock. The shales of the upper part of the Augusta which are exposed in the southwestern corner of the county may also, in time, be brought into use.

Kinderhook Shales.—These shales are confined in their surface exposure to an extremely narrow belt. Yet the quantity present is sufficient to supply the entire country for centuries. They form the base of the Mississippi escarpment along the entire eastern border of the county, a distance of thirty miles. While they may not be fully exposed everywhere along the line, the removal of the talus at the foot of the bluff will reveal the shales at probably every point. In many of the smaller streams which enter the Mississippi the Kinderhook is often exposed for a short distance above the point where the water courses cut into the escarpment.

There is a thickness of over 200 feet of the shales at Burlington, three-fourths of which is below the river level. The only place however where they are used for making clay products is at the "Cascade" two miles below the city of Burlington. Beneath the upper thirty feet, which is too sandy for use, the best argillaceous portion has a thickness of about thirty-five feet. This is a gray or bluish ashen, rather massive bed, exhibiting few indications of lamination. Immediately below is what is called fire clay, which may prove refractory enough to permit the construction of crucibles and fire brick.

Augusta Beds.— Since the Augusta formation is made up largely of limestone there are slight chances for the occurrence of extensive clay deposits which would be suitable for manufacturing it into a high grade of clay products. The clay beds which occur between the limestone layers are usually very thin; though one is known to be at least four feet in thickness. It could probably be readily mined if it should prove to be of good quality. One of the best outcrops of the bed is at the Miller quarry above the Cascade, south of Burlington. In the southwestern part of the county the shales of the extreme upper part of the formation might be utilized, yet the existence of practically inexhaustible supplies of a much better grade of clay near the known exposures precludes the idea that they will ever be used very extensively.

Coal Measures.—The Upper Carboniferous formation have an areal extent in Des Moines of only a few square miles. There is but a single locality now known, and this in the extreme southwestern corner of the district. The deposit is a small oval outlier which lies partly in Des Moines and partly in Henry county. Over thirty feet of argillaceous shales are disclosed at one point in a single section. A thin coal seam has been worked in the same vicinity (Tp. 70 N., R. IV W., sec. 5, NW. qr., NW. ¼). Fuel was taken out as early as 1834. Besides supplying unlimited quantities of raw material for draintile and building brick a three and one-half foot bed of fire clay is present, capable of being transformed into fire brick or after washing into the higher grades of refractory products and pottery.

Till.—The superficial deposits consist largely of the boulder clay in which are frequently sand and gravel beds. Two rather well marked phases are shown in some places. One is the widely prevalent yellow variety and the other is red to brown in color. The latter is well exhibited in the neighborhood of Burlington where it has been exposed in many street gradings. It lies immediately beneath a red gravelly clay upon which rests the loess. As it is rather plastic and contains a large percentage of iron oxide it would serve excellently for making brick and tile when freed from the concretions of lime which it bears.

Loess.—This fine silicious clay is found capping the bluffs in many parts of the county. In the vicinity of the Mississippi river the loess resembles more closely than elsewhere the typical deposits of this formation; over the inland it appears somewhat altered.

Alluvium.—Wherever shown along the streams the material is well adapted to the manufacture of common brick. With the other good clays at hand the alluvium is not destined to come into extensive use for making building material.

CLAY INDUSTRIES.

Burlington.—The sources of raw materials found in the neighborhood of the city of Burlington have already been referred to at length. The most extensive operations are carried on by the Granite Brick Company, whose plant is located at the Cascade immediately south of Burlington on the river bank, a distance of two miles below the Union railway station, and on the line of the St. Louis, Keokuk and Northwestern railroad, a part of the Burlington system. An extensive vertical exposure is presented at the pit from which the material is obtained. The details, according to Mr. E. H. Lonsdale are:

Section at Clay Pit of Granite Brick Company.

		FEET.	INCHES.
15.	Loess, reddish	10	
14.	Chert, white	2	6
13.	Limestone, white and brownish	10	
12.	Shale parting		3
11.	Shale, arenaceous "sandstone"	3	
10.	Limestone, hard, fine-textured	12	
9.	Shale, arenaceous, compact, "sandstone"	2	4
8.	Shale parting		2
7.	Shale, arenaceous, "sandstone"	10	6
6.	Shale parting		4
5.	Shale, compact, "sandstone"	12	2
4.	Shale; very compact and massive	12	
3.	Sandstone	1	1
2.	Shale, massive, silicious	7	8
1.	Shale, massive, argillaceous	10	6

Except when number 1 is used, in which case a siliceous loess-like clay is mixed, all the material taken out is from the Kinderhook beds. Beneath the lowermost stratum given in the section the shale is too refractory to serve for pavers. The treatment of the clay that comes from the pit is essentially as follows. The shale, as it is quarried is loaded on small cars which are drawn up a steep incline and dumped into a dry pan having an eighth-inch screen. The pulverized material is then elevated to a Frey-Sheckler pug mill and from thence into an Improved Acme of the same make. As the cylinders of clay issue from a double dye they encounter a rotary cut off. The green brick are transferred to a large furnace-heated floor where they are allowed to dry a day or sometimes a day and a half before firing. There are five Eudaly kilns having a combined capacity of 105 000 brick.

In the southern part of the city, on the corner of Moltke and Wilhelm streets, is the Kupper brickyard. "The Ohio" machine of Fate and Freese make is used. The material worked is the upland loess of the district and is removed for a distance of three or four feet. The moulded brick are dried on shelved racks.

In the north part of Burlington, at "Sunnyside," is the Ritter yard. Sand-rolled brick are made and the output is quite large. The material used in making the brick appears to be a modified loess and is used to a depth of from three to five feet. The green brick are spread in the yard or in roofed sheds to dry and afterward burned in ordinary temporary kilns. In addition to the regularly shaped brick there is moulded a form with one corner rounded.

The Schott yard has recently been opened on Osborn and Bernard streets. Ashen or white loess is used to a

GORGE OF THE MISSISSIPPI RIVER; GRANITE BRICK PIT, BURLINGTON.

depth of about four feet. The moulded brick are dried on the ground.

Mediapolis.—The Johnson Brick and Tile Works are situated a short distance north of the railway station. Operations have been carried on successfully for a period of more than ten years. The clay which is obtained near the factory, is an ash-colored loess, having a thickness of about eight feet. Beneath it nine feet of till is used; then comes gray drift and finally the blue boulder clay. Bed rock is encountered at a depth of thirty feet. From the pit the material is conveyed to a Penfield smooth roller and from thence to a No. 6 Brewer machine. The moulded product is raised to the second floor of the shed and dried. Three kilns are in use; one a Swift, and the others round, down draft. Four days are required to burn the tile and over a week for the brick.

One and one-half miles north of Mediapolis the Burlington, Cedar Rapids and Northern Railway Company established a station for burning clay for ballast. The material used was the ashen loess similar to the clay at the surface at the Johnson plant. Operations were only carried on for a period of four months, though during this time enough clay was treated to ballast over ten miles of track. It appears that the methods of burning the clay were not fully understood and consequently all of the material was not thoroughly prepared. With proper treatment the clay would doubtless be well suited for the purpose.

Kossuth.—Brick making has gone on in this vicinity for some years. The Pratt yard makes a sand-rolled brick from an altered till. The clay is dug only to a depth of about one foot, below which the deposit becomes jointy. The product is burned in cased kilns.

A mile south of the town is the Lundeen Brick and Tile Factory. The raw material used is similar to that taken out at the Pratt yard. The output is chiefly three-inch tile. It is burned in an updraft kiln.

Parrish.— One of the oldest clay concerns in all southeastern Iowa is the Melcher Pottery, which is situated in the southwestern corner of the county (Tp. 70 N., R. IV W., sec. 31, west half). Manufacturing of clay goods has been carried on here almost uninterruptedly for nearly half a century. The material used is from the Coal Measures, and is obtained from two localities, one about a mile north of the factory and the other a short distance south. At the former place the shale is gray or white becoming darker below. The thickness of this stratum varies from three to five feet. The usual combination is one part from the first pit and two parts from the second; and very satisfactory results are thus obtained.

Before moulding, the clay is cleaned; a process which consists in agitating the wet clay in a tub in which is suspended a rotating harrow. After being thoroughly stirred, the clay held in suspension is passed through fine screens into vats and dried, and afterwards pugged in an ordinary mill. Four turning wheels and one jolly are in operation. In the summer the green products are dried in the sun; in winter on furnace-heated floors. Albany slip is used in glazing. There are two kilns; a Howard patent, with a capacity of 3 800 gallons, and an ordinary potter kiln holding 2 000 gallons. All the common articles issuing from potteries are made. The largest sized ware is the fifteen-gallon jar. Some experimenting in glazing with a Coal Measure clay from a five-foot bed near the Skunk river, a short distance to the south, has been carried on with partial success. The results make it appear not improbable that with certain admixtures the material may yet be used advantageously, and a glaze produced not inferior to that at present obtained.

COAL.

The coal-bearing strata of Iowa reach Des Moines county only in isolated basins. The district is too far to the eastward to expect very extensive deposits of carbonnaceous material as a part of the Iowa field, and not quite far enough east to come within the Illinois area. The district is thus situated between two large coal producing regions which touch its borders but which do not as yet allow fuel to be taken out in commercial quantities within its boundaries. With the exception of a few square miles the entire area is covered beneath the drift mantle by strata which are older than the Coal Measures and which therefore lie beneath the productive beds.

The coal measures consist chiefly of dark and light colored shales, and brown ferruginous sandstones. Occasional nodular bands of dark calcareous rock occur immediately over the coal seams. The only shales which are likely to be mistaken for coal shales are the Kinderhook beds. In the vicinity of Burlington several shafts have been sunk at different times into these layers with the hopes of obtaining coal. Some of these excavations have reached depths of forty to fifty feet before the enterprises were given up as fruitless. In all of these cases a considerable expenditure of time and money was wasted in places which were entirely below the coal-bearing beds. At other places in the county similar searches after mineral fuel have been undertaken with like results.

As stated in another place, the limited areas of Coal Measure rocks which occur in the county are found in depressions in the limestone floor; depressions which were once ancient valleys or ravines excavated in the hard bed rock by old water courses that existed previous to the laying down of the coal strata.

The various basins now isolated may have been at one time connected and subsequently the strata eroded until now only occasional remnants are left. The only areas of Coal Measures at present known in Des Moines county are in the southwestern part. Others may occur in the western half of the district, in the central and northern portions and in all probability do exist, though as yet they have not been located. It would not be at all surprising to find at no distant day several such pockets containing coal seams of sufficient thickness to be profitably worked and to afford supplies for local use.

The most extensive deposits of Coal Measures now known in the district are two miles northeast of Augusta. The exposure is largely a buff to brown sandstone, massive, firm, and homogeneous in its texture. It rises in bold almost perpendicular cliffs and is thought to have a thickness of more than one hundred feet. Its base has not been observed so that it is not known whether shales and coal are associated. It probably represents the basal sandstone of the Coal Measures in this region, in which case the carbonaceous layers, if any exist, are to be looked for toward the top rather than at the bottom. The position of the outcrops is such that with very little trouble tests could be made to find out whether or not coal exists at the base of the sandstone.

The most important outcrops and the most hopeful from an economic standpoint are on Cedar creek, about three miles southwest of Danville station on the Chicago, Burlington and Quincy railroad. The area covered by

Coal Measure shales and sandstone comprises a number of square miles, part lying in Des Moines and part in Henry county. The best section now exposed is on the Jester place (Tp. 70 N., R. IV W., sec. 5, NW. qr.), where fourteen inches of coal may be seen.

MINERALS.

In addition to the mineral deposits which are now operated on a commercial scale, and which have been already described, there are a number which are known to occur within the limits of the county but which are not yet worked to any extent. Most of these probably are not sufficiently abundant to be profitably mined, but some of them doubtless will prove eventually to be commercially valuable. With others there is small hope of their ever occurring in sufficient quantities to pay for the time and money expended. Yet, periodically more or less excitement bursts forth over some reputed discovery of gold, lead or other mineral.

Copper in the native state is found in Des Moines only as erratic fragments in the drift, having been transported from the far north by the glaciers.

Gold likewise occurs only in small quantities. It is often concentrated by running water from the drift and accumulates in the stream beds in sufficient quantities to be perceptible after panning. Starr cave is the principal place where the yellow metal is reported and from time to time such reports lead to a working of the gravels for several days at a time. There are similar sands and gravels in different parts of the district which yield small amounts of gold. But it is hopeless to expect that paying deposits of this mineral will be found.

Zinc.—Sphalerite, or zinc sulphide, is occasionally found in small crystals in cavities in the limestones. The samples are of interest chiefly as mineralogical specimens.

Pyrite.—The sulphide of iron, while abundantly and widely distributed in minute crystals through certain rocks, is never found in large enough deposits to make it commercially valuable. In the Kinderhook shales it is found usually in small balls from the size of shot up to three or four inches in diameter. Many of these masses consist of aggregates of small crystals with bright faces. Frequently also the crystals occur singly. The crystallographic habit is commonly the octohedron modified slightly by the cubic faces. Small amounts are also found in the bituminous shales of the southwestern part of the county.

Marcasite, which is another form of iron sulphide, also occurs in some of the shales but it is not nearly so widely distributed as the pyrite.

Galena.—The common ore of lead is found in the same way as the zinc, small masses scattered through cavities in the limestone. It rarely is of interest from a mineralogical standpoint and is of no value economically. The reports of the finding of this mineral in paying quantities in Des Moines have been frequent, but all have thus far proven false.

Quartz, though usually widely distributed, is of rare occurrence in the district under consideration and is found as small crystals and masses in limestone cavities. None of the quartzose sands are sufficiently free from impurities to permit their use for making glass.

Limonite exists in small amounts as a pseudomorph after pyrite.

Hematite is not found in quantities of commercial value, though frequently occurring in some of the Coal Measure sandstones in apparently considerable quantities.

Calcite is one of the most abundant of minerals found in the region. Aside from its occurring in seams and masses through the limestones, it is found in beautiful crystals lining cavities in the rock.

Gypsum occurs only as small crystals in the Coal Measure shales of the southwest.

Epsomite, the sulphate of magnesium, or native epsom salts, is found at Starr cave, northwest of Burlington, where it accumulates under the overhanging cliffs of limestone along Flint creek. It forms efflorescent encrustations on the rocks when sheltered from rains. Its origin as given by White is as follows:

The rock upon which the epsomite accumulates is an impure limestone containing also some carbonate of magnesia, together with a small proportion of iron pyrites in a finely divided condition. It is doubtless by the double decomposition of these that the epsomite results. By experiments with this native salt in the office of the survey, a fine article of epsom salts was produced, but the quantity that might be annually obtained there would amount to only a few pounds, and of course is of no practical value whatever, on account of its cheapness in the market.

POLISHING MATERIALS.

An abundance of a white amorphous silicious material in the form of chert exists in nearly every ledge of rock exposed in the county. At the limestone quarries large amounts of it are thrown out as worthless. As yet no use is made of the Des Moines cherts. In other states these cherts are ground into a flour-like powder which is sold for scouring and polishing purposes. Large quantities are also mixed with certain soaps to make them more effective. The pure white varieties which are obtained in almost every quarry in the county appear to be admirably adapted for this purpose.

LIME.

Des Moines county is so well supplied with good limestone that it is somewhat surprising that the manufacture of lime is not carried on much more extensively than it is. Although there are a number of lime kilns in the county none of them have more than a local output and most of them are idle a good part of the time. In former years considerable quantities of lime were burned at several points, principally at Burlington. In the vicinity of that city are several old kilns which are now rarely used. Certain of the beds in the Burlington limestone are surely well adapted to the manufacture of a good grade of lime. At Hannibal, and especially Louisiana, on the Mississippi river one hundred miles to the south, large quarries have been opened in identically the same layers that occur at Burlington and large kilns are kept in active operation the year around, making and shipping away great quantities of a very excellent lime.

That a good grade of lime can be produced is shown by what has been done in previous years in the vicinity of Burlington, at one or two points on Flint creek, and at Augusta. Besides the ordinary limestones of the Augusta formation, particularly the Upper and Lower Burlington limestones, there is the buff limerock lying near the top of the series which occurs in the southwestern part of the county and which in certain parts should supply a very superior grade of material for lime. It contains sufficient magnesia to make it especially sought after since the limes composed of a mixture of calcareous and magnesian elements are usually regarded as very much better than one made from the former alone. The white Saint Louis limestone, also exposed in the southwestern corner of the district, furnishes a good rock, and in other parts of the state the same stone is used extensively for burning lime.

ROAD MATERIALS.

Good highways form a prominent factor in the material prosperity of a community, and the constantly increasing interest which is being taken in the subject everywhere makes it important to know just what materials in each locality are available for the betterment of the roadways. Suitable gravels for improving the roadways occur not only along the larger streams but in the drift in various parts of the district. The location of several of these beds is well known and the quantity found is sufficient to supply very considerable areas. Other similar deposits will doubtless be found when the material begins to be used extensively.

The limestones which are exposed in nearly every township afford an abundance of good material for macadam and may be widely used. The cost of breaking into suitable sizes may deter somewhat the extensive use of this material, but with proper appliances and the right kind of supervision this could be readily overcome. In this connection it may be well to state that the chert which is so abundant in all the limestones of the region might form an excellent material for road purposes. At all the quarries it is thrown out as useless and it accumulates in large piles. It breaks readily under the hammer into sizes of the right dimensions, is much harder than the limestone, more durable, cleaner, and on account of the angularities on the fragments it packs better in the roadway, forming a very smooth, clean bed. The ease with which it yields to hammer blows, its worthlessness as a quarry rock, its hardness, and the cheapness with which it may be obtained, recommend it for highway purposes.

Another material which is certainly destined to become widely used for making good roads, is burnt clay. It forms a non-plastic, hard, smooth surface, almost noiseless, and in all respects equal to macadam. In other parts of the state it has been used successfully for private driveways. Some of the railroads are utilizing it extensively for ballasting the roadbeds, it forming a good elastic surface, allowing the cars to run with less jar and noise than with stone ballast, and on the whole causes much less wear in the rolling stock. Much of the drift and alluvial clay is well adapted for this use. Aside from its cheapness and ease in preparing and handling, it has the great advantage of usually occurring in localities where few or no rock exposures exist.

SANDS.

Sand for building and other purposes may be obtained from several geological formations. Commonly it is taken from the bars in the streams. At Burlington, where the channel of the Mississippi comes up to the very foot of the escarpment on the west side of the river, the sand used is dredged up from the bottom of the stream and carried over to the city in barges. As a rule the river sand is quite clean, sharp and well adapted for mortars of all kinds. In the drift deposits numerous lenticular beds of fine to coarse sand occur and these are available in every township of the county. Often considerable coarse material and gravel are mixed or interstratified with fine sand but this rarely prevents the latter from being utilized. Certain of the arenaceous strata of the Coal Measures in the southwestern part of the county are suitable for utilization in building; and the softer sandstones, especially the weathered portions from the same formations, are also available. The upper layers of the Kinderhook are composed of soft sandstone, fine-grained and homogeneous. They readily disintegrate upon exposure into loose sand which often forms a bed a dozen or more feet in thickness. Such deposits exist near Starr cave, four miles northwest of Burlington.

WATERS AND WATER POWERS.

With waters for domestic uses the district is well supplied. The principal streams are never failing sources of water which may be readily utilized for all purposes. Abundant springs occur everywhere in the eastern and southern portions of the county along the escarpments of the Mississippi and Skunk rivers, and also along Flint creek. These send forth gushing streams of cold crystal waters. For the most part they are small in size but others are larger and form the headwaters of creeks, which do not run dry even in periods of protracted drought. None of the spring waters contain sufficient quantities of dissolved salts to allow them to be called mineral waters. Many of the springs burst forth from immediately beneath the Burlington limestone; where these occur along the bluffs of the two largest rivers the little streams dash along in miniature torrents to the foot of the escarpment. The creeks rising some distance back from the eastern and southern borders flow gently along until they reach the brow of the cliffs formed by the hard limestone overlying the softer shale of the Kinderhook when they break into cascades or waterfalls often of considerable height.

In all parts of the county good, clear and a medium soft water is readily reached by sinking wells to moderate depths. As yet no deep wells have been sunk for artesian purposes, but it is quite probable that practically the same conditions prevail that exist to the southward in Lee county, at Keokuk, Mount Clara and Fort Madison. Moreover, the depths to which it would be necessary to go in order to reach the water bearing strata could not be so great as in the neighboring district.

The water powers have not been utilized very much. On Skunk river, at Augusta, a dam has been constructed from which power was secured for running a mill for many years. On Flint river also, a small dam has been built. On both of these streams a much greater amount of water power could be readily brought under control than is at present.

ACKNOWLEDGEMENTS.

In the preparation of the account of the geology of Des Moines county, Mr. F. M. Fultz of Burlington assisted in the field mapping of certain portions of the district, and took detailed notes of these areas. The photographs reproduced were also taken by him. To Mr. Charles Wachmuth, also of Burlington, acknowledgment is due for information regarding numerous localities which were visited several years ago during a two years residence in that place. Mr. E. H. Lonsdale visited all the clay works and from him chiefly were obtained the notes on the clay industry.

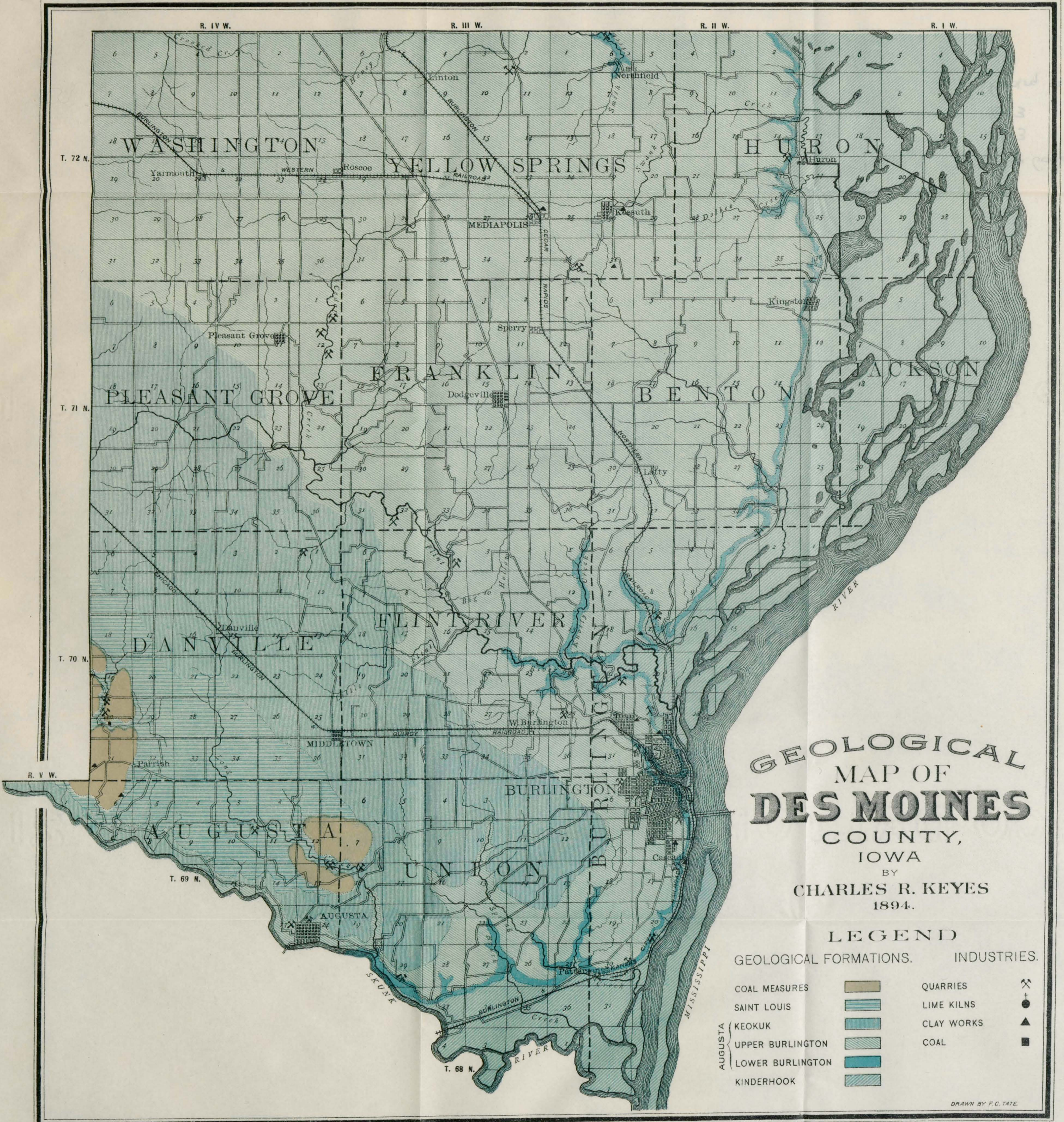


PHOTO LITH BY A. HOEN & CO. BALTIMORE, MD.

INDEX.