IOWA
GEOLOGICAL
SURVEY

VOL. V.

ANNUAL REPORT
1895

IOWA

GEOLOGICAL SURVEY

VOLUME V.

ANNUAL REPORT, 1895,

WITH

ACCOMPANYING PAPERS.

SAMUEL CALVIN, A. M., Ph. D., State Geologist.

H. FOSTER BAIN, Assistant State Geologist.

DES MOINES:
PUBLISHED FOR THE IOWA GEOLOGICAL SURVEY.
1896.

DES MOINES:
F. R. CONAWAY, STATE PRINTER.
1896.

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ADMINISTRATIVE REPORTS.

FOURTH ANNUAL

Report of the State Geologist.

IOWA GEOLOGICAL SURVEY,
DES MOINES, December 31, 1895.

To Governor Frank D. Jackson and Members of the Geological Board:

GENTLEMEN—Pursuant to provisions of the statute organizing the Iowa Geological survey I have the honor to report on the work done by this branch of the public service during the year 1895.

In accordance with the purpose expressed in the report of last year, the energies of the survey have been chiefly directed to areal geology, taking the several counties as the areal units. The third annual report, issued during the year, is the first volume devoted wholly to county reports, and it will serve to illustrate the plan which it is proposed to carry out in setting forth fully and exhaustively the geological resources of the several counties of the state.

In addition to county work there are still, however, a number of general problems of especial interest to the people generally without respect to county lines. These general problems embrace questions relating to water supplies, lead and zinc ores, coal, clays, building materials of every kind from quarry stones to mortars and cements, and these as will presently appear, have not been neglected.

The work of administration has been greatly lightened by the very helpful and efficient aid of the assistant state geologist, Mr. H. Foster Bain. Mr. Bain has had charge of the headquarters of the survey at Des Moines. On him has fallen the burden of attending to the numerous executive details inseparably connected with the central office. He has superintended the publication and distribution of reports, has corrected proof, received and installed collections, and in many other ways has performed the larger share of the unproductive administrative work. His thoroughness and efficiency in discharging all the duties assigned him, whether in the office or in the field, it gives me pleasure hereby to acknowledge.

My own time has been very fully occupied with a great variety of duties, embracing details of administration and office correspondence that cannot be assigned to anyone else. My work in the field during the season was directed to the accomplishment of three things. First, I have been aware for some time that the geological maps of Iowa, published some years ago, and which formed in part the basis for our preliminary map, needed rectification so far as relates to the eastern edge of the Devonian in Buchanan, Fayette, Howard and Winneshiek counties. In some cases the margin of the Devonian was located from fifteen to twenty miles too far to the east, while in other cases it was nearly as far out of the way toward the west. Beds of Galena limestone on the one hand, and beds of dolomitized Devonian on the other, have been incorrectly mapped as belonging to the Niagara series. My first field work of the season had reference therefore, to collecting the data for making the necessary corrections on the future geological maps of the state. The dolomitization of the Devonian in the northern part of the state, and the abrupt feathering out of both the Niagara limestone and Maquoketa shales before reaching the Minnesota line are facts of no small degree of economic importance. Second, it was desired to prosecute definite areal work as vigorously as possible. To this end the field work for Jones county, begun two years before, was completed, some portions of Delaware county were reviewed, and detailed work in Buchanan and Johnson counties was taken up and practically finished. The work in Jones county made it necessary to investigate in some detail certain phases of the LeClaire and Anamosa limestones in Cedar and Scott. Third, the soils of Iowa, which are among the most important geological deposits of the state, vary with the nature of the drift and the modifications to which it has been subjected. In the northern part of the area covered by the season's field work, there are two drift sheets; in the southern part there is but one. Some time was devoted to tracing the margin of the second drift sheet beyond the limits of the counties under immediate investigation.

Apart from the unavoidable details of administration and correspondence, the unproductive work of the office consumed a large amount of time devoted to editing and revising manuscript reports submitted by other members of the survey. The more directly productive work was devoted to preparing for publication the results of investigations made in the field. The report on Jones county is finished and is submitted as part of the accompanying volume, and reports on the other counties studied will soon be ready for submission. A number of articles containing general information on a variety of subjects, were prepared and have been widely published in the newspapers of the state. These articles treated on such subjects as Natural Gas in Iowa, Uses for Iowa Chalk and Coal Slack, Some Iowa Building Stones, and the History and Genesis of Iowa Soils. Besides furnishing articles on subjects of popular interest to the newspapers, it was deemed worth an effort to call public attention to Picturesque Iowa, in articles contributed to an Iowa magazine.

The work accomplished by Mr. Bain is fully set forth in his administrative report, which is hereto appended.

Prof. A. G. Leonard has continued his work on lead and zinc. His administrative report shows the progress made in the investigation of the subjects assigned him.

Prof. W. H. Norton has spent such time as he could spare from his duties at Cornell College upon the Artesian Well report. Very satisfactory progress has been made, and it is expected that the completed manuscript will be in hand in February. A full statement of the work undertaken, and the progress so far made by Professor Norton, appears in his administrative report.

Prof. G. E. Patrick, chemist to the survey, offered his resignation, which was accepted in May. The board then authorized the state geologist to make suitable arrangements regarding chemical work. Satisfactory arrangements have been made with Dr. J. B. Weems of the agricultural experiment station, and he will in future have charge of this line of work. But little chemical work has been done this year, though Dr. Weems is about to undertake the analyses of a series of artesian waters in connection with Professor Norton's work on that subject.

Dr. S. W. Beyer has finished his study of the Sioux quartzite and has prepared a very interesting and valuable report upon this formation and certain associated eruptive rocks. The report is now being prepared for the press, and will probably form a portion of Vol. VI. Dr. Beyer has also continued his work on Boone and Story counties. Owing to illness during the summer months the report on Boone county has but recently been completed, and the completion of the reports on Story and Marshall must be left to a later date.

Prof. J. L. Tilton has continued work on Warren county. His report, which has been submitted and is now ready for the printer, is particularly interesting in that he has discussed quite fully the origin of the drainage system. The results of his work as a whole are of the highest interest. His studies of the coal horizons are likely to prove of considerable economic importance. Since his sections were drawn, but before they were published, a new mine has been opened upon a bed of coal indicated by the sections, though otherwise unknown. The importance of the study of coal horizons as distinct from coal beds is emphasized by this occurrence.

The general preparation of the maps and illustrations has been in the hands of Mr. F. C. Tate, of the Iowa Engraving company, under the direction of Mr. Bain. In this work Mr. Tate has been at times assisted by Mr. C. F. Wilcox, Miss Charlotte M. King and Mr. James Hedge. The general excellence of the work is in the main due to Mr. Tate's skill and care. Within the year the maps of Allamakee, Keokuk, Mahaska, Jones, Warren, Boone, Appanoose, Woodbury and Washington counties have been drawn, as well as most of the minor illustrations appearing in volumes IV and V.

The reproduction of the Allamakee county map by photo-engraving from a series of tracings thoroughly proved the capabilities of this method of work. The success which attended the effort, which was in no small degree due to Messrs. A. Hoen & Co., who made the reproductions and printed the maps, has confirmed me in my determination to use the process in the future work of the survey. The saving, as compared with engravings on stone, is, as has already been pointed out, fully 40 per cent.

Miss Nellie E. Newman has continued to be the efficient secretary of the survey.

Satisfactory progress has been made in the publication of the results of the survey. Four volumes have so far been distributed, and have met with hearty reception. They have been very favorably commented upon by the leading geological and engineering magazines of this and foreign countries, and have brought to the office of the survey letters of commendation from the leading geologists of all countries. The statements as to the resources of Iowa, as given by the survey reports, are finding their way into trade journals and text-books, and thus the reports form the best possible advertisement for the state. Not only outside, but within the state, the reports have received full recognition. Numerous local papers have published long extracts from them, and in a few instances the county reports have been republished entire by local papers.

The four volumes so far issued contain the following papers:

VOLUME I. FIRST ANNUAL REPORT, 1892.

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 H. F. 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.

VOLUME II. COAL DEPOSITS.

BY CHARLES ROLLIN KEYES.

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 North Central 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. SECOND ANNUAL REPORT, 1893.

CONTENTS:

Administrative Reports.
Report of State Geologist.
Report of Assistant State Geologist.

Report of Chemist.
Work and Scope of the Geological Survey; by Charles Rollin Keyes.
Cretaceous Deposits of the Sioux Valley; by H. F. Bain.
Certain Devonian and Carboniferous Outliers in Eastern Iowa; by William Harmon Norton.
Geological Section Along Middle River in Central Iowa; by J. L. Tilton.
Glacial Scorings in Iowa; by Charles Rollin Keyes.
Thickness of the Paleozoic Strata of Northeastern Iowa; by William Harmon Norton.
Composition and Origin of Iowa Chalk; by Samuel Calvin.
Buried River Channels in Southeastern Iowa; by C. H. Gordon.
Gypsum Deposits of Iowa; by Charles Rollin Keyes.
Geology of Lee County; by Charles Rollin Keyes.
Geology of Des Moines County; by Charles Rollin Keyes.

VOLUME IV. THIRD ANNUAL REPORT, 1894.

CONTENTS:

Administrative Reports
Geology of Allamakee County; by Samuel Calvin.
Geology of Linn County; by W. H. Norton
Geology of Van Buren County; by C. H. Gordon.
Geology of Keokuk County; by H. F. Bain.
Geology of Mahaska County; by H. F. Bain.
Geology of Montgomery County; by E. H. Lonsdale.

Volume V, which is herewith submitted, contains, in addition to the administrative reports, the following:

Geology of Jones County; by Samuel Calvin.
Geology of Washington County; by H. F. Bain.
Geology of Boone County; by S. W. Beyer.
Geology of Woodbury County; by H. F. Bain.
Geology of Warren County; by J. L. Tilton.
Geology of Appanoose County; by H. F. Bain.

Volume VI, which will soon be ready for the printer, will contain the following papers:

The Sioux Quartzite and Associated Rocks, with Especial Reference to an Intrusive Diabase Sill; by S. W. Beyer.
The Lead and Zinc Deposits of Iowa; by A. G. Leonard.
Report on the Artesian Wells of Iowa; by W. H. Norton.

In addition, a number of other papers, by various members of the survey corps, are in an advanced stage of completion.

Since the inauguration of the survey, it has been the practice to furnish to the newspapers of the state preliminary notes on the results of survey work while it was still in progress. These reports have been quite generally used by the papers, and have been an important aid in bringing to the notice of the people of any community the results of the work in their region. Among the papers so published, in addition to preliminary notes on the reports on the various counties, have been such papers as, "The Soils of Northeastern Iowa," "The Essential Properties of Building Stones," "Some Iowa Dolomites," "Geologic Conditions of Economic Mining in Iowa," "Coal Mining by Machinery in Iowa," and numerous others.

During the last two years it has been the policy especially to push to as early completion as might be consistent with good work, the reports on the various counties. With that end in view the work has been concentrated in certain counties. Some of these offered special facilities for work, by reason of their easy accessibility or because they were the residence counties of local assistants. In other cases counties have been selected because their geologic structure furnished the key to neighboring regions, or because they contained deposits of prominent and generally recognized economic importance that seemed to demand immediate attention. So far reports on eight counties have been completed and published, six more are completed and are submitted with this report, and a considerable additional number are in an advanced stage of progress.

Professor Tilton has the work in Madison county well under way and will doubtless be able to finish it within the next year.

Dr. Beyer has begun work in both Marshall and Story counties.

Mr. Bain has the work in Polk county in hand, and is, in addition, engaged in a study, preparatory to finishing up the work in that area, of the notes which Messrs. Jones and Lonsdale collected in 1893 and 1894 in Guthrie county.

I have the work in Delaware, Buchanan and Johnson counties practically finished, and have made preliminary reconnoissances in Winneshiek, Howard, Fayette, Cerro Gordo, Cedar, and Scott.

Building Stones.—The collection of materials and notes for a study of the building stones of the state has been carried forward. By the co-operation of Professors Ross and Higgins and Mr. H. B. Murray of Drake University, and Prof. A. Marston of the Agricultural College, it has been possible to begin the testing of samples of quarry stones. Owing to the limited time at the disposal of those co-operating with the survey in this work, it was thought impracticable to undertake a complete study of the building stones of the state at this time. A circular letter was, in October, addressed to a number of quarrymen in different parts of the state, asking their assistance in the work. The responses have been most hearty and generous. It is proposed to collect for immediate study a series of the typical and better known stones now marketed from Iowa. These will be subjected to absorption, compression and shearing tests, and in certain cases chemical analyses will be made. With the results of this work as a guide, later and more elaborate studies may be undertaken.

The work along this line has already begun, and the results will be made public as early as possible. In the meantime the work of the county surveys is affording considerable material for later study, and is pointing out the vast number of excellent ledges not yet opened up.

During the year a series of short articles have been furnished to the local press bearing on various phases of the building stone industry. Among other papers a brief communication giving the results of work on the several counties studied, so far as relates to quarry stone, was furnished to the United States Geological Survey, and published in the sixteenth annual report of that organization. The undeveloped and recently developed quarry resources of Iowa were by this means brought to the attention of a large number of interested readers.

Cement.—The fact that Iowa contains vast quantities of material suitable for manufacture into the best grades of cement is becoming rapidly known, and we may reasonably hope to see a large cement industry grow up in the state within the next few years. The survey has already pointed out the ready availability of the deposits along the Big Sioux river, and has, during the year, been called upon to answer many letters of inquiry regarding them. An arrangement has been entered into whereby Mr. S. B. Newberry, manager of the Sandusky Portland Cement company, of Sandusky, Ohio, has undertaken to make for the survey the fullest practical tests of various cement deposits. Some material has been shipped to Mr. Newberry, and more will be sent as soon as it can be collected.

Coal.—A large share of the energies of the survey during the period of its existence has been devoted to investigations on coal. The work of the last year has been no exception, though in this case the investigations have been carried on in connection with the county work. Of the fourteen counties upon which reports have already been prepared, nine have been in the coal field, and one other has, in the past, produced coal. The effort has been, from the first, to give that subject the fullest possible consideration. With this end in view, the counties which lie along the eastern border of the coal field have been examined and reported upon first. Along much of the eastern border of the Iowa coal field the deposits are thin, and frequently have been cut off from the main body of the coal measures by erosion. The entire region is drift covered, and, hence, the exact limits of the coal measures are not easily defined. It is but natural under such circumstances, that in the past considerable sums of money have been spent in prospecting areas lying wholly without the coal measures. For this reason it has been considered important that the first work of the survey should be directed to tracing the eastern margin of the coal field, so that the ground which may legitimately be prospected can be known from that which is surely barren. With this end in view, the maps of Lee, Des Moines, Keokuk, Mahaska and Van Buren counties have been published, and a similar map of Washington county accompanies this report.

In the course of work in the coal-bearing counties, important data relating to the conditions of deposition and formation of coal, and the methods of working it economically, are being collected. From time to time brief articles, bearing on these subjects, have been furnished to the press, and when the work is completed, the facts will be published as part of the final report.

Museum.—In connection with the office of the survey at Des Moines, a museum has been established which is designed to show to the best advantage the present material resources of the state. This collection is receiving constant additions through the efforts of the members of the survey corps, and the generosity of individual producers. Within the last year several important additions have been made. The collection of clay products includes samples from every clay-working plant in the state; brick yards, tile yards and potteries being alike represented. The collection of building stones, while important, is not yet so complete. The collection of minerals, particularly from the lead and zinc regions, is quite complete, and makes a striking and attractive exhibit.

A few of the larger and more important building stone and clay producers have made attractive individual displays, and room is held for a few more. Among those who have recently installed exhibits are Hon. J. A. Green, proprietor of the Champion Quarries, at Stone City, the Platt Brick Co., and the Sargents Bluffs & Sioux City Brick Co. The value of an attractive display in the capitol building, where it is visited by large numbers every day, is being recognized, and the limited space at the disposal of the survey for such purposes will soon be completely occupied.

The collection of photographs grows rapidly. While the views are taken primarily for the immediate purpose of the survey work, they afford excellent illustrations of the natural features of the state, and can be made of large service in teaching geography and kindred studies. Recognizing this fact, and wishing to encourage in every possible way the movement toward better teaching, a list of the photographs available was prepared last February and sent with the following explanatory letter to such as it was thought would be interested.

IOWA GEOLOGICAL SURVEY.

S. CALVIN, State Geologist.
H. F. BAIN, Assistant Geologist.

DES MOINES, January 10, 1895.

SIR—The law governing the geological survey of this state makes provision whereby duplicate specimens may be distributed to the various colleges. It is believed to be in accord with the spirit of this provision that the following statement is made:

In the course of the regular work of the survey a considerable number of photographic negatives has accumulated. Some of these views possess more or less educational value in connection with instruction in geology and geography, and prints of them are offered at the mere cost of production. The negatives will be placed in the hands of a competent photographer, who will fill all orders at a uniform price of 12½ cents each. They will be in part 4½x7½ and in part 6x8, with a few of larger size. They will be printed on American aristo paper, and mounted on heavy white cards 8x10.

The list offered is neither complete nor systematic, but it is hoped it may prove serviceable. There is a supplementary list of views in the Black Hills, which are the personal property of the state geologist, and which may be obtained upon the same terms.

Please order by number, and address all communications to

SAMUEL CALVIN,
State Geologist.

A considerable number of responses have been received, and it is thought that, as the offer becomes more widely known, it will be taken advantage of by a larger number of teachers.

The museum affords an opportunity, by means of various special charts and diagrams, to set forth graphically the various resources of the state. Certain of these charts have been prepared, and as the work of the survey progresses these can be made from time to time more exact and useful.

The library of the survey has continued to grow by donation and exchange. The reports of the various state and certain foreign surveys, as well as the proceedings of numerous learned societies, are being regularly received in exchange for the volumes published by the Iowa survey. These reports, together with the books afforded by the state library, make a satisfactory working collection. The liberality of the state librarian and the board of trustees of the state library, in purchasing the books needed by the survey officers, has made it unnecessary to spend more than a small sum of money in this direction. It is a pleasure to acknowledge this hearty and much valued co-operation.

In the general conduct of the survey it has been the effort to direct the work along those lines which should be productive of the most practical economic benefits. It has been recognized that a survey paid for by the state can only justify its existence in proportion as it is a benefit to the state. So long as problems of fundamental economic import remain to be solved, the energies of the survey should be directed to them rather than to the elucidation of equally interesting, though less directly valuable, problems of pure science. It should not, however, be forgotten for one moment that the truest and most practical results are only attained by the most careful and exact scientific investigation of all the significant phases of a question. A right understanding of the problems of deeper water supplies, and the ability to make estimates of the distance to water and the rate of its flow to any point, which the survey is constantly asked to do, can only be had by a thorough investigation of the character and stratigraphy of the Paleozoic beds of eastern Iowa. One bore hole, even if driven to China, will not settle the question of gas or oil supply for the state or any considerable part of it, and anyone at all familiar with practical prospecting in the best known portions of the Iowa coal fields knows that neither one nor a dozen deep bore holes will settle the question of deeper coal seams in the southwestern part of the state. Yet careful stratigraphic studies may, and doubtless will, shed much light upon the subject. After these investigations it will be possible to direct prospecting to the best advantage. It is the proper duty of the geological survey, as outlined in the law under which it was organized, to make these investigations. Yet it must not be thought that the survey is primarily or even principally a "bureau of research." Its duty has been interpreted by the present corps to be first to find out exactly what resources of economic importance the state possesses, and second to make these resources as widely known as possible. If the reports of the survey accomplished nothing but the latter, the return to the state would still be large in proportion to the sum spent on the work.

It is not generally recognized to what an extent the reports of a geological survey are quoted and accepted as authority. Statements taken from such reports are reprinted in technical and trade text-books, journals, encyclopedias, etc. Coming from the state they are accepted as official and hence carry far more weight than similar statements or statistics put forth by any other authority. A new geography which will be largely used in Iowa schools is now being prepared, and the editor is making use of the reports of the survey in compiling his facts. The data collected by the survey are widely used, quoted and re-quoted. One of our leading coal companies put on its advertising calendar last year a sentence quoted from the "report of the state geologist." A minor article furnished by a member of the survey corps for local publication was copied entire by three of the leading trade journals of the United States. Letters of inquiry are constantly received from all parts of the country, so that as an advertisement of the resources of the state alone the reports have a high value.

I am glad to believe that the work has other values as well. The increased and more exact knowledge of our coal fields, our zinc, lead, gypsum and clay deposits, the better underderstanding of our soils, building stones and water supplies, and the discovery of important cement beds cannot but result in large economic gains to the state as a whole. A large and well equipped lime burning plant has been put up at a point suggested by one of the assistants on the survey. At another an important brick plant has been installed after consultation with the survey officers. A number of other new enterprises are known to be under consideration and have only been held back by the present unfortunate financial conditions of the country.

Respectfully,

SAMUEL CALVIN,
State Geologist.

REPORT OF MR. H. F. BAIN.

IOWA GEOLOGICAL SURVEY,
DES MOINES, December 31, 1895.

SIR—I have the honor to submit herewith a report of my personal work during the year past.

The amount of administrative and office work placed in my charge has prevented the accomplishment of as much in the field as during former field seasons. Much of the months of January and February was spent in superintending the printing and distribution of the final pages of Volume III. March, April and part of May were spent in the preparation of the manuscript, illustrations and maps appearing in Volume IV, which was printed during the latter part of May, the month June and the early part of July.

Within this period time was found for a few short field excursions, one being through Washington county, another to Dubuque, and a third, in company with Professor Tilton, down the Des Moines river. A short visit was made to Mount Vernon and Ames for the purpose of arranging with Professors Norton and Weems the details of the work on artesian wells.

In July the regular field work of the season was taken up, some time being spent in Woodbury and neighboring counties. New and valuable data were collected and incorporated in the report on Woodbury county. Later the work in Appanoose county, originally taken up in 1893, was completed and the report written out. In September a brief excursion was made in your company for the purpose of studying the drift deposits of Johnson and Buchanan counties. A day was also spent with Dr. Beyer in tracing the moraine in Story county, another with Professor Leonard in studying the drift of Tama county, and two days with Professor Norton studying the drift near Mount Vernon and in consultation regarding the artesian well report.

In October and November numerous points of interest in Polk county were visited, and it is expected that the report on this county can be completed in the spring. Preliminary to a study of the drift of Polk county visits were made to the Aftonian deposits lying to the southwest and the moraines near Valeria and Cedar Falls to the northeast, as well as to numerous intermediate points.

Since the close of the field season the reports on Washington, Woodbury and Appanoose counties have been given final revision, the illustrations and maps for Volume V and a portion of Volume VI prepared, and the manuscript for the former, as well as a portion of the latter, assembled.

During the year I have continued to make such notes on mining methods as was compatible with other duties. The usual brief communications to geological journals and newspapers have been furnished.

Respectfully,

H. FOSTER BAIN,
Assistant State Geologist.

TO PROF. SAMUEL CALVIN,
State Geologist.

REPORT OF PROF. W. H. NORTON.

CORNELL COLLEGE,
MT. VERNON, IOWA, December 31, 1895.

SIR—I have the honor to make to you the following report of the work done during the year just closing and since my appointment as special assistant in charge of artesian wells.

A correspondence necessarily large, onerous and as yet unfinished was at once opened with well drilling firms, water companies, owners of deep wells, and with all others who might in any way aid the investigation. Several cities were visited personally. The facts thus obtained form the basis of a report now approaching completion. Of each of the 100 or more deep wells in the state, all the obtainable data will be set forth in this report, including the depth, size of bore, tubing, packing, water horizons, and the flow, head and quality of the water from each horizon, together with its availability for the various domestic and communal uses.

Full description will be given also of the strata penetrated by the drill wherever drillings have been preserved, and the geological section of each well will be shown as completely as the facts in hand will permit.

Thus the experience of drillers in all parts of the state and in the various underlying rocks, and the experience of our citizens in the use of different artesian waters, will be made a matter of permanent record.

In order that this mass of data may be as completely intelligible and as widely available as possible, the entire question of artesian wells and waters will be canvassed with special application to the Iowa fields.

The sources of artesian waters, their chemical composition, and the conditions of their transmission will receive deserved attention. Among other topics considered are the interpretations of water analyses, the adequacy and permanence of artesian supply in Iowa, the sanitary and therapeutic qualities of our artesian waters, and their availability for manufacturing and household purposes, including a resume of recent methods for the improvement of waters naturally unsuited for these uses.

As the question of artesian supply is directly related to other possible sources, the general question of water supply may receive consideration. Statistics have been collected of the waterworks of the state and the various sources of their supply. The purity of our rivers, lakes and shallow wells, their adequacy in times of drouth, the effectiveness and expense of methods of purification now in vogue, are vital questions which must be considered by every community which has the problem of public water supply under consideration. Graphic illustrations are in preparation, such as maps and sections setting forth the structure of artesian basins, the character and attitude of the geological formations, the position of water-bearing rocks, and the hydraulic gradient of artesian waters.

It is hoped that nothing may be omitted from this report germane to its subject and of practical value to the citizens of Iowa.

Very respectfully your obedient servant,

WILLIAM HARMON NORTON,

Special Assistant in charge of Artesian Wells.

TO PROF. SAMUEL CALVIN,

State Geologist.

REPORT OF PROF. A. G. LEONARD.

IOWA GEOLOGICAL SURVEY,
DES MOINES, Iowa, December 30, 1895.

DEAR SIR—I submit herewith a report of the work intrusted to my care during the past year.

The field work upon the lead and zinc deposits of the state was begun in the spring of 1894, and occupied a considerable portion of that year. During the fall and winter, such time as could be spared from other duties was devoted to the preparation of the report. In June last some weeks were spent at Des Moines in preparation of the manuscript, and in November a brief field excursion was made for the purpose of noting such new developments as had taken place within the season just past. Many important items were secured and have been incorporated in my report, which is now complete and has been submitted.

It is a pleasure to state that the outlook for the field is encouraging. The rapid introduction of improved machinery and better mining methods is having an important effect upon the output of the district. The total production for the year 1895 was 750,000 pounds of lead ore and 3,500 tons of zinc, with a total valuation of $42,000.

Respectfully,

A. G. LEONARD,

Special Assistant in charge of Lead and Zinc Deposits.

TO PROF. SAMUEL CALVIN,

State Geologist.

GEOLOGY OF JONES COUNTY.

BY

SAMUEL CALVIN.

GEOLOGY OF JONES COUNTY.

BY SAMUEL CALVIN.

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INTRODUCTION.

SITUATION AND AREA.

Jones county is in the second tier of counties west of the Mississippi river, and is partly included in that conspicuous eastward extension of the state known as Cromwell's Nose. A very important area was added to Iowa by the deflection of the Mississippi from its southerly course near the mouth of the Turkey river, from which point the great stream makes a broad sweep to the east, and then, bending more abruptly to the west, returns to the meridian from which it departed, near Muscatine. A part of Jones county lies east of this meridian.

Clinton and Jackson counties separate Jones from the Mississippi river on the east, on the north lie Dubuque and Delaware, Linn bounds it on the west and Cedar county on the south. Jones county embraces sixteen congressional townships, and, making no allowance for convergence of north and south lines, or for possible errors in surveys, it contains 756 square miles.

PREVIOUS GEOLOGICAL WORK.

The structural features of Jones county, whether considsidered economically or from a purely scientific point of view, have long attracted the attention of geologists, and much has been written concerning various phases of the geological phenomena which the county presents. No exhaustive description of these phenomena has, however, been attempted. The writers on the one hand have dealt with a narrow range of geological facts, or on the other hand they have treated the region in a general way in connection with the consideration of some larger area.

Reference is made to the geology of Jones county in the following official publications:

1844. David Dale Owen. *Report of a Geological Exploration of part of Iowa, Wisconsin and Illinois.*

The explorations reported on were made in the autumn of the year 1839. In the report, on pages 101–107, the several townships now included in Jones county are briefly described, particular attention being given to the distribution of forests and the quality of the soil. On the maps following page 64 of Owen's report, plates ii and iii, the region now called Jones county is embraced in the area occupied by the Coralline beds of the Upper Magnesian limestone.

1852. David Dale Owen. *Report of a Geological Survey of Wisconsin, Iowa and Minnesota.* No reference is made in the body of this report to any part of Jones county, but on the geological map accompanying the report the townships which now make up the county are included in the territory covered by what he now calls the Pentamerus and Coralline beds of the Upper Magnesian limestone.

1858. James Hall and J. D. Whitney. *Report on the Geological Survey of the State of Iowa.* Volume I, Part 1. Geology.

In this report Jones county is grouped with Scott, Cedar and Clinton, and all four counties are disposed of in the four pages 278–281. There are only a few references to special phenomena in Jones.

1868. Charles A. White. *First and Second Annual Reports of Progress by the State Geologist, Etc.*

On pages 27–30 of this report there is a description of some of the geological characteristics of Jones county, especial attention being given to the quarry stone near what is now Stone City. The paper which forms the basis of this part of the report had been published in the Anamosa Eureka in May, 1866.

1870. Charles A. White. *Report on the Geological Survey of the State of Iowa*, Volumes I and II.

In Volume I of Dr. White's report on the geology of Iowa, pages 183 and 184, there are some references to geological phenomena in Jones county; while in Volume II, pages 309–311, the Anamosa quarries, now known as the Stone City quarries, are somewhat fully described.

1886. T. C. Chamberlin and R. D. Salisbury. *Preliminary Paper on the Driftless Area of the Upper Mississippi Valley.*

The paper cited constitutes pages 205–322 of the Sixth Annual Report of the United States Geological survey under direction of Major J. W. Powell. Jones county lies only a short distance away from the margin of the driftless area, and while not directly named is included in the region covered by the general discussion of marginal drift. Some of the surface characteristics of this county are mapped on plate xxvii, and its indurated rocks are indicated by appropriate coloration on plate xxiv.

1891. W. J. McGee. *The Pleistocene History of Northeastern Iowa.*

McGee's memoir embraces pages 189–577 of the eleventh annual report of the United States Geological survey under the direction of J. W. Powell. In this memoir geological features in Jones county are frequently referred to, particularly the topographic forms, drainage and surface materials. An interesting series of well sections in Jones county is given on pages 529–531.

Short papers dealing with other facts of interest in connection with the geology of Jones county, such as White's description of *Stricklandinia castellana* and Calvin's note on the occurrence of *Goniophyllum pyramidale*, have appeared in various publications.

PHYSIOGRAPHY.

TOPOGRAPHY.

Jones county, in its northeastern part at least, is not very far removed from the southwestern edge of the driftless area of the upper Mississippi valley, and its physiographic features have been determined in no small degree by the heaps of drift and ridges of loess developed, during various stages of advance and retreat, along the thin margin of the Iowan ice sheet. While, therefore, over certain portions of the county the topography is that of the gently undulating drift plain, only slightly modified by erosion since the retreat of the glacial ice, there are large areas in which the topography is that characteristic of loess covered regions in which the surface is ridged and billowy, with sharply rounded hills separated by steep-sided, V-shaped ravines. There are also regions in which rather low loess covered hills alternate with nearly level intervals of drift from an eighth to a half mile in width. There are one or two well developed alluvial plains along the principal drainage streams, and there are a few examples of deep valleys of erosion in which streams flow between beetling cliffs of limestone.

Drift Plains.—The principal drift plain of Jones county is continuous with the drift of northern Linn and southern Delaware. It occupies all or part of Castle Grove, Cass, Monticello, Wayne and Scotch Grove townships. This plain is terminated on the south by a large area occupied by loess hills developed along the Buffalo and Wapsipinicon rivers near Anamosa. East of Anamosa the loess ridges leave the river and pass north of the valley of Bear creek through the southern part of Wayne and northern part of Jackson township. On the north the plain is bounded by the irregular topography—at first, below Monticello, erosional, but afterward of loess type—along the south fork of the Maquoketa. Another drift plain begins at the foot of the loess ridges south of Fairview and occupies portions of Fairview, Greenfield, Rome and Hale townships. There is a small drift region known as Bowen's Prairie north of the Maquoketa; and more or less isolated areas are found in Wyoming and Oxford townships. The valley of Bear creek in Madison township is occupied by drift, though on both sides of the valley loess covered hills rise to a height of 30, 40 or 50 feet above the general level of the adjacent drift plains. All the larger drift plains are interrupted more or less by the peculiar morainic ridges covered with loess, to which McGee has given the name paha.

Loess Hills.—The fine yellow clay known as loess, often homogeneous, though sometimes more or less sandy, seems to be developed in all portions of the county where the surface is particularly broken and rolling. There are certain peculiarities of surface configuration that have come to be recognized as loess topography, and yet as noted later on, nearly all the evidence at hand supports the view that much of the physiographic irregularity characterizing loess covered regions was developed before the loess was deposited. The thickness of the mantle of loess spread over the pre-loessian surface varies from a few inches to ten or twenty or even thirty feet. It is only where the deposit attains considerable thickness that the true loess topography appears. The deposit occurs on high ridges, or wider areas, that overlook the drift plains or stream valleys. It washes easily, and sharply rounded hills separated by steep-sided gullies combine to render the surface over the wider loess regions a perplexing maze of swelling prominences that seem at first to be arranged without definite order. It would be difficult to find an acre of level ground in many square miles of such areas. The hillsides are too steep for cultivation. Roadways must wind back and forth to follow ridges or descend to lower levels through tortuous ravines. The topography is a complex affair, partly erosional; but even the essential features have been largely determined and modified by the original irregularity of the surface.

McGee in the work already cited calls attention to the fact that the loess in this part of Iowa is found only on the higher levels and never on the much lower drift plains. The constant relation of drift plain to loess ridge, so far as Jones county is concerned, is well illustrated on both sides of the Wapsipinicon river near Anamosa. Directly north of Anamosa, near the northwest corner of section 2, Fairview township, the loess ridge rises to an elevation of nearly 200 feet above the river and overlooks the broad drift plain which lies still farther north. From the summit of the ridge the road from Anamosa to Cass Center descends until, near the southwest corner of section 22, Cass township, it reaches the drift plain. The difference in elevation between the plain and summit of the ridge is 100 feet. The loess ridges south of the stream near Anamosa are equally as high as those on the north. Near the northwest corner of section 16, Fairview township, the elevation is 230 feet above the river and the descent to the drift plain, a short distance south of Fairview, is more than 100 feet. The river here runs between loess ridges rising fully 100 feet above the level of the adjacent plains. There is no better example anywhere of McGee's paradoxical streams, running in valleys that cleave high ridges and separated from each other by low valley-like divides.

The principal loess areas of Jones county lie along the two branches of the Maquoketa in the northeastern townships. Here they blend practically into one continuous area covering all, or nearly all, of the townships of Richland, Washington and Clay, as well as the northeastern part of Scotch Grove. The area next in importance is four to six miles in width. It begins at the Linn county line, embraces the Buffalo and Wapsipinicon to their confluence at Anamosa and continues below Anamosa for a distance of three or four miles. A ridge of loess continuous with the Anamosa area extends eastward through the southern part of Wayne township, past Amber, almost to Center Junction. The eastern end of this ridge, near Center Junction, is broken up into discontinuous hills, with intervals of drift.

A special type of topography is developed wherever the loess is so thin as to be easily eroded down to the underlying drift. In such localities the hills are low with long, sweeping curves, and the nearly flat-bottomed vales between are relatively broad. The hills are capped with a thin veneer of loess and the gracefully curving valleys expose the drift. The areas exhibiting this type of topography are usually small, but one such area, several miles in length and width, is found west of Wyoming and south of Center Junction.

The paha of McGee, the peculiar ridges and isolated elliptical hills that often rise abruptly in the midst of a drift plain, are striking physiographic features that are intimately related to the loess hills. The paha are usually heaped up masses of drift covered with loess. Numerous examples of these curious hills and ridges occur in Greenfield township. One of the most striking, rising to a height of nearly a hundred feet above the broad plain at its base, is found in section 31. Others are found in sections 17, 18 and 19. In section 10 is a broad wooded paha, and a still larger ridge of the same type, covered with primeval forests, extends through sections 14, 15, 23 and 24. Almost every township affords a greater or less number of examples of the same peculiar topographic forms. Two loess covered hills are conspicuous west of Olin in Rome township. The beautiful paha west of the railroad, a few miles south of Monticello, have been described by McGee, but others equally interesting must, for the present, be left undescribed.

Alluvial Plains and River Valleys.—There are few alluvial plains in Jones county, and the few there are make but little impression upon the general topography. Below Newport the Wapsipinicon escapes from a rather narrow valley and enters a broad alluvial plain which, however, extends only to a short distance below Olin. A mile or two below Hale the valley again widens, and presents the characteristics of a broad flood plain all the way to the eastern limit of the county. For a short distance near Monticello the Maquoketa runs through a low plain. Elsewhere the three main streams of the county flow in narrow valleys of erosion. These valleys are not infrequently 200 feet in depth, and the walls are in part ridges of loess and in part cliffs of limestone. The North Fork of the Maquoketa in Washington township flows through a rocky gorge that has a depth, measured from the general level of the loess ridges a half mile back from the stream, of 225 feet. The rocky walls immediately bounding the river channel often rise vertically, or nearly so, for 75 or 100 feet. At intervals these walls are cut by erosion of secondary streams into a series of jutting prominences, and the lateral valleys are often picturesque, deep, rock-walled ravines, damp and shaded at the bottom, and having the sides diversified with salient crags, castles, supporting buttresses and other rock masses that have been wrought by the active agents of rock decay into all conceivable fantastic shapes.

The South Fork of the Maquoketa flows in a rock-bound gorge from a short distance below Monticello to the Jackson county line. The valley, taken as a whole, is wider than that of the North Fork and the lateral ravines are also broader. The general features, however, are the same; and crag and castle and wooded rocky bluff give pleasure to the general observer as well as stimulate the interest of the student of topographic forms. One of the rocky promontories left between two deeply excavated secondary ravines, is locally known as Eagle Rock. Eagle Rock is situated on the left bank of the stream about a mile above Canton. It rises to a height of about 150 feet above the water in the channel. Its eastern face is nearly vertical, and a short distance from the river the ravine on its eastern side terminates in a rocky amphitheater. On the west side of Eagle Rock is a broad lateral valley carrying a small tributary stream. Eagle Rock and its adjacent valleys illustrate the general character of the topography bordering this river throughout the greater part of its course in Jones county. Everything betokens long continued erosion. At least the period required to produce the observed effects must antedate both drift sheets and is probably comparable to the length of time required to produce the physiographic characteristics of the driftless area.

The valley of the Wapsipinicon varies from a rather narrow and partly rock-walled gorge above Anamosa to a broad plain, bordered by low rounded hills, between Newport and Olin. At Stone City the limestone rises in the sides of the valley to a height of ninety feet above the stream, while a short distance back from the river, as, for example, near the northwest corner of the Nw. ¼, Nw. qr. of Sec. 15, Fairview township, the upper beds of limestone have an elevation of about 150 feet above the water at Anamosa, and nearly fifty feet above the level of the drift plain on either side of the loess covered area. Between Olin and Hale the valley becomes narrow and is bounded by limestone cliffs or swelling prominences of loess that repeat, but on a smaller scale, the characteristics of the valley above Anamosa. The broad plain between Newport and Olin has its characteristics repeated in the plain above and below Oxford Mills.

The valley of the Buffalo so far as its course lies in Jones county, resembles that of the Wapsipinicon near Anamosa.

The valley of Bear creek is at first a broad shallow depression in the drift plain, with some loess-capped hills rising above the plain at some distance on either side. Below Wyoming, however, the stream enters a narrow rock-bound valley bordered with wooded hills that exhibit the typical loess topography; and these characteristics persist to beyond the Jackson county line.

There are some minor topographic areas, but the whole topography of the county, over larger and smaller areas alike, is to be interpreted in the light of effects of aqueous and glacial action produced along the attenuated and much lobed and incised border of the Iowan ice sheet, the whole modified more or less by subsequent erosion. Over the larger drift plains erosion has produced scarcely any effect since the Iowan glaciers retreated from the region. Over areas deeply covered with loess, erosion in combination probably with wind action has given rise to the rounded hills and gully-like ravines that divide the surface into such a tangled topographic maze. The drift deposited by both Kansan and Iowan ice sheets was in some places very thin, and so it has been possible for both branches of the Maquoketa, and probably the Wapsipinicon above Anamosa, to return to their old channels, and by a little scouring to restore some of the features of the preglacial topography.

DRAINAGE.

The drainage of Jones county is quite as unique as the topography. Like the topography it has been determined by the anomalous distribution of drift and loess along the lobed border of the Iowan ice. The Wapsipinicon is the largest river, and it pursues a much longer course within the limits of the county than any other stream; but the area it drains, so far as relates to Jones county, is less than that drained by the South Fork of the Maquoketa. Apart from the Buffalo, which brings drainage waters from Buchanan, Delaware and Linn counties, the Wapsipinicon receives from the north no tributaries of sufficient consequence to be worthy of name. The natural drainage area of the river is encroached upon by Bear creek, an affluent of the Maquoketa. The valley of Bear creek is nearly parallel to that of the Wapsipinicon; for a long distance the streams are not more than a few miles apart, and so the drainage area tributary to the Wapsipinicon is reduced on the north side to a narrow belt only a mile or two in width. The portion of Jones county south of the Wapsipinicon, as far east as Olin, is drained by Walnut creek, but below Olin the streams entering from the south are insignificant.

Bear creek is also nearly parallel to the Maquoketa, but the distance between the two streams will average ten or twelve miles. All the valley of Bear creek and all the intervening region drains into the Maquoketa. This intermediate area is traversed by Mineral creek, which joins the primary stream a few miles below Canton. Kitty creek flows into the Maquoketa near Monticello. Its valley is for some distance nearly parallel to that of its primary, but its flow is in the opposite direction. Grove creek drains the northwest corner of the county, and Farmers creek in the northeast passes down through the center of Washington township to join the Maquoketa near Clay mills. Farmers creek encroaches on the area belonging to the North Fork of the Maquoketa as Bear creek encroaches on that of the Wapsipinicon, and reduces the surface tributary to the North Fork to a strip a mile or two in width. The Makoqueta proper receives the drainage of nearly three-fourths of the entire county.

The North Maquoketa and White Water creek, with insignificant tributaries that flow only when recent rains or melting snows furnish favorable conditions, drain a small area in the northeastern corner of Washington township.

STRATIGRAPHY.

General Relations of Strata.

The geological formations of Jones county represent three systems. Only two systems, however, are developed to an extent that would command general attention, and they are widely separated from each other in point of time. The indurated rocks belong chiefly to the Silurian system; the superficial deposits belong chiefly to the Pleistocene. Belonging to the indurated rocks are some inconspicuous fragments of Carboniferous strata, and among the superficial deposits are beds of residual clay or geest of pre-Pleistocene origin, but referable to no particular series.

The Silurian strata, while exhibiting many stratigraphic and local variations, are all lithologically and paleontologically intimately related. Throughout the whole thickness of the beds exposed in this county the rocks are dolomitic limestones, and the fossil fauna, however much it may vary in different localities and in different beds, is always and everywhere characteristic of the Niagara series. The lower beds contain such forms as *Halysites catenulatus* Lin., *Favosites favosus* Goldfuss, and *Pentamerus oblongus* Sowerby. The uppermost beds of Niagara seen in this county have so far furnished no fossils, but the Anamosa quarry stone lying next below them has yielded specimens of *Dalamites verrucosus* Green, and *Calymene niagarensis* Hall. This last species occurs in the Williams quarry in the northeast corner of Fayette county only a few feet above the Maquoketa shales, while at Stone City, in Jones county it is found, though very sparingly, in the building stones which lie at least 250 feet higher in the geological column. The whole assemblage of strata between the top of the Maquoketa shales and the base of the Devonian is referred to the Niagara.

The taxonomic relations of the geological deposits of Jones county, as provisionally adopted, are shown in the following table.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.		Alluvial.
		Glacial.	Iowan.	Loess.
				Second Till.
			Aftonian?	Buchanan gravels.
			Kansan.	First Till.
Paleozoic.	Carboniferous.	Upper Carboniferous.	Des Moines	
	Silurian.	Niagara.	Bertram.	
			Anamosa.	
			Le Claire.	
			Delaware.	

Geological Formations.

NIAGARA SERIES.

Though the great beds of dolomite, which may be referred to the Niagara series, represent deposition during a single geological epoch, and so in a certain sense constitute a single stratigraphic unit, they are yet divisible into four more or less perfectly defined stages.

DELAWARE STAGE.

The lower stage of the Niagara has a thickness of about 200 feet. *Pentamerus oblongus*, *Halysites catenulatus*, *Favosites favosus*, *Ptychophyllum expansum*, *Strombodes mamillaris* and a large number of other species, are the characteristic fossils. *Halysites catenulatus* begins near the base of this stage. At first the corals are all small, a few inches only in diameter, and the individual corallites rarely have a diameter exceeding one-sixteenth of an inch. Among the residual products of erosion derived from other phases of the Delaware stage there are, on section 6, Scotch Grove township, weathered fragments of coralla of this same species five feet in diameter, three or four feet in depth, and made up of corallites measuring fully one-eighth of an inch. Pentamerus crowds the beds at various levels and shows a great number of interesting variations. The strata through which these fossils range compose the coralline beds of the Upper Magnesian cliff limestone, as that term is used in Owen's report on work done in the fall of 1839. They comprise the coralline and Pentamerus beds of the Upper Magnesian limestone, as indicated on the map accompanying the report of the same author in 1852. This division is the equivalent of the Niagara limestone of the report of Hall and Whitney, but it embraces only part of the Niagara of Dr. C. A. White.

Prof. A. G. Wilson has recently written on the Upper Silurian in Northeastern Iowa*, arranging the strata of the formation considered in five divisions. Divisions one to four of Professor Wilson's paper, collectively, make up the lower stage as here defined, a stage that embraces all the sediments lying between the summit of the Maquoketa shales and the top of the Pentamerus and Coralline beds that furnish *Strombodes mamillaris* Owen, *Strombodes pentagonus* Owen, *Strombodes gigas* Owen, enormous coralla of *Halysites catenulatus* Linnæus, and equally ponderous masses of *Diphphyllum multicaule* Hall.

*American Geologist, Vol. XVI, p. 275. 1895.

There is no one locality where all the phases of this lower division of the Niagara may be seen in a single section, but all may be studied within the limits of Delaware county, and for this reason it is proposed to call it the Delaware stage. The four divisions of Professor Wilson, so far as they can be delimited, may rank as sub-stages. The Delaware stage contains large quantities of chert, and silicification of the corals is very general, while silicification of the brachiopods is not infrequent.

LE CLAIRE STAGE.

The second stage of the Niagara is represented by the Le Claire limestone of Hall, and may, with propriety, be called the Le Claire stage. Strata of this stage are well developed at Le Claire, in Scott county. They are seen in the same stratigraphical relations at the lime kilns on Sugar creek, and near the quarries at Cedar Valley, in Cedar county. They occur beneath the quarry stone at Stone City, and near Olin and Hale, in Jones county, and they are also seen at many points west of the Jones county line in Linn. Indeed, they are somewhat generally, though by no means universally, distributed in the east central part of Scott, southwestern parts of Clinton, western Cedar and the southern parts of Jones and Linn. They seem, however, to be limited to the southwestern corner of the Niagara area, There are no indications of them in the northeastern part of Jones. A line drawn from the mouth of the Wapsipinicon through Anamosa would mark approximately their northeastern limit.

The Le Claire limestone is generally a massive or heavy bedded, highly crystalline dolomite. It contains scarcely any chert, and in its lower parts there are very few fossils. There are occasionally a few specimens of Pentamerus of the *P. occidentalis* type, and the principal coral is a long, slender, tortuous Amplexus, which is represented only by casts of the vacant or hollow parts of the original corallum. On account of the complete solution of the original structure the spaces occupied by the solid parts of the coral are now mere cavities in the limestone. In the upper part of the Le Claire stage, small brachiopods abound. They belong to the genera Homeospira, Trematospira, Nucleospira, Rhynchonella, Rhynchotreta, Atrypa, Spirifer, and probably others. In most cases the fossils have been dissolved out, leaving numerous cavities. The calcareous brachial apparatus of the spire-bearing genera is often perfectly preserved, and is the only portion of the original structure represented. No statement can well give any idea of the numbers of these small shells that crowded the sea bottom near the close of the Le Claire stage, nor of the corresponding number of minute cavities that are now, so characteristic a feature of this portion of the Le Claire limestone. In some localities in Cedar county, the small brachiopods of this horizon are represented by very perfect casts that were formed by a secondary filling of the cavities left by solution of the original shell. The external characters are thus fairly well reproduced.

Compared with the beds of the Delaware stage, the Le Claire limestone as a rule lies in more massive ledges, it is more completely dolomitized and its fracture surfaces exhibit a more perfectly crystalline structure. It contains an entirely different fauna, a fauna in which small rhynchonelloid and spire-bearing brachiopods are conspicuous. Its fossils are never silicified, and in marked contrast with some portions of the Delaware, its upper part at least is notably free from chert. The Le Claire limestone is the lime burning rock of Sugar creek, Cedar Valley, Port Byron, and Le Claire. Wherever it occurs it furnishes material for the manufacture of the highest quality of lime.

The Le Claire limestone is, in some respects, unique among the geological formations of Iowa. In the first place, it varies locally in thickness, so much so that its upper surface is exceedingly undulating, the curves in some places being very sharp and abrupt. In the second place, it differs from every other limestone of Iowa in frequently exhibiting the peculiarity of being obliquely bedded on a large scale, the oblique bedding often affecting a thickness of fifteen or twenty feet. (Plate i.) The phenomena suggest that during the deposition of the Le Claire limestone the sea covered only the southwestern part of the Niagara area; that at times the waters were comparatively shallow, and that strong currents, setting sometimes in one direction and sometimes in another, swept the calcareous mud back and forth, piling it up in the eddies in lenticular heaps, or building it up in obliquely bedded masses over areas of considerable extent. The oblique beds observe no regularity with respect to either the angle or direction of dip. Within comparatively short distances they may be found inclining to all points of the compass. Again the waters at times were quiet, and ordinary processes of deposition went on over the original sea bottom, the beds produced

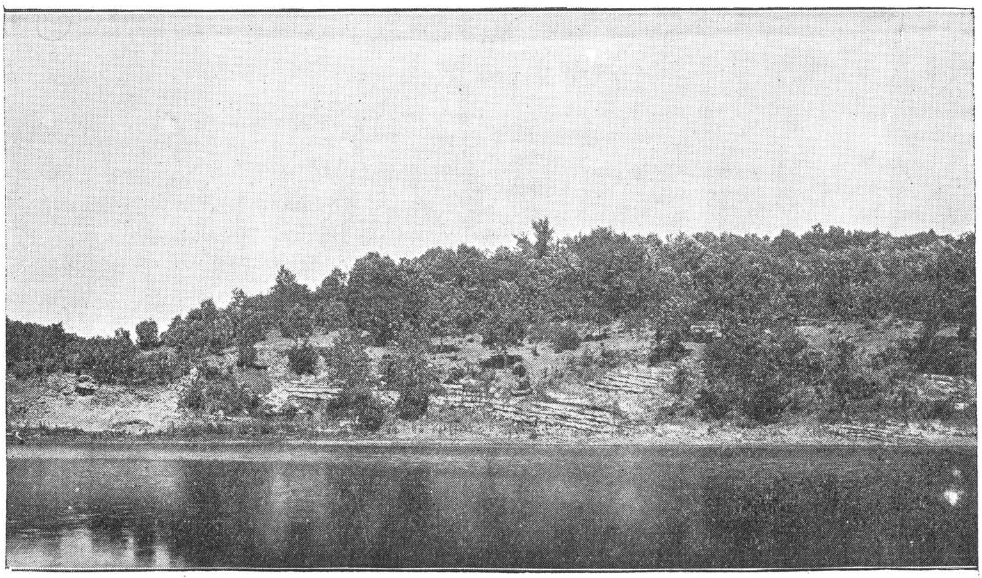
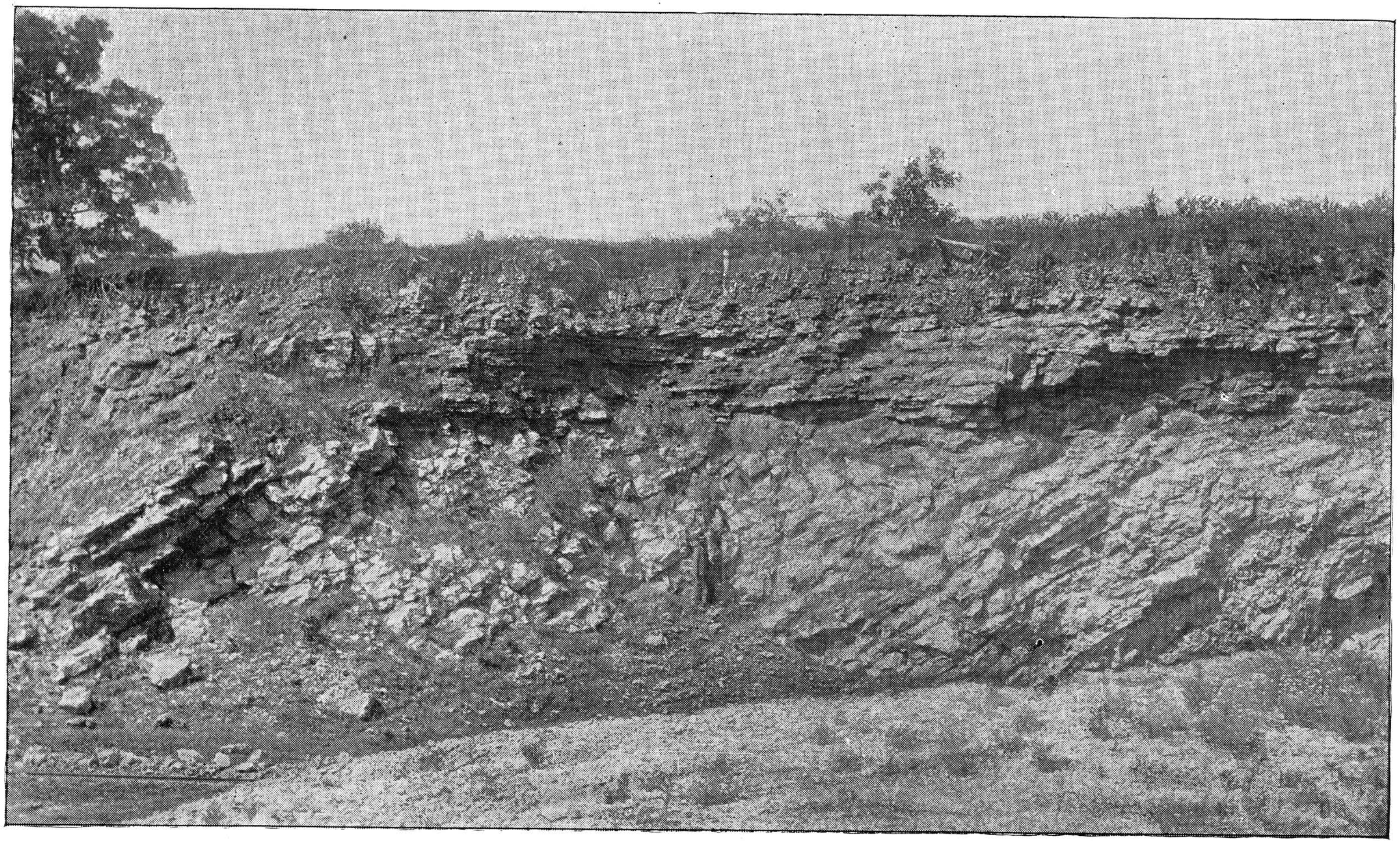


FIG. 1. Inclined, undulating beds of the Le Claire stage near Newport, Jones county, Iowa.

under such circumstances conforming to the undulating surface on which they were laid down. In some cases these beds were horizontal, as in the upper part of the section illustrated in plate i, while in other cases they were more or less flexuous and tilted, as seen in the left bank of the Wapsipinicon above Newport.



TILTED SILURIAN STRATA.

Professor Hall accurately describes some of the variations in the inclination and direction of dip in the Le Claire limestone, as seen at Le Claire,* but he assumes that the inclination of the beds is due to folding and uplift subsequent to their deposition. On this assumption, the Le Claire limestone would have a thickness of more than 600 feet, whereas the maximum thickness does not exceed eighty feet, and the average over the whole area is very much less. Prof. A. H. Worthen† studied this limestone at Port Byron, Illinois, and Le Claire, Iowa, and describes it as "presenting no regular lines of bedding or stratification, but showing lines of false

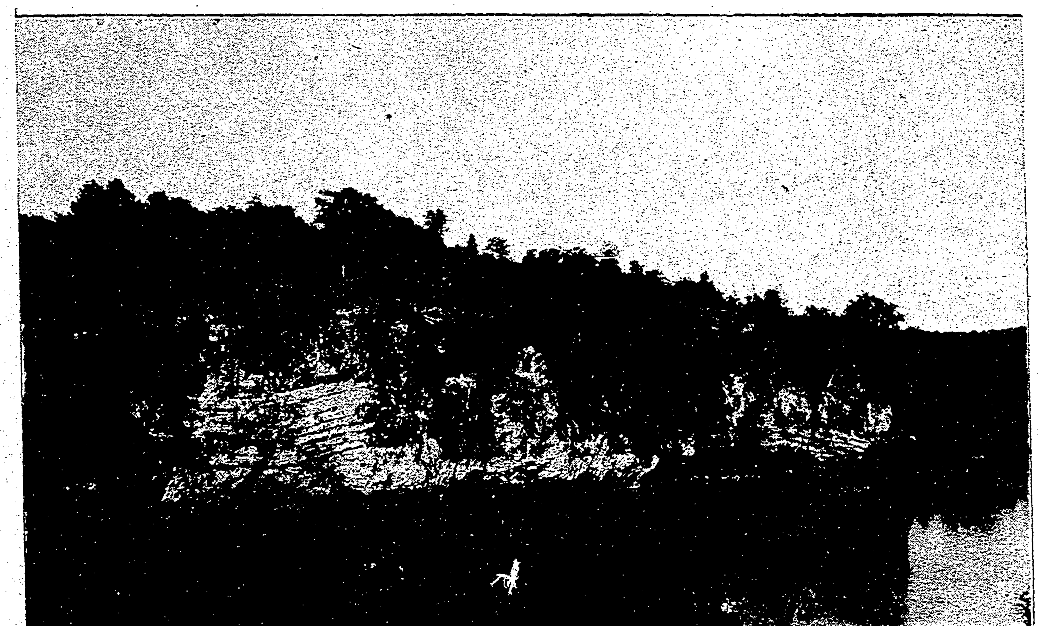


FIG 2. Exposure of gently folded Le Claire limestone below bridge southeast of Hale.

bedding or cleavage at every conceivable angle to the horizon." He assigns to these beds a thickness of fifty feet, but offers no explanation of what he calls false bedding or cleavage. In White's report on the geology of Iowa,‡ the oblique bedding seems to have been taken as evidence that a line of disturbance crossed the Mississippi river at Le Claire with a direction nearly parallel to the Wapsipinicon valley. This

*Rept. on the Geol. Surv. of the State of Iowa, Hall and Whitney, vol. I., part I., pp. 73-74 1858.

†Geol. Surv. of Ill., vol. I, p. 130, 1866.

‡Report on the Geol. Surv. of the State of Iowa; Charles A. White, vol. I, p. 183, 1870.

apparent disturbance was last recognized about three miles west of Anamosa. The angle of dip, it is said, reached in some places twenty-eight degrees with the horizon. McGee, in discussing the regular deformations of northeastern Iowa,* quotes Dr. White on the Wapsipinicon line of disturbance, and accepts the observations on which the statement is based as evidence of a synclinal fold extending from Le Claire to Anamosa. White's observations appear to have been made only at the two points mentioned. At both places the strata seem to be inclined at a high angle. On the assumption that the inclination of the strata indicates orogenic disturbance, the conclusion that the disturbed beds were parts of the same fold was very natural. There is, however, no fold, nor is there any line of disturbance. In the whole Niagara area southwest of the line which marks the limit of the Le Claire limestone, the phenomena seen at Le Claire and west of Anamosa are repeated scores of times and in ways that defy systematic arrangement. The beds incline at all angles from zero to thirty degrees, and even within short distances they may be found dipping in every possible direction. Twenty miles southwest of the line supposed to be traversed by the synclinal fold, for example at the lime kilns on Sugar creek, along the Cedar river above Rochester, at Cedar Valley, as well as at many intermediate points distributed promiscuously throughout the area of the Le Claire limestone, the beds stand at a high angle, and the multiplicity of directions in which they are inclined, even in exposures that are relatively near together, is wholly inconsistent with the idea of orogenic deformation. The beds are now practically in the position in which they were laid down in the tumultuous Niagara sea. The principal disturbances they have suffered have been the results of epeirogenic movements which affected equally the whole region over which these limestones are distributed, as well as all the adjacent regions of the Mississippi valley.

*Pleistocene History of Northeastern Iowa, p. 340. 1891.

The Le Claire limestone is sharply set off from the deposits of the Delaware stage by its hard, highly crystalline structure, its freedom from chert, its easily recognized fauna, and its record of anomalous conditions of deposition. In the field the distinctions between the Le Claire and Anamosa stages are even more easily recognized, though faunally the two stages are intimately related. In the Anamosa stage oblique bedding is unknown; lithologically the rock is an earthy, finely and perfectly laminated dolomite, not highly crystalline in its typical aspect, and too impure for the manufacture of lime. It may be quarried in symmetrical blocks of any desired dimensions, while the Le Claire limestone breaks into shapeless masses wholly unfit for building purposes. The quarry beds of the Anamosa stage are quite free from

FIG. 3. Top of cliff at Clay Mills, illustrating character of bedding below the building stone layers of the Delaware stage.

fossils, but along the Cedar river in Cedar county, the brachiopod fauna of the upper part of the Le Claire reappears in great force in a stratum four feet in thickness, up near the top of the formation. The beds of the Anamosa stage are very undulating and dip in long graceful, sweeping curves in every possible direction. The knobs and bosses and irregular undulations developed on the sea bottom as a result of the peculiar conditions prevailing during the Le Claire age, persisted to a greater or less extent after the age came to an end, and it was upon this uneven floor that the Anamosa limestone was laid down. The puzzling flexures of the Anamosa limestone and the puzzling variations in altitude at which it occurs were largely determined by irregularities in the upper surface of the Le Claire formation.

ANAMOSA STAGE.

The typical phase of the Anamosa stage is well illustrated in the beds that furnish the quarry stone at Stone City. Deposits of this stage, however, were first noted in Iowa at Le Claire and were correlated by Hall with the Onondago Salt Group of New York.* Since Hall's work in Iowa was completed these beds have been studied by White at what is now Stone City,† by Houser at various localities in Scott and Cedar counties‡ and by Norton in Linn county.§ McGee's description of the building stones from the Niagara of Iowa applies in part to the Anamosa limestone.‖ All the writers mentioned, except Professor Hall, refer the Anamosa beds to the Niagara. The rocks of this stage, excepting a few favored localities such as Mount Vernon and Cedar Valley, are remarkably destitute of fossil remains. At Le Claire recognizable fossils are practically wanting and Hall made his determination of the age of the formation on lithological grounds alone.

The quarries at Stone City are about four miles west of Anamosa. When they were first opened Anamosa was the nearest railway station and on this account they became generally known as the Anamosa quarries. The stone was shipped to many points in Iowa and even beyond the limits of the state, and became known among architects and engineers as Anamosa limestone. Under this name it was discussed in trade

*Rept. on the Geol. Surv. of Iowa; Hall and Whitney, vol. I, part I, pp. 76-80. 1858.

†Rept. on Geol Surv. of the State of Iowa, vol. I, p. 184; vol. II, pp. 309-311. 1870.

‡Iowa Geol. Surv., vol. I, pp. 203-207. 1893.

§Ibid., vol IV, pp. 127, 130, 184, etc., 1895. In the text of Prof. Norton's report on Linn county these strata are called the Mount Vernon beds.

‖Tenth Census of the U. S., vol. X, Building Stone, p. 263, 1883. Iowa Geol. Surv., vol. I, pp 30-32. 1893.

journals as well as in the newspapers wherever reference was made to the product of these quarries. The name has also been used in some of the minor publications of the survey. While therefore the beds of this particular stage do not occur at Anamosa, it seems best to retain a name so long and so firmly established, a name that has a definite meaning over an area as wide as that in which this quarry stone finds a market; and therefore it is proposed to recognize these beds as the Anamosa stage of the Niagara series, and to call the rock belonging to this particular horizon, wherever found, the Anamosa limestone.

The Anamosa limestone varies locally; but in general it is composed of evenly bedded, perfectly laminated layers of

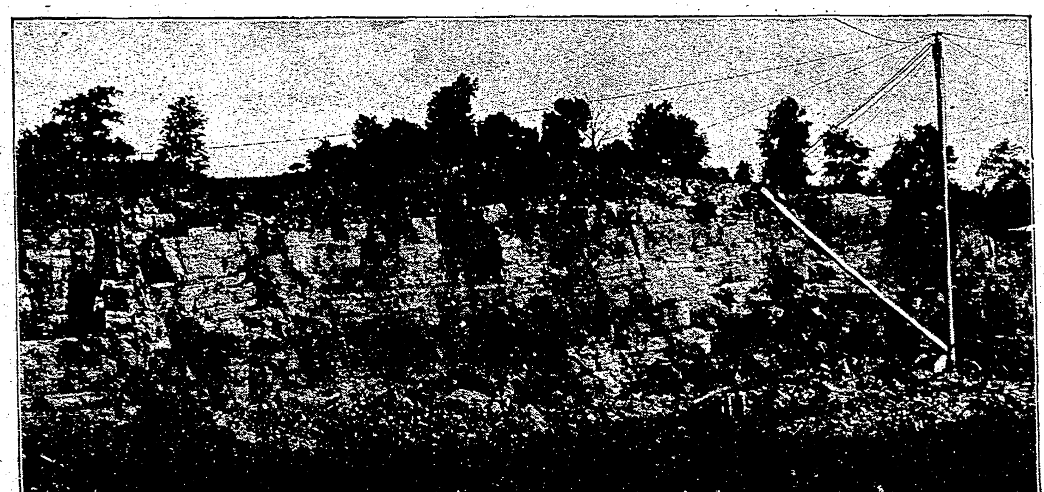


FIG. 4. Beds of the Anamosa stage in the western part of Champion quary at Stone City, showing the moderately strong eastward dip at this locality.

rather impure dolomite that in color ranges through shades of buff, to gray on the one hand, and almost white on the other. In many cases the beds are practically horizontal, but they more commonly exhibit long sweeping undulations due to the uneven character of the floor upon which they were deposited. At the Penitentiary quarry the strata dip to the northwest at the rate of 100 feet to the mile, and at the west end of Champion quarry No. 1, the beds for several rods incline to the east at even a greater angle. Furthermore the same bed varies in thickness, the variation ranging from six to eighteen inches in less than a quarter of a mile. In general, however, the curves of flexure are so gentle and the changes in thickness of individual beds so gradual that within the dimensions of any block of stone that may probably be called for or could possibly be handled, the lamination planes are true and parallel.

The planes of lamination are at the same time the bedding planes of the Anamosa limestone. The formation as seen in Jones county is not divided into definite layers separated by partings of clay or softer limestone, but for a thickness of many feet the rock presents all the appearance of a single finely laminated bed. Such a bed, however, is not throughout of uniform texture, but is made up of parallel bands differing from each other in minor characters. There are certain planes along which the union of contiguous laminæ is weaker than elsewhere, and it is along these weaker planes that the rock tends to split when it is quarried. The quarrymen recognize these particular planes and divide the quarry somewhat arbitrarily into beds varying from three or four to thirty-six inches in thickness. It is sometimes possible to work two or more of the beds recognized by quarrymen together when blocks thicker than either bed alone are wanted; and on the other hand any of the beds may be split or "capped" when stones for flagging or thinner slabs for any other purpose are desired.

At Stone City this limestone has a thickness of sixty feet, and is divided by a porous, worthless ledge into two nearly equal parts. The lower thirty feet is known as the "gray limestone;" the beds in the upper half of the formation are described as the "white limestone." The most valuable quarry stone comes from the lower or gray limestone. In the upper beds the cleavage along the lamination planes is more perfect than in the beds below, for which reason the rock in this part of the quarry tends to split into thin slabs, and long exposure to the weather reduces it to chip stone. The unweathered ledges of this upper limestone, while unsuited to many architectural purposes, serve well for ordinary masonry, for, if the blocks are properly quarried and are laid in the wall on the "quarry face" with only the edges of the laminæ exposed to the weather, they will last indefinitely. On the other hand the lower beds furnish excellent material for almost any kind of structure in which stone may be employed. There are ledges that will furnish massive blocks suitable for bridge piers; and there are beds compact, fine-grained, and imperfectly laminated that afford dimension stone suitable for cutting into forms befitting the higher grades of architectural work.

In the lower division of the formation there are some planes along which the rock is vesicular, the cavities though rather indefinite in shape, being evidently produced by solution of small brachiopods similar to those characteristic of the Le Claire. Occasionally there are cavities of larger size, one, two or three inches in diameter. Some of these are lined with crystals of calcite, some are studded with minute crystals of quartz, and there are others in which both minerals occur. The upper white limestone furnishes many interesting, almost agate-like concretions of chert.

Joints at intervals intersect the beds of the Anamosa limestone, but on the whole they are few and distant. They occur more frequently in some quarries than in others; and as a rule they cut through the whole thickness of the formation in a nearly vertical direction. These joints facilitate the work of quarrying, in many cases rendering the use of a channelier unnecessary, and yet are not so numerous as to interfere with the getting out of blocks of any desired dimensions. There are some indications that the joints are not all of the same age. Those of more recent origin are still but a fraction of an inch in width and have the walls undecayed; in those that bear signs of greater age the fissures have been widened by water and other agents chemically active in rock destruction, the walls show decay for some distance from the vertical surface, and the spaces are occupied with a ferruginous residual clay which the miners of lead regions recognize as "crevice dirt," but which in some recent geological literature is known as geest.

BERTRAM STAGE.

Above the perfectly stratified beds of the Anamosa stage there occurs an irregularly bedded, non-fossiliferous rock of unknown thickness, which may be correlated with the Bertram beds described by Professor Norton*. The Bertram limestone is a yellowish dolomite without lamination planes, and quarrying in shapeless masses of no possible utility. "Bastard stone" is what the quarrymen call it. At Stone City it appears at the top of the Anamosa quarries belonging to Mr. John Ronen. A greater thickness of it is exposed in the same relation to the quarry stone in the quarry known as Champion No. 2, belonging to Hon. John A. Green. In Senator Green's Champion No. 1, some beds of this stage have been exposed by recent stripping. As the work of quarrying progresses the exposed thickness of the Bertram beds is certain to increase. At Champion quarry No. 2, for example, the upper surface of the Anamosa stage rises about fifty-five feet above the level of the Wapsipinicon river, but the bluff at the foot of which the quarry is opened, has an altitude of 180 feet above the same level. While the bluff is covered with a thick mantle of loess, there is yet room for a hundred feet of indurated rock above the level of the Anamosa limestone.

CARBONIFEROUS SERIES.

DES MOINES STAGE.

In the southeastern part of section 24, Fairview township, a great many loose fragments of coal measure sandstone were found in the side of a small ravine. The sandstone was not seen in place, although it was evident that the original ledges were not very far away. The region is thickly covered with

*Iowa Geol. Surv., vol. IV, p. 135 et seq.

loess and drift; it is also wooded and densely overgrown with underbrush; the geological structure is quite effectually concealed. The blocks of sandstone were associated with exposures of tile clay that were manifestly secondary deposits derived by ordinary erosion or by glacial action from beds of Carboniferous shales. McGee mentions a bed of pebbly ferruginous sandstone three miles northeast of Oxford (probably Oxford Junction), in Jones county.* The relations of the deposit are somewhat uncertain, although it is quite probable that the bed in question belongs to the age of the Iowa coal measures. Outlying fragments of coal measure strata are not uncommon in Jackson, Cedar, Linn, Johnson, Scott and Muscatine counties.

During all the time represented by the Devonian and Lower Carboniferous beds of Iowa, Jones county was dry land. The forces that elevated the continental masses had lifted this part of the strata above sea level. The shore line at first passed through the southeastern part of Cedar, the northeastern part of Johnson and the eastern part of Linn. The sea, however, gradually retreated toward the south and west, the shore line became more and more remote from Jones county, until, toward the close of the Lower Carboniferous, probably the whole of what we now call Iowa had become a part of the continent. About the time the coal measure epoch was inaugurated the whole southern and western portions of the state subsided and were largely covered by the encroaching Carboniferous sea. This sea spread sandstones, shales and conglomerates as far north as Rockville in Delaware county. Such Carboniferous deposits were spread over the whole of Jones, but the deposits were thin, the sea soon again retreated, and subsequent erosion has removed nearly every vestige of these later sediments. Notwithstanding the lack of evidence from direct observation, it is still very probable that numerous outliers of Carboniferous strata are concealed beneath the superficial deposits of this county.

* Pleistocene History of Northeastern Iowa. Eleventh Ann. Rep. U. S. Geol. Surv., p. 305.

GEEST.

The superficial deposits of Jones county fall naturally under two heads, (1) geest and (2) Pleistocene beds. The geest is a product of secular rock decay. In this county it is composed chiefly of the insoluble constituents of dolomitic limestones, though it may contain some residual material derived from the decay of Carboniferous sandstones and shales. Neglecting the small portion of possible Carboniferous origin, the history of Jones county geest may be briefly summarized. At the close of the Silurian or early in the Devonian the region, which had previously been covered by the sea, was elevated above tide level. The surface layers of limestone were promptly attacked by the "weather." Moisture, atmospheric gases, and all other agents that work silently and unobtrusively in causing rocks to crumble, combined to bring about disintegration of the exposed beds. Surface waters carried away the soluble constituents, and the insoluble clayey and ferruginous portions, reduced to an incoherent layer of soil, remained. Excepting the short period represented by the invasion of the Carboniferous sea, the work of rock disintegration and removal of soluble constituents has progressed uninterruptedly from the first elevation of the region till the present. This work was interfered with more or less by the incursions of Pleistocene ice and the consequent distribution of a protective covering of drift, but in some localities it is progressing to-day as rapidly as ever. Geest cannot be referred to any particular geologic age.

The geest of Jones county is a dark colored ferruginous clay, which usually contains fragments of chert. In places it is largely made up of chert, for the finer clay is more easily removed by ordinary erosion, and so has been carried away by the mechanical effects of water, while the chert fragments, too large for transportation, have been left. At times the geest contains many silicified fossils, and the most satisfactory specimens of corals and brachiopods are often derived from this source. All the fossil remains found in the geest, as well as all the chert which it contains, were originally distributed through beds of limestone that have slowly disappeared as a result of ceaseless energy on the part of agents concerned in producing rock decay. A typical example of fossil-bearing geest occurs on the land of Mr. James Delay, in section 3 of Castle Grove township. The residual material is here only about a foot in thickness, but it abounds in well preserved silicified specimens of *Pentamerus oblongus* Sowerby, *Stricklandinia castellana* White, *Zaphrentis stokesi* Edwards and Haime, and *Favosites* (*Astrocerium*) *hispidus* Rominger. In the road that runs north and south through the middle of this section the geest is exposed in rain cut channels at the sides of the driveway, and contains a few specimens of *Pentamerus oblongus* mingled with great numbers of angular fragments of whitish chert. In section 6 of Scotch Grove township the residual products resulting from the decay of beds of limestone of unknown thickness contain three species of Favosites, two of Lyellia, two or three Heliolites, one Syringopora, three Strombodes, many Stromatoporoids, gigantic coralla of Halysites and Diphyphyllum, together with beautifully preserved specimens of Cladopora, Goniophyllum, Amplexus, Zaphrentis and a very large explanate Streptelasma.

PLEISTOCENE DEPOSITS.

The superficial deposits of Pleistocene origin are somewhat complex. They embrace (1) two sheets of till known respectively as the Kansan and Iowan drift; (2) some beds of waterlaid sands and gravels that are probably interglacial or Aftonian in age; (3) beds of loess clays and associated sands that overlie both first and second till and are connected genetically with events taking place between, and in front of, the ice lobes developed along the attenuated margin of the Iowan glaciers, and (4) alluvial beds of clay, sand and gravel of more recent origin, deposited on the flood plains of the streams.

The Kansan drift is quite generally concealed by the newer till. It is seen, however, in a few natural exposures where rain wash has cut through the thin Iowan drift, or in places where the second drift has been bodily removed. The newer till, if present at all, is very inconspicuous around Center Junction, and there are here many characteristic exposures of the lower or Kansan drift. The Kansan drift is fundamentally a blue clay, but its upper surface, as seen near Center Junction, is dark reddish-brown, the color being due in part to the oxidizing effect of the atmosphere, and in part to the effect of growth and decay of many successive generations of plants. Below the superficial oxidized portion the blue color predominates. The boulders of the older drift are small, usually are striated, and consist largely of greenstone. All the distinguishing features of the Kansan drift are well seen in railway cuts and in channels by the roadsides, not only in the region indicated, but at many other points in Jones county.

The Kansan drift varies in thickness from zero on bald rocky prominences to more than 200 feet in old preglacial valleys. While fundamentally a blue clay, it contains many bands of sand and gravel which possess no small degree of economic importance since they are the source of water supply in wells of moderate depth. Near Center Junction the drift is more than 200 feet in thickness, but usually farm wells reach a supply of water in gravel beds seventy-five or eighty feet beneath the surface.

In all surface wells of any considerable depth the blue clay of the Kansan drift is reached, and it is from wells that the facts relating to its distribution and general characteristics have chiefly been learned. A short distance west of Amber the railway cuts through a hill of superficial deposits which show the following section.

		FEET.
3.	Loess ....4 to	5
2.	Yellow till with rather large pebbles and small boulders (Iowan drift)	10
1.	Blue clay with small pebbles, clay somewhat stratified (Kansan drift)..........	12

The section is instructive as showing the stratigraphic relations of the three prevailing types of superficial deposits. At the same time it shows the usual characteristics of the Kansan drift. In the central part of the cut the clay is blue, imperfectly stratified and is charged with rather small, fine-grained, greenish colored boulders. Toward the sides of the cut the Kansan drift comes near to the surface. It shows the effect of oxidation in its dark brown color. Its materials have been mingled more or less with the lower portion of the overlying thin layer of Iowan drift, so that it becomes impossible to draw a definite line between the newer and the older deposits. The mingling of elements of the two tills along their line of contact is, as might be expected, a very common occurrence.

A shallow well near the center of section 20 in Fairview township may stand as the type of a very large number distributed throughout the drift covered portions of the county. This well was dug just outside the margin of the loess which is developed along the Wapsipinicon river. It shows the following section:

		FEET.
5.	Black loam or vegetable mould..........	1
4.	Yellow clay of Iowan stage..........	8
3.	Dark brownish band, upper portion of Kansan stage.	4
2.	Blue clay, unoxidized portion of Kansan stage......	12
1.	Sand in which occurs an abundance of water......	½

Below number 1, a test with an auger shows a recurrence of blue clay. The water-bearing sand is interbedded with the characteristic clays of the Kansan stage. No. 3, is quite ferruginous and highly oxidized at top. Lower down it passes into the blue clay of No. 2. In many wells the yellow till of Iowan age has a thickness of fifteen to twenty feet. Between the two tills the well-diggers often encounter trunks and branches of trees, the remains of an old forest that occupied the region during the long interval which separated the two glacial periods recorded by the Kansan and Iowan drift.

The Iowan till is superficial over the larger part of the drift plains already noted in describing the physiography of the county. Its thickness rarely exceeds twenty feet, and usually it is much less. Compared with the Kansan till it presents the following differences: (1) It is very much thinner. (2) It is yellow in color, while the Kansan clays are blue. (3) It contains large boulders. Boulders exceeding a foot in diameter are rare in the Kansan drift. In the Iowan drift boulders six or eight feet in diameter are common, and great masses measuring twenty feet in some of their dimensions, are not infrequent. (4) The larger and more characteristic boulders of the Iowan drift are composed of coarsely crystalline, light colored granite; the characteristic boulders of the Kansan drift are fine-grained, dark colored greenstone. (5) The small boulders of the Iowan drift are less frequently striated than in the Kansan. (6) The second till contains a much smaller proportion of fragments of local origin. (7) The Iowan ice sheet rode over the older surface materials without disturbing them to any considerable extent; the Kansan ice sheet cut down to bedrock and recorded the direction of its movement in striæ engraved on the native limestone ledges.

Between the two drift sheets in Buchanan county there are occasionally beds of yellowish, stratified, generally cross-bedded sands and gravels that may be Aftonian in age. It is proposed to call them the Buchanan gravels.* Yellow stratified sands and gravels of similar appearance occur at many points in the Pleistocene deposits of Jones county. They may, possibly, be referable to the same age as those of Buchanan county, but their relations to the sheets of till have not

* *The Buchanan Gravels: An Interglacial Deposit in Buchanan County, Iowa,* by Samuel Calvin. Am. Geologist. vol. xvii, p. 76. 1896.

been definitely determined. Typical exposures of such Pleistocene sands are seen along the border of the "second bench" or upper flood plain of the Wapsipinicon river in the Ne. qr. of section 14, Fairview township. Wherever these gravels occur they furnish the best of materials for the improvement of clay roads.

The loess is a fine yellow clay having nearly the same color as the Iowan drift. It is fairly homogeneous in composition, the differences which it presents being due to varying proportions of sand mixed with the clay. Loess contains neither pebbles nor boulders, a fact which distinguishes it from the yellow clay of the second till. It is one of the most important Pleistocene deposits of Jones county, for fully half the area is occupied by beds of this peculiar formation. The largest continuous loess covered region occupies a space of more than a hundred square miles in the northeast corner of the county and embraces all of Washington and Clay townships with portions of Richland, Scotch Grove and Wyoming. The area next in importance has a width of from two to four miles on both sides of the river at Anamosa. Ridges of loess extend with some interruptions through the southern part of Wayne and the northern part of Jackson and Madison townships, and connect the Anamosa with the northeastern area. In the central and southern parts of Jackson and Madison townships narrow ridges of loess alternate with flat bottomed intervales covered with Iowan drift. Southeast of Hale is a loess area embracing quite a number of square miles; west of Olin there are high ridges covered with the same formation; while in Greenfield township there are numerous conspicuous paha ridges capped with loess. The northwestern part of Jones county is comparatively free from loess. The gently undulating surface studded with conspicuous boulders of gray granite, announcing as it does the universal presence of the Iowan drift, is, even here however, occasionally broken by loess covered paha ridges. Such a ridge, having a length of several miles, crosses obliquely the north line of Cass township in section 4, and McGee's Monticello paha occurs in the south half of section 33 of Monticello township.

McGee has called attention to the peculiar hypsographic distribution of the loess in this part of Iowa.* It not only overlies the drift, but it seems preferably to be distributed on plateaus, crests of rock, and morainic ridges of till that rise conspicuously above the level of the average drift plain. Reference has already been made to the fact that the summits of the loess covered ridges on both sides of the river near Anamosa, rise to a height of one hundred feet above the level of the adjacent regions which are covered with Iowan drift. All the isolated, loess-capped paha ridges have an elevation of from forty to sixty feet above the neighboring boulder-dotted plains, and the large loess area in the northeastern part of the county is a plateau having an average elevation of sixty or seventy-five feet above the drift covered areas that interdigitate with its lobed or sinuated margin.

In the case of isolated ridges and minor areas of loess there is evidence that many of the peculiarities of the present topography were developed before the loess was deposited. Around Anamosa there are ridges of limestone that would rise above the level of adjoining areas if all the loess were stripped from their summits. As McGee has pointed out, the river flows in a gorge which cleaves a rocky ridge, and the presence of this ridge seems to have been an important factor in bringing about the deposition of the loess. The Monticello paha is simply a mantle of loess spread over a prominent crest of rock that, before it was concealed by the fine yellow loess silt, stood out conspicuously above the general level. At the northwestern end of the paha the rocks are still exposed in a number of bold precipices twenty to twenty-five feet in height. A short distance southwest of the main paha ridge there is a second rocky crest, but smaller and lower than the first. This crest is bare even of drift for a length of thirty rods, but at its southeastern end it passes under a veneer of

* Pleistocene Hist. of Northeastern Iowa, Eleventh Ann. Rept. U. S. Geol. Surv., p. 301.

loess which eventually blends with the loess of the larger ridge. Within the distance of half a mile to the southwest there are many less prominent knobs and bosses of rocks which are bare toward the southwest but covered with soil on the southeast. They were not prominent enough to bring about the conditions necessary for the deposition of loess.

A typical illustration of loess distribution may be seen one and a half miles south of Center Junction. The surface is ridged and rolling, and superficially the ridges, particularly on their summits, are made up of loess. But the roadway is cut into some of the ridges far enough to show that the loess is insignificant in amount, and that it forms only a thin veneer over the summit of ridges of drift. The drift is mainly of the Kansan type, with brownish, ferruginous clay containing many small, dark green, fine-grained and usually striated boulders. The ridges, however, were present before the loess was laid down. The loess simply accentuates some features of a pre-existing topography.

That the major topographic features of Jones county were developed before the deposition of the loess is well shown at a number of points. Even the river channel between Stone City and Anamosa, which is cut 120 feet below the average level of the drift and 220 feet below the summit of the loess that crowns the walls of the valley is not only pre-loessal, but is preglacial. Both loess and drift, in beds undisturbed since first deposited, come down on the sides of the valley practically to the present level of the water. At Senator Green's Champion quarry No. 1, undisturbed loess overlies a thin bed of Kansan drift. Near the fair ground, northeast of Anamosa, and about 40 feet above the river there are exposures of drift. Three-fourths of a mile north and 65 feet higher, the loess has been eroded down to the drift, and exposes a large gray granite boulder of the Iowan type, and yet this point is 120 feet below the summit, which the road finally surmounts near the southwest corner of section 30, of Wayne township.

Beds of alluvium or river silt have been deposited on the flood plains of all the streams. In the table of geological formations on page 48 alluvium is referred to the recent epoch. The formation has been in progress of deposition ever since the withdrawal of the second ice sheet. Some of it dates only from the latest overflow, but by far the most important part of it is but little, if any, younger than the loess. The flooded streams carrying torrents of water from melting glaciers carried also enormous loads of gravel, sand and fine glacial silt, and these materials, deposited upon the overflowed plains, furnished the larger portion of the present alluvium.

Bodies of alluvium of sufficient importance to deserve special notice are found at only a few points in the county. Monticello has been built on the margin of an alluvial plain that extends up the valley of Kitty creek for some distance on the one hand and up the valley of the Maquoketa to beyond the Delaware county line on the other. The thickness of the deposit varies from a foot or two at the margins to more than thirty feet in the axial parts of the valleys. At the base the deposit is composed of gravel. This is covered by sand, and on the sand rest beds of stratified clays of excellent quality for the manufacture of brick and tile. The broad flood plain that extends from Newport almost to Hale is occupied with alluvial deposits. These deposits are often very sandy, but in the neighborhood of Olin they contain tile clays of demonstrated excellence. Oxford Mills and Oxford Junction stand in the midst of a plain covered with alluvium.

Typical Exposures.

A large proportion of the rock exposures in Jones county belong to the Delaware stage of the Niagara. The characteristics of the different beds of this stage are, however, very inconstant; and the strata of the same horizon vary locally to such an extent as to make the correlation of the several exposures exceedingly difficult. The contact of the Niagara with the underlying Maquoketa was not seen. The lowest beds observed lie at least sixty feet above the line of junction between the two formations. At this lowest observed horizon the dolomitic limestone is sometimes crowded with casts of large individuals of *Pentamerus oblongus* Sowerby. In the valley of the North Maquoketa near Cascade, a few feet above the level of the river, there are Pentamerus beds with cherty partings, in which the fossils are unusually perfect. As a result of conditions somewhat unusual in our Iowa dolomites, many of the individuals retain portions of the original shell. Pentamerus beds, alternating with some coral-bearing and many unfossiliferous layers, are found in the bluffs up to a height of sixty feet above the level of the river. The horizon of small silicified colonies of *Halysites catenulatus* and *Syringopora nitella* occurs below the middle of this section, and the corals named range through ledges that together have a thickness of eight or ten feet. The coral beds are followed by one foot of Pentamerus-bearing limestone and twelve feet of coarse limestone without fossils. Higher up is a third Pentamerus bed, above which the rock becomes massive for fifteen to twenty feet, and shows no fossils. Above these massive beds the strata are again crowded with Pentamerus, but the individuals are smaller, and many belong to the species *Pentamerus pergibbosus* Hall and Whitfield. Associated with *P. pergibbosus* are *Cerionites dactylioides* Owen, *Caryocrinus ornatus* Say, and *Leptæna rhomboidalis* Wilckens. In other portions of the county there often occur, above the horizon of Cerionites, massive barren ledges of variable thickness, followed by some twenty or thirty feet of evenly bedded building stone.

The forgoing facts are not derived from any one section. They are offered as a generalized statement of what may be learned by combining the observations on a number of different exposures. They illustrate the succession of beds for the lower 200 feet of the Delaware stage. The difficulties in the way of correlation of the numerous outcrops of this stage arise from the fact that, during the progress of deposition of the limestone, the types of life were not uniformly distributed over the bottom of the Niagara seas. At any given time there were areas supporting vigorous colonies of certain species, but the assemblage of species differed more or less in different localities, and there were at the same time intervening areas over which living forms were very sparsely distributed, or from which they were entirely absent.

The exposures of Le Claire limestone in Jones county are neither numerous nor conspicuous. Isolated masses of this limestone, when free from fossils, and so situated as not to show its relations to the Delaware and Anamosa stages, cannot be distinguished from certain heavy bedded, highly dolomitized, unfossiliferous portions of the lower stage. Beds of the Anamosa stage have pronounced lithological characteristics which render them easily recognized, but the Bertram beds can only be distinguished by their stratigraphical relations to the Anamosa.

Without in all cases entering into details of sections, which would not be instructive, or attempting to correlate the several exposures, which would often be impossible, the more important and instructive of the rock exposures in the several townships may be briefly noted.

CASTLE GROVE TOWNSHIP.

Characteristic exposures are found in Castle Grove township, along Grove creek, Silver creek and West creek. In the northeast quarter of section 3, the soil is thin in places, and on the north side of Grove creek weathered masses of dolomite belonging to the Delaware stage appear on the surface. South of the creek, in the same quarter section, a quarry was formerly worked, and furnished a fairly good quality of stone for ordinary purposes. Interbedded with the limestone in this quarry are many bands of chert. Overlying the quarry stone is a layer of dark, ferruginous, residual clay, or geest, resulting from secular decay of overlying beds of limestone. This geest contains beautifully preserved silicified specimens of *Pentamerus oblongus subrectus* Hall var., *Stricklandinia castellana* White, *Favosites* (*Astrocerium*) *hispidus* Rominger, and *Zaphrentis stokesi* Edwards and Haime. At the point where the quarry is opened the soil is composed wholly of geest, with a thin layer of vegetable mould. Till seems to be entirely absent, and yet lying on the surface of the geest or partly imbedded in it, there are a few rather small erratic boulders. The amount of detritus left by the ice sheets was in many places exceedingly small.

North of Grove creek, in the southwest quarter of section 2, the scant soil is insufficient to conceal a great number of dolomitic ledges which crop out on a gently sloping hillside facing the south. Some of the badly weathered masses are in place, but many seem to be strewn irregularly over the surface. The most conspicuous fossils here are very large internal casts of *P. oblongus sinuatus* McChesney var. Some of the beds at this locality when first laid down included gigantic coralla of a slender stemmed Diphyphyllum. The coral, however, was not subsequently silicified, and it has been entirely removed by solution leaving sinuous, anastomosing, closely crowded, tube-like channels which pass vertically through ledges many inches in thickness. About fifteen feet below the level of the large sinuated Pentamerus the beds contain silicified fossils; and Pentamerus of the ordinary type, together with *Alveolites interstinctus*, *Lyella americana*, *Favosites niagarensis* and other corals, occur in cherty masses upon the surface. Stricklandinia is present in beds immediately beneath the coral-bearing horizon. Other exposures in this township are found in section 24.

MONTICELLO TOWNSHIP.

In section 19 of Monticello township there are outcrops of the Delaware stage, the chief interest of which lies in the fact that a stratum about twenty feet in thickness, made up of cemented segments of crinoid stems and containing but little magnesium carbonate, lies in the midst of unfossiliferous dolomite. This crinoidal bed, so strikingly different in its fossil contents and chemical composition from any of the ordinary phases of the Niagara, occurs in adjacent sections of Monticello and Castle Grove townships and in section 4 of Wayne, but was seen nowhere else in the county.

In sections 32 and 33 of Monticello township, rough, jagged, worn masses of Niagara illustrate in a typical way the effects of weathering on this formation. Around the northern foot of the Monticello paha the exposures assume the form of weather-corroded cliffs, twenty-five or thirty feet in height. Southwest of the paha the rocks project above the general level in the form of sharp ridges, trending southeast, and probably ten feet in height. West of the road which runs past the foot of the paha a few small quarries have been worked to supply local needs. The rocks here are generally without fossils. Specimens of a small tubed variety of *Favosites favosus*, an unrecognizable silicified Stromatoporoid and rocks containing tube-like channels, from which stems of Diphyphyllum have been removed by solution, occur very sparingly. The rock generally has an earthy fracture quite unlike that of the semi-crystalline portions of the formation composed of pure dolomite.

In the bluffs that border the river bottom east of the mouth of Kitty creek, there are exposures which contain a fauna characteristic of the horizon of *Pantamerus pergibbosus*. The rocks are badly weathered, are intersected by numerous fissures, and contain a great many cavities. The fossils, which are all in the form of casts, embrace *Favosites forbesi* or a related spherical species, *Halysites catenulatus*, a species of Thecia, *Cerionites dactylioides*, *Saccocrinus christyi*, another crinoid related to Hexacrinus, *Pentamerus pergibbosus*, *Spirifer eudorus*, and an undetermined Orthoceras. From two to three miles northeast of Monticello, in the southeast of section 11 and in adjoining parts of 13 and 14, there are many outcrops; and in the ravine followed by the road running between 11 and 14 the *P. pergibbosus* horizon is exposed. Fossils are more numerous than in the bluffs east of Monticello, and among the other forms belonging to this horizon there are casts of *Eucalyptocrinus crassus*. South of the road the hill rises fifty feet above the level of the *P. pergibbosus* beds. The surface is strewn with detached rock fragments and diversified with numerous small outcrops of ledges in place. The rocks are generally barren, but a few colonies of Halysites and Syringopora were observed in the loose masses scattered over the surface. Near the summit of the hill the evenly bedded building stone layers of the Delaware stage have been quarried on a small scale.

One and one-fourth miles northeast of Monticello a quarry has been opened in the quarry stone portion of the lower stage. The rock here is rather soft and as usual furnishes no fossils. This quarry stone horizon of the Delaware is quite constant about 200 feet above the base of the formation, and twenty, thirty or forty feet above the beds that furnish *P. pergibbosus* and Cerionites.

Other exposures occur along the Maquoketa in sections 23, 25 and 26 of this township; and in the southern parts of 35 and 36 there are many stony hills and outcrops, the beds of which furnish no fossils nor do they show any characteristics by which they could be referred to a definite horizon.

RICHLAND TOWNSHIP.

Richland township is largely covered with loess. The rock exposures are limited to the bluffs along the Maquoketa river in sections 30 to 35, and to the valleys of some small streams in the neighborhood of Bowen's Prairie. Along the river there are cliffs of limestone thirty to forty feet in height, and composed of massive beds intersected with numerous joints and fissures. The foot of the cliffs is often undermined for a distance of ten or fifteen feet, and cavernous recesses have been excavated, by weathering, in their vertical faces. Fossils are rare, but the horizon is clearly indicated by the presence of Cerionites and *P. pergibbosus* eight or ten feet above the level of the water.

There are some exposures near Bowen's Prairie; and in the bed of the small creek east of the schoolhouse and cemetery the rocks contain many small individuals of *Pentamerus oblongus*. The horizon is lower than the *P. pergibbosus* beds.

WASHINGTON TOWNSHIP.

Rocks are exposed in the valleys of all the streams in Washington township. Along White Water creek and the North Maquoketa, the sides of the valleys are quite precipitous, sometimes standing in vertical cliffs. More frequently, however, they take the form of steep bluffs, that here and there expose moss-covered walls of rock, ten, twenty or thirty feet in height; while elsewhere the rock is concealed by soil and talus which support gloomy forests of oak and maple. Mosses, ferns and trailing vines conceal immense detached masses of limestone, that, in the erosion of the valleys, were undermined and rolled down from some higher levels. An exposure typical of a large number along the North Maquoketa is seen in the walls of the gorge, down which the road winds on its way to the ford in the northeast quarter of section 26. The rocks are not very fossiliferous, but the section shows various phases of the Pentamerus and Cerionites beds up to the evenly-bedded quarry stone of the Delaware stage which here occurs 150 feet above the level of the river. The paucity of corals in this section, and the absence of silicified fossils of any kind, are in striking contrast with what occurs in many other places at the same horizons. Even Pentamerus is scarce, while only a few miles away there are beds at the same stratigraphic level composed entirely of crowded individuals of *P. oblongus*. The county furnishes many equally striking illustrations of local variations in the distribution of the Niagara fauna or in the dolomitization and other processes that have affected the Niagara limestone since its deposition.

Exposures of the quarry stone beds on Farm creek, in section 28, furnished the material used in the erection of Saint Peter's church and other buildings at Temple Hill.

CASS TOWNSHIP.

Cass township has a number of interesting rock exposures along Buffalo creek and its tributaries in sections 29-34. The cliffs of massive bedded dolomite are mostly of the Le Claire stage, but in section 33 the building stone beds of the Anamosa stage are well developed. Two large quarries are operated near the south line of the southwest quarter of 33. One is the Penitentiary quarry or State quarry, owned by the state and worked by convict laborers; the other is the Johnellen quarry, owned and operated by Hon. J. A. Green. The two quarries are in fact continuous, and present a frontage of nearly a quarter of a mile. The quarry face is a curve, describing the quadrant of a circle, trending at first toward the west at the east end of the State quarry, and finally trending north at the north end of the Johnellen quarry. The strata dip toward the northwest. Fully twenty feet of Le Claire limestone are exposed above the railway grade at the east end of the State quarry, but for a few rods the beds dip at a steep angle, and the base of the Anamosa stone soon reaches the level of the tracks. The inclination is afterwards more gentle, but at the north end of the Johnellen quarry the base of the quarry stone is twelve or fifteen feet below the level of the railway. A short distance northeast of the last point the upper surface of the Le Claire beds rises even above the level of the top of the quarries just noted, and the Anamosa stone has disappeared as a result of erosion. The floor of the sea at the beginning of Anamosa time was exceedingly uneven.

The Le Claire limestone along the Buffalo would furnish excellent material for lime.

WAYNE TOWNSHIP.

Rock exposures in Wayne township are confined to its northern part. The central part of the township is occupied by gently undulating drift, and its southern portion is traversed by morainic ridges capped with loess. There are unfossiliferous, characterless exposures of rock in section 1, but the most conspicuous outcrops occur in sections 4 and 5. On both sides of the valley of Kitty creek, in the west half of section 4, there is an area, more than 200 acres in extent, over which the surface is broken and hilly, the depressions are occupied by a thin soil, and the eminences are in the main projecting weather-beaten crags of dolomite. The surface is largely strewn with displaced fragments. Similar conditions prevail in the eastern part of section 5. This area in Wayne is continuous with the area of rock exposures west and north of the Monticello paha in Monticello township. The rocks represent some of the multitudinous phases of the Delaware stage. In places they are massive. Elsewhere they lie in layers thin enough to be easily quarried, but they are rendered almost useless by the presence of large quantities of chert. Half way between the center and the northwest corner of section 4 the imperfectly dolomotized crinoidal limestone already noticed is exposed. Tubular cavities left by solution of coralla of Diphyphyllum are seen occasionally in the dolomitized portions of the exposures. More rarely silicified stems of Diphyphyllum occur, and there are occasional specimens of *Favosites favosus*. The rock has been quarried at a few points, and the loose masses with which the surface is encumbered have been used in building miles of fences.

A small cut on the railway, one mile northeast of Langworthy, shows well one phase of the Delaware stage. There are no signs of true bedding. The rock is cleft and fissured in every possible direction and if quarried would come out in shapeless pieces. Furthermore the rock is not uniform in character for any distance in any direction. A part of a given block defined by the irregularly disposed fissures may be hard, crystalline dolomite, while the rest of it is soft, yellow, granular and earthy. Fossils are scarce. The few observed belong to the general Diphyphyllum, Favosites and Rhynchonella.

SCOTCH GROVE TOWNSHIP.

The whole course of the Maquoketa river, so far as it lies in Scotch Grove township, is bordered by bluffs of dolomite belonging to the lower two-thirds of the Delaware stage. Along the great loop of the river in section 5 the cliffs include beds containing *Pentamerus pergibbosus* and *Cerionites dactylioides*. The faces of the cliffs are worn into caverns. There are re-entrant recesses due to widening of fissures, and there are threatening masses which overhang the receding, softer and more easily eroded basal portions of the ledges.

In the southwest quarter of section 6, and on both sides of the road that passes diagonally through section 7, there are, in the thin-soiled, stony fields, many rocky exposures of the same type as those seen in the adjacent parts of Wayne and Monticello townships. In general the rock is barren of fossils, but about one mile northeast of Scotch Grove, in section 7, there are masses containing the tubular spaces left by solution of stems of Diphyphyllum, indicating the growth in this locality of gigantic coralla many feet in diameter. Along the west side of section 5, and in the east half of section 6, the surface is strewn with silicified corals belonging to a great number of species. The elevation is about the same as that of the barren, or nearly barren, beds only a mile or two to the west. Among the silicified corals are enormous coralla of *Diphyphyllum multicaule* comparable in size to the corals that have disappeared by solution northwest of Scotch Grove, and doubtless belonging to the same species. In this locality it seems the growth of corals was very luxuriant and the conditions for their preservation by the substitution of silica for the original calcium carbonate were usually favorable. In the other locality, only a mile or so away, life was absent except in a few favored spots, and the metasomatic or pseudomorphic changes essential to the preservation of the skeletal parts failed because the necessary conditions were not present. The corals scattered over the surface in the western part of section 6 are part of the residual products resulting from decay of layers of dolomite that have been removed from the region. They are constituent parts of the geest. Similar corals are wholly or partly embedded in residual soil, and the same species occur in silicified condition in the undecayed, underlying ledges of dolomitic limestone. Along with the corals the undecayed beds often contain numerous internal casts of *Pentamerus oblongus*, some of which are silicified, though the majority are not. The assemblage of corals in this interesting locality embraces the following species:

Heliolites megastoma McCoy.
Heliolites interstinctus Linnæus
Lyellia americana Edwards and Haime.
Lyellia, undescribed species.
Halysites catenulata Linnæus.
Syringopora annulata Rominger.
Springopora verticillata Goldfuss.
Favosites favosus Goldfuss.
Favosites niagarensis Hall.
Favosites (*Astrocerium*) *hisingeri* Edwards and Haime.
Favosites obliquus Rominger
Alveolites undosus Miller.
Cladopora laqueata Rominger.
Zaphrentis stokesi Edwards and Haime.
Streptelasma patula Rominger.
Amplexus shumardi Edwards and Haime.
Ptychophyllum expansum Owen.
Strombodes gigas Owen.
Strombodes pentagonus Goldfuss.
Strombodes mamillatus Owen.
Goniophyllum pyramidale Hisinger.

Besides the species mentioned, there are large silicified Stromatoporoids, forms related to Diphyphyllum, with stems three-eighths of an inch in diameter and growing embedded in *Favosites hisingeri*, a very large, wheel-shaped Streptelasma, related to *S. patula*, half an inch in length, and more than two inches in diameter, an encrusting species of Thecia, and a number of others that have not yet been studied. While most of the species occur elsewhere, no other locality affords evidence of such luxuriance of coral growth as is witnessed here. Nearly all the species are represented by coralla of unusual size. Gigantic masses of Halysites that are evidently mere fragments of the original coralla, are five feet in length, four feet in width and three feet in thickness; and there are many fragments of colonies of Diphyphyllum equally as large. The conditions favoring the exceptional growth and perfect preservation of the corals were limited to a relatively small and sharply defined area. We have here another striking example of definitely localized conditions.

CLAY TOWNSHIP.

The principal rock exposures in Clay township are found in the bluffs along Farm creek and the Maquoketa river, and in the lateral gorges that open into the valleys of these two streams. At the bridge, a short distance southwest of Clay Mills, there are massive beds without signs of stratification, crowded with casts of beautifully preserved, medium sized individuals of *Pentamerus oblongus*. The Pentamerus beds have here a thickness of about thirty feet. They are almost wholly free from silica, and they contain no conspicuous corals. Above the Pentamerus beds there are weathered ledges of dolomite, bearing few fossils, and having a thickness of fifty to seventy-five feet. Immediately west of the village of Clay Mills the dolomitic cliffs have an altitude of 145 feet above the bed of Farm creek, and 150 feet above the Maquoketa river. The lower fifty feet at the base of the cliff, including the prolific Pentamerus beds seen at the bridge, are concealed by talus. Above the talus slope the ledges form a vertical wall ninety-five feet in height. (Fig. 3.) The structure of similar cliffs may be studied east of the village, along the road which, taking advantage of a favorable arrangement of the talus, follows close to the foot of the vertical wall and gradually attains the summit of the bluff. Pentamerus is found sparingly up to fifty or sixty feet above Farm creek; there are a few traces of feeble colonies of Halysites; but fossils of every kind are rare above the horizon of the Pentamerus beds at the river, and none of the species are silicified. At the summit of the bluff, about a quarter of a mile east of Clay Mills, the road reaches the level of the quarry-stone of the Delaware stage. The quarry beds, horizontally and evenly stratified, vary from three to fifteen inches in thickness, and are much superior in quality to beds of the same horizon in many other localities. Eagle rock is a conspicuous rocky promontory facing the river in the southwest of section 13. It has an altitude of 150 feet above the water near its base. It shows essentially the same succession of beds as seen at Clay mills, and its summit is capped with layers of evenly stratified building stone. The road, which winds diagonally through section 15, follows a deep ravine with high, rocky walls. The walls exhibit the same characteristics as the sections already noted, and include all the ledges, from the prolific Pentamerus horizon up to the building stone beds. But in none of these sections is there anything to correspond to the coral beds of section 6 in Scotch Grove township. A few small, silicified corals were found free in the bed of a creek in the northwest of section 15 of Clay township; but although the creek bed should have contained residual products from probably 200 feet of limestone removed by erosion, silicified fossils, or even fragments of chert, were so few in number and so small in size that they could be found only by careful search. This region probably never supported more than a few feeble colonies of corals at any given time, and only a small proportion of these was preserved by the substitution of silica for the original material.

The exposures at and near Clay Mills and at Eagle Rock are typical of the majority of exposures occuring in this township. In the southeast of section 24, however, corals were more plentiful than near Clay Mills, and some ledges in the dry bed of an intermittent creek furnish small silicified specimens of *Favosites favosus*, *F. hisingeri*, *Lyellia americana*, *Heliolites interstinctus* and *Halysites catenulatus*. Besides the species named there are two species of Zaphrentis, one Rhynchotreta, the common Pentamerus, and a large species of Straparollus more than four inches in diameter. The poverty of the fauna at this locality was one of its most striking characteristics.

FAIRVIEW TOWNSHIP.

Fairview township is the center of the building stone industry for Jones county. The great shipping quarries of this township are located in sections 5 and 6. The quarries are worked in beds of the Anamosa stage, and it is in these quarries that the typical exposures of this stage are found. The original quarry which produced building stone on a commercial scale for other than local markets, was called the Anamosa quarry, and the special kind of rock which it furnished became known in the building trade as Anamosa limestone. Under this name it is still known, and the name is to be perpetuated by calling the particular geologic horizon in which these great quarries were opened, the Anamosa stage. The evenly bedded quarry stone of the Anamosa stage has already been described. In sections 4, 5, 6, 7 and 8 of this township it overlies massive beds of the Le Claire. The Le Claire beds, however, are not very thick and at the mill near Anamosa the Wapsipinicon river has cut down into the thin cherty beds of the Delaware stage. The bluffs, however, from Stone City to the center of section 13 are largely of Le Claire limestone.

Gold Hill quarry, the property of F. S. Brown & Co., is located near the western edge of section 6. All the ledges exposed in this quarry belong to the Anamosa stage. About eighty rods southeast of Gold Hill is Champion quarry No. 1, belonging to Hon. J. A. Green. Mr. Green takes out the laminated stone down to the massive beds of the Le Claire. Between the level of the river and the thin layer of drift overlying the rock at Champion quarry No. 1, the following section is exposed:

		FEET.
5.	Remnants of a non-laminated, yellow magnesian limestone, Bertram stage	2 to 3
4.	White limestone of the Anamosa stage, much decayed and broken into small fragments in the upper part	30
3.	Gray limestone of Anamosa stage	30
2.	Heavy bedded limestone, forming in places vertical walls above level of railway track, Le Claire	15
1.	Slope from level of railway track to river, unexposed	25

The Stone City quarry, one-fourth of a mile east of the center of section 6, is owned by H. Dearborn & Sons. The quarry stone is worked down to the non-laminated Le Claire, which everywhere forms the floor on which the Anamosa limestone was deposited. The section in its general details is the same as that on the property of Mr. Green. The upper surface of the Le Claire, as already noted, is very uneven, and here slopes to the east. In the Anamosa quarries owned by Mr. Ronen, and located in the western part of section 5, the floor on which the quarry stone rests descends below the level of the railway tracks, and at Mr. Green's Champion quarry No. 2, one-fourth of a mile southeast of Ronen's, the lower Anamosa beds pass beneath the level of the river. Farther east the Anamosa limestone again rises, and in section 4, to use the quarryman's expression, "throws itself out of the ground." The Anamosa stone is seen in its normal relations to other geological formations at a number of points in the walls of the valley of the small creek which flows through sections 7 and 8.

There are some peculiar phases of the Le Claire limestone along the river, between Stone City and the east line of the township. Some of the characteristics are illustrated in the bold cliff in sections 13 and 24. Near the center of 13 is an exposure twenty-five feet in height which, as usual in this region, shows no definite bedding planes. The rock near the base of the cliff is very much fractured, and broken into small, angular bits in such a way as to impart a close resemblance to limestone breccia. There are crevices in the lower part of the exposure, and a large amount of work has been done in developing and exploring them, in the hope of finding lead ore. Prospecting for lead has been carried on in corresponding beds in sections 14 and 24. In the upper part of the exposures the rocks are more solid. The only fossils noted were the impressions of a small Zaphrentis, diminutive colonies of Favosites and a small brachiopod resembling *Rhynchonella whitei*. The rocks are free from chert, and the fossils are represented by cavities left as a result of solution of the original organic structures.

JACKSON TOWNSHIP.

Ledges of Le Claire limestone, similar to those seen in sections 11, 13, 14 and 24, of Fairview, are continued along the river in Jackson township, as far as Newport in section 33. Above the mill dam, near Newport, the ledges exhibit fairly defined bedding, and may be quarried with some success for rough masonry. In the left bank of the river, above the dam, the beds are folded into a long, sweeping, double curve, more than 300 feet in length. The steepest part of the curve dips to the northeast at an angle of twenty degrees.

A small area, near the center of section 22, is occupied by beds of the Anamosa stage overlying the Le Claire, and at what is called Slife's ford, in the southwest of 26, the river has cut its channel in the upper layers of the Anamosa limestone. Quarrying has been done on a limited scale at both the points mentioned.

MADISON TOWNSHIP.

Madison township has no rock exposures. The entire surface of the township is covered with loess and drift. South of Center Junction the indurated rocks are covered with superficial deposits to a depth, in places, of 200 feet. The greater part of the township was, in preglacial times, occupied by a broad, deep valley.

WYOMING TOWNSHIP.

Rock exposures occur in Wyoming township, in the valley of the small creek followed by the Chicago & Northwestern railway, in sections 3 and 15. There are other exposures in the hills bordering the valley of Bear creek, in the southeastern corner of the township. In the northern sections the

FIG. 5. Monument of Niagara limestone, Delaware stage, 80 rods north of southwest corner of section 35, Wyoming township.

stone is generally coarse in texture, very vesicular, and breaks in irregularly shaped masses. The bedding is not very definite, and the layers often seem to be more or less flexed and tilted. In section 9, Ne. qr., Se. ¼, there are even horizontal beds of quarry stone of the Delaware stage, overlying the rough vesicular ledges that outcrop lower down in the sides of the valley. In the southeastern corner of the township, the beds are also of the Delaware stage. Eighty rods north of the southwest corner of section 35, there are exposures on the hillsides, high above the bottom of the valley of Bear creek. One of the interesting phenomena of the locality just mentioned, is a column of limestone eight feet in diameter, and rising above the general surface about sixteen feet (Fig. 5.) The soil is thin, but what there is is chiefly drift, and boulders are scattered over the hillside all around the column. The column is the result of unequal erosion of the limestone. It evidently stood there before the drift was laid down. How it escaped destruction by the glacial ice that deposited the boulders now lying around its base, is a question not easily answered. The exposures in Wyoming township belong to the upper part of the Delaware stage. Fossils are rare. In the vicinity of the monument described above, there were traces of Halysites and Cœlospira.

GREENFIELD TOWNSHIP.

There are very few rock exposures in Greenfield township. The drift is in places more than 100 feet in thickness, and the surface, more than in any other township, is diversified with paha ridges. The rocks, however, come to the surface at a few points along Walnut creek. The exposures seem to be wholly confined to the northwest quarter of section 15. All belong to the Le Claire stage, and the oblique bedding peculiar to this stage is one of their prominent characteristics. Altogether there is a thickness of twenty-five feet exposed, and the oblique beds, which are confined to the lower part of the exposure, are inclined to the east at an angle of 28°. Among the uppermost ledges there are some that contain numerous cavities from which small costate, Retzia-like shells have been removed by solution. The same kind of cavities is very characteristic of the strata overlying oblique beds of Le Claire limestone at many points beyond the limits of Jones county.

ROME TOWNSHIP.

The most important rock exposures in Rome township occur southeast of Olin in the valley of Sibyl creek. Mr. A. Rummel has opened a quarry in typical beds of the Anamosa stage, not far from the township line, almost directly east of the center of section 24. The thickness of the beds worked in this quarry is about thirty feet. The lamination planes occur as usual in the Anamosa limestone, but there are no planes separating the mass of sediments into distinct layers. The whole exposure is practically one continuous ledge that may be split with almost equal facility along any one of the numerous planes of lamination. The creek near the base of the quarry cuts down into non-laminated beds belonging to the Le Claire stage.

HALE TOWNSHIP.

A short distance east of Rummel's quarry, in section 19 of Hale township, there are several exposures of Anamosa limestone underlain by beds of Le Claire. At two or three points quarries have been opened, the most extensive being that on the land of Mr. A. J. Dolby. The stone is very similar to that in the Rummel quarry in Rome township, except that it is more definitely divided into layers, and that nodules of chert are very numerous. On the slopes below the level of the quarries there are exposures of Le Claire limestone containing casts of the species of Amplexus that is so marked a characteristic of this formation at many of its typical localities in Cedar and Scott counties.

There are undeveloped beds of Anamosa limestone in the northwest quarter of section 20, and deposits of the same stage occur on both sides of the river near Hale. The highly crystalline dolomite of the Le Claire stage, suitable for lime burning, is exposed in a number of places on the land of Mr. J. R. Clay in the western half of section 15. At the bridge over the Wapsipinicon southwest of Hale, there are bluffs of massive Le Claire limestone fully twenty feet in height. (Fig. 2.)

The imperfectly defined lines of bedding show the anomalous folds and dips that so generally mark this particular horizon. For purposes of lime burning the rocks at this point are unexcelled, but, although lime has been made here on a small scale, there is none manufactured at present.

East of Hale, near the center of section 11, the Anamosa beds are somewhat extensively quarried. The quality of the stone is better than that near Olin. The beds show the effect of having been deposited on an uneven floor. The layers are all somewhat warped. North of the center of the quarry they slope in all directions from a dome-like arch, but before reaching the north end of the working the dip is reversed. On the south side of the dome the dip is steeper than on the north, and is continuous as far as the quarry has been opened. The total exposure here has a thickness of about thirty feet. The lower beds of the Anamosa stage have not yet been taken out. On the south side of the river, about eighty rods east of the center of section 15, the John Clay quarry exposes from twenty-five to thirty feet of Anamosa limestone. The quarry stone is taken out down to the upper surface of the Le Claire. Near the middle of the west line of section 14 there is another quarry belonging to A. Ballou, which affords the following section:

		FEET.
5	Soil and geest only a few inches	--
4.	Anamosa stone of usual quality, ledges varying in thickness from five inches to two or three feet	25
3.	Unlaminated ledges of Le Claire limestone, nearly uniform in thickness, good bridge rock	2¾
2.	Massive coarse Le Claire limestone without partings	8
1.	Unexposed to level of water in river	6

A few rods east of the Ballou quarry another opening has been made and worked on a small scale. The usual features are shown, the only point of interest arising from the fact that owing to the irregularities attending the deposition of the Le Claire, the base of the Anamosa formation descends below the level of the roadway, a descent of at least eleven feet in as many rods. The last two quarries are opened in the side of a wooded bluff seventy-five feet in height. The beds overlying the Anamosa are not exposed, but it may be assumed that they belong to the Bertram stage and possess the characteristics of this formation as developed near Stone City.

OXFORD TOWNSHIP.

The exposures in Oxford township are not very numerous. The Delaware limestone, with casts of the ordinary type of *Pentamerus oblongus*, comes to the surface in the level plain within the limits of the town of Oxford Junction. One and a half miles further north, sixty rods south of the center of section 10, and only a few feet higher than the Pentamerus beds at Oxford Junction, there is an exposure of Anamosa limestone underlain by heavy beds of Le Claire.

Unconformities.

The peculiar conditions attending the deposition of the Le Claire limestone, described on preceding pages, have produced a great number of apparent unconformities. Horizontal beds of Le Claire seem to rest on the edges of inclined strata of the same age (plate i), and the inequalities of the sea bottom at the close of the Le Claire produced many anomalies in the position and relation of the Anamosa beds. It often looks very much as if the surface of the Le Claire formation had been deeply eroded before the Anamosa beds were deposited. The appearance is not wholly deceptive, for the materials of the Le Claire were scooped out in some localities and were irregularly heaped up in others immediately before the opening of the Anamosa stage. The erosion, however, was not subaerial. All the observed effects were produced beneath the water as the result of vigorous currents acting on the bottom of a shallow sea. At many points along the South Atlantic coast of the United States analogous effects are now being produced by storm-driven currents acting on submerged sands.

True unconformity occurs between the Niagara and the Carboniferous. The region was elevated above the sea near the beginning of the Devonian and was subjected to subaerial erosion during all the stages of the Devonian and Lower Carboniferous. It was not indeed until probably the middle of the Upper Carboniferous that the sea returned to deposit a new series of sediments upon the deeply eroded surface of the Silurian. The time during which the Carboniferous sea occupied the county was, geologically speaking, very short, and nearly all the sands and shales which accumulated above the Niagara dolomite have been carried away by subsequent erosion.

The Pleistocene deposits rest unconformably upon all the indurated rocks, the two drift sheets are unconformable, the loess is unconformable on the Kansan drift, and the alluvium occupies valleys of erosion that have been cut in all the deposits preceding it in point of age.

Deformations.

That examples of deformation of strata occur within the limits of Jones county is scarcely to be doubted; but if such do occur, they are so completely disguised by the anomalies of deposition consequent on conditions existing during the progress and at the close of the Le Claire stage, that it has not been possible to recognize them with any degree of certainty.

ECONOMIC PRODUCTS.

SOILS.

From an economic standpoint the soils of Jones county easily outrank in importance all the other geological formations. These soils fall naturally into four divisions, namely: residual soils or geest, glacial soils or drift, yellow clay soils or loess, and alluvial soils which may consist of clay or sand, or varying admixtures of these two materials. The history, origin and distribution, and some of the physical characteristics of each of these types of soil have already been discussed. It remains only to note briefly their relative importance judged from an agricultural point of view.

The residual soils of the county are comparatively unimportant. The area exclusively occupied by them is small. Where they prevail the soil is thin and is usually insufficient to conceal the indurated rocks of the region. Weather beaten crags project above the surface, and the scant soil is encumbered with numerous rock-masses detached by the processes of disintegration. Sections 2 and 3 of Castle Grove, 19, 33, 34 and 36 of Monticello, 4 and 5 of Wayne, 5, 6 and 7 of Scotch Grove township afford numerous typical illustrations of residual soils.

The drift soils, on the other hand, are the most important and valuable of all the classes named. In the drift covered portions of the county the indurated rocks are usually effectually concealed by a mantle of glacial detritus that is, in places, more than 200 feet in depth. The efforts of ants, earthworms, gophers, and other burrowing animals, that, during all the years since the retreat of the Iowan ice, have been effective in carrying the fine-grained portion of the deposit up to the surface, aided as these have been by rains and frosts and vegetable growth and decay, have resulted in developing upon the surface of the drift a mellow loam, rich in organic matter and so constituted physically as to offer advantages of easy cultivation coupled with the assured hope of generous harvests. The drift occupies certain plains already described under the head of physiography. The limits of the drift plains circumscribe the regions in which wealth is, on the whole, accumulating most rapidly with least effort. The drift covered regions are everywhere characterized by masses of gray granite, and so the distribution of boulders is practically coextensive with areas marked by the highest degree of agricultural prosperity.

The loess soils are represented by the surface materials covering the hills of yellow clay, on both sides of the river, near Anamosa. They are illustrated on even a larger scale in the broken, rolling, hilly regions of Clay, Washington and Richland townships. Before the settlement of the county the drift plains were prairies supporting annually a wealth of grass. The yellow loess hills, on the contrary, were wooded, and supported groves of white oak, basswood and poplar. The loess washes easily, and the fields into which these wooded clay hills have been transformed are often deeply gashed and gullied by recent rains. The soil is poor and difficult of cultivation, and the farmsteads of loess regions are often sadly wanting in signs of comfort and prosperity.

Alluvial soils are found in the river valleys. The areas occupied by such soils have been described in connection with the subject of alluvium. Alluvial soils rank, in fertility and ease of cultivation, with those of the drift.

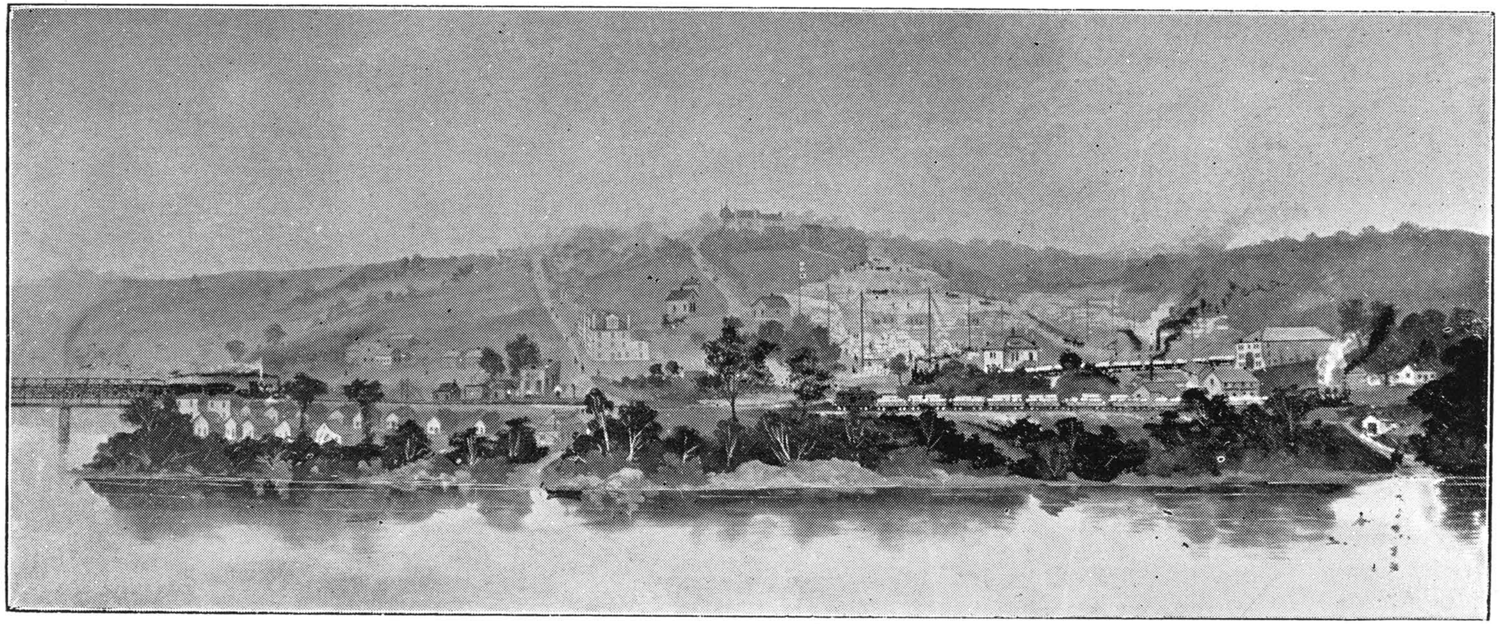
BUILDING STONES.

Each stage of the Niagara furnishes constructive materials that may be used in some grade of masonry; but the Anamosa stage and the evenly bedded horizon near the top of the Delaware, furnish the only building stones worthy of present consideration. The building stone beds of the Delaware stage afford some excellent material, particularly in the neighborhood of Clay Mills, Canton and Temple Hill. Near Clay Mills the ledges vary from three to fourteen inches in thickness. The stone is generally of good color, it is firm, compact, without laminæ, and, in the most trying situations, it resists admirably the action of the weather. All the exposures of the Delaware stage building stone are unfortunately located, so far as relates to facilities for transportation. Their only use for many years to come will be the furnishing of building material to supply local demands. Their distribution and stratigraphic position have been already noted.

The quarry industries of Jones county, so far as these are conducted on a scale of commercial importance, are all dependent on the evenly bedded, finely laminated strata of the Anamosa stage. The most important quarries of this stage are located near the western border of the county, in Fairview and Cass townships. The several quarries in this important group were mentioned and some of their characteristics discussed in the discriptions of the typical exposures of the county.

The evenly bedded stone in the river bluffs west of Anamosa early attracted attention. The first extensive use of it was made by the United States army in constructing military roads while Iowa was yet a territory. Some of the old bridge piers built under the direction of the military engineers, are still standing and bear conclusive testimony to the durability of stone from this horizon. For some time the quarries were worked on a small scale and supplied only a local trade, but the market widened as the qualities of the stone became better known, and long wagon hauls were made in order to secure this material for use in structures of sufficient importance to justify such expensive methods of transportation. In 1852 stone was hauled from what is now Stone City to Mount Vernon for use in construction of one of the first buildings belonging to Cornell College.

Shipments by rail began from this locality in 1859, and since that time the stone industry of the region has steadily increased. From supplying a very restricted local trade, the business of quarrying and shipping stone has grown until it now reaches markets distributed throughout Iowa, Illinois, Wisconsin, Minnesota, South Dakota, Nebraska, Kansas and Missouri. Many of the most important structures in the several states named are built of Anamosa stone. It competes in Chicago and Minneapolis with the product of quarries more advantageously located, so far as distance is concerned. All the important railways of the northwest have used Anamosa stone in the construction of bridge piers. The stone has been used extensively in erecting the shops and other buildings at the Rock Island Arsenal. Iowa and Nebraska have both used it in building hospitals for the insane. It



ENVIRONS OF STONE CITY. VIEW FROM THE NORTH SIDE OF THE WAPSIPINICON, SHOWING SOUTH WALL OF THE CANYON-LIKE GORGE IN WHICH THE RIVER FLOWS.

meets the requirements of all grades of architectural work, from the humblest to the highest. As architects and engineers become better acquainted with its merits, the stone finds an ever widening market. From the limited shipments in 1859 the stone industry of this locality grew until in 1887 nearly 9,000 car loads were sent out. The total shipments from 1859 to November, 1895, amount to 156,229 cars, which, at the low average of twenty dollars per car, gives an aggregate value of $3,124,580. The future of the stone industry around Stone City depends wholly on the extent of the markets that can profitably be reached from this as a distributing center, and on the extent to which stone will be employed in building the homes and business palaces and new structures of every kind that give tangible expression to the increasing wealth and growing sense of architectural beauty throughout this great northwest. No possible demand can ever outrun the supply. The geological structure indicates beyond question the presence of inexhaustible stores of quarry stone easily accessible. So long, therefore, as stone is used in construction, the business of quarrying and shipping from Stone City is one of assured permanence.

GOLD HILL QUARRY.

Gold Hill quarry is situated within 600 feet of the west line of Jones county, in Fairview township (Sec. 6, Nw. qr., Sw. ¼). It belongs to F. S. Brown & Co., and is operated in conjunction with the Crescent quarry, which belongs to the same company, and is located west of the line in Linn county. During 1895 the Gold Hill property in Jones county was practically idle, the company finding it more convenient to fill orders for the particular grade of stone called for from its quarry in Linn county.

The quarry stone at Gold Hill is overlain by loess varying from a few feet up to fifteen feet in thickness. Beneath the loess is a thin layer of till which contains pebbles and small boulders of types characteristic of the Kansan drift sheet. The drift rests on ferruginous residual clay or geest, which fills crevices and pockets in the upper weathered portions of the quarry stone, while associated with the geest are masses of grayish powder, sometimes several feet in thickness, representing an early stage of rock decay when only the cement which binds together the constituent grains has been removed by solution.

The equipment of the quarry includes a steam plant which is used chiefly as a pumping station to supply water under necessary pressure for the hydraulic apparatus used in stripping. There are also derricks, horse power hoists, steam channelers, and other devices for quarrying and handling stone. A large force of laborers and stone cutters is constantly employed. Since 1887, when the present company began operating, there has been shipped a total of about 12,000 cars. The largest shipments in any one year were 2,248 cars in 1890.

CHAMPION QUARRY NO. 1.

The Champion quarry, No. 1 (Fig. 6), is the property of Hon. J. A. Green. It is situated a few rods east of Gold Hill,

FIG. 6. View in Champion quarry, Stone City.

and presents essentially the same features as the quarries farther west. As already noted, the quarry beds of this region are not definitely divided into layers. Throughout their whole thickness they constitute practically one layer very perfectly laminated and capable of being split along almost any one of the numerous lamination planes. The division into ledges is therefore more or less arbitrary. For the purpose of illustrating the manner in which these quarries are divided, the following section from Champion quarry No. 1 is given:

		FEET.	INCHES.
26.	Loess, varying in thickness, maximum	20	
25.	Fine sand associated with loess, the sub-loessial sand of Norton	2 to 6	
24.	Drift and residual clay	1	
23.	"Shelly stone," the partially decomposed beds of the upper, or white limestone, broken into thin flakes or chips	2 to 10	
22.	"White stone" splitting readily into smooth surfaced slabs, used chiefly for riprap	16	
21.	"Rotten layer," a soft vesicular ledge of poor quality which separates the gray from the white limestone	2	4
20.	Compact, fine-grained, ledge, good building stone	1	5
19.	Same as 20	1	5
18.	Ledge of good building stone		11
17.	Same as 18		11
16.	Upper bridge stone, coarse	2	6
15.	Inferior layer containing many small cavities lined with calcite		10
14.	Fine-grained building stone	1	1
13.	Ledge containing at base a thin layer of very fine-grained, compact limestone, which cracks into angular fragments under the action of frost (the bands of very fine-grained limestone differing from the ordinary granular dolomite are called "flint" by the quarrymen)	1	3
12.	Ledge with bands of "flint"	1	11
11.	Solid ledge of good building stone	1	4
10.	Compact ledge, best quality afforded by the quarry	1	2
9.	"Wavy ledge" good for ordinary masonry; the laminæ are more or less undulated	2½ to 3	
8.	Good building ledge		11

		FEET.	INCHES.
7.	"Flint ledge," compact limestone, breaking into angular fragments on exposure to weather	⅓ to 1	4
6.	Flagging ledge, easily split	1	4
5.	Ledge containing cavities lined with crystals	1	
4.	Ledge of good building stone		11
3.	Lower flagging ledge	2	
2.	Lower bridge stone ledge, very durable, though occasionally containing cavities lined with crystals	2	4
1.	Ledge that may again be split into blocks convenient for building purposes	3	

Below the quarry stone there are here, as everywhere in this region, massive beds of the Le Claire limestone. The uppermost ledge of the Le Claire at the Champion quarry ranges from two and one-half to three feet in thickness, and was formerly quarried to a limited extent for use in heavy bridge piers.

The machinery employed in the Champion quarry includes a steam channeler, a number of horse power hoists, seven large derricks, circular rubbing beds for dressing stone, a Gates crusher, steam plant containing an eighty horse power engine, besides a pumping station containing pumps and hydraulic engine, used in stripping off the superficial clays and sands. The hydraulic process of stripping was first employed in this region at the Champion quarry. On account of the great saving effected, the expense of removing a given number of cubic yards of earth being less than one-fifth of what it was by the methods formerly employed, hydraulic stripping has been adopted by all the larger quarries.

The Champion No. 1 furnishes crushed stone, riprap, rubble, bridge stone, flagging and all grades of dimension stone. A large force of laborers, machinists and stone cutters finds constant employment; the number of employes on the payrolls at any one time has varied from 40 to 460. This quarry is located almost in the very center of the area which, in this locality is occupied by the evenly bedded, laminated stone of the Anamosa stage. It was opened by Mr. Green in 1869. During the first year 150 car loads were shipped. In 1882 the business had grown to 4,801 cars. The total shipments since the quarry was opened aggregates 47,618 car loads. A number of switches or spurs of railway track lead into the quarry, making it possible to load the stone at the point at which it is quarried.

STONE CITY QUARRIES.

The Stone City quarries (Fig. 7) were opened by Mr. H. Dearborn in 1869. They are now owned and operated by H.

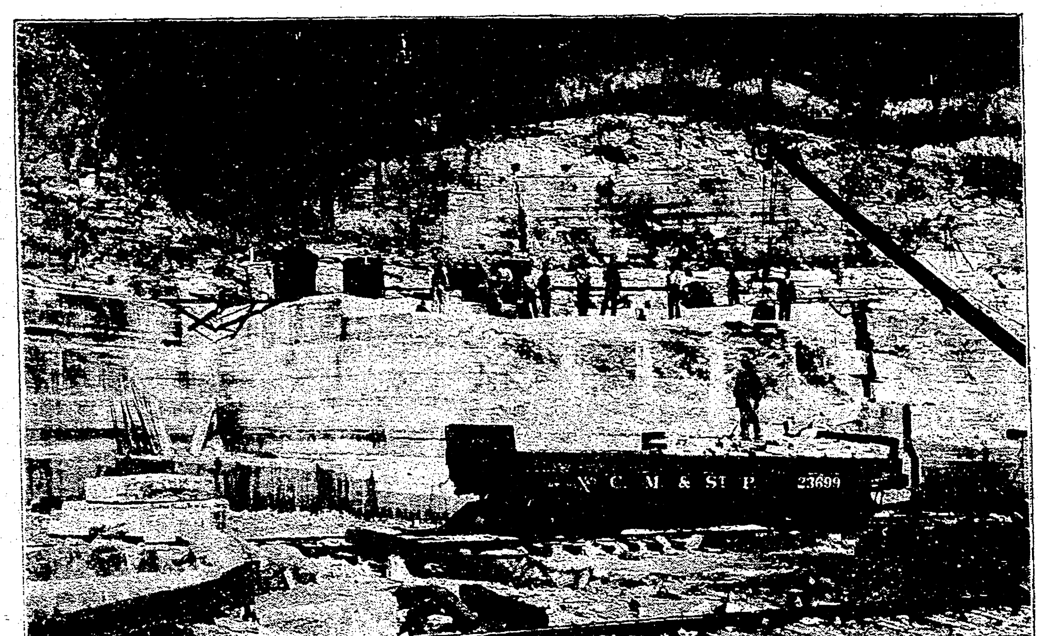


FIG. 7. View in Stone City quarry, Stone City.

Dearborn & Sons. They are located near the middle of the south half of the northeast quarter of section 6, Fairview township. The quarry face forms a long sweeping curve about a quarter of a mile in length and nearly parallel with the sweep of the Wapsipinicon river that here flows close to the foot of the bluffs in which the quarries were opened. The quality of the stone and the succession of ledges are essentially the same as at the quarries already described. Overlying the stone is a bed of loess, sand and drift, with an average thickness of five feet and a maximum thickness of fifteen feet. Some six or eight feet of stone at the top of the quarry are to be counted with the refuse, the beds being broken into small angular pieces as a result of weathering prior to the deposition of the superficial drift and loess. These quarries expose the whole thickness of the "gray stone" or lower half of the Anamosa beds, above which are serviceable beds of the "white stone," or upper half, having a thickness of ten or fifteen feet. The beds are worked out down to heavy ledges of non-laminated Le Claire. The quarries are capable of furnishing dimension stone from three to thirty-three inches in thickness, and of any desired length and width. Four railway tracks, following the curve of the quarry face, afford facilities for handling cars. The equipment comprises channelers, derricks, steam and horse power hoists, and steam pumps for use in hydraulic stripping. The men employed include the usual grades of workmen, from the common laborer to the most skillful stone cutter, and the number has varied from 20 to 100. The number of car loads of stone shipped from the time the quarries were opened till November, 1895, amounts to 27,432. In one year, 1892, the shipment amounted to 2,765 car loads.

ANAMOSA QUARRY.

The Anamosa quarry was the first in this locality to ship stone abroad, the first shipments by rail being made in 1859. The quarry was opened by David Graham, but its present owner is Mr. J. Ronen, who has opreated it since 1881. The Anamosa quarry is located near the northwest corner of the southwest quarter, section 5, Fairview township. Mr. Ronen's quarry is indeed double, for there are two openings a short distance apart. At the first opening the amount of clay stripping is very small. Beneath the clay there are a few feet of non-laminated worthless rock belonging to the Bertram stage. Then in descending order there follow fragmentary beds of the "white limestone," "shell rock," then the usual succession of ledges down to the lower bridge layer, or No. 2 of the Champion quarry section. Owing to the eastward dip of the beds at this locality, the lower bridge rock at the second Ronen quarry is too low to be worked, the lowest workable beds being about the level of the "flint ledge," or No. 7 of the section at the Champion. Since 1859 there has been shipped from the Anamosa quarry a total of 28,134 car loads, of which 20,484 cars were shipped by Mr. Ronen since he took possession of the property in 1881.

CHAMPION QUARRY NO. 2.

The Champion quarry No. 2 is now the property of Hon. J. A. Green. Its location is near the center of the southeast quarter of section 5, Fairview township. This quarry was opened by Crouse, Shaw & Weaver in 1866. In 1872 it was sold to the state of Iowa, from which date until 1884 it was worked by convicts from the penitentiary at Anamosa. Afterwards it was purchased by the present owner, who works it on a small scale in connection with the larger quarry, Champion No. 1. At this quarry there are about eight feet of clay to be removed. The Bertram beds have a thickness of from ten to fifteen feet. The full thickness of the "white rock" is exposed. It is somewhat fragmentary or "shelly" near the top, but the lower two-thirds is good. The "gray stone" is not fully exposed. The lower bridge rock lies here beneath the level of the river, and the quarrying is carried down only as far as the "flint ledge," No. 7 of the Champion quarry section. About 15,000 car loads, all told, have been shipped from this opening.

GEM QUARRY.

The Gem quarry is a small opening near the northeast corner of the northwest quarter of section 4, in Fairview Township. Work was begun here in the spring of 1894. The quarry is opened in the bluffs on the west side of the Buffalo creek. At the foot of the bluff runs a spur of the Northwestern railway, which affords the necessary shipping facilities. At this quarry very little stripping is necessary; only a thin layer of soil overlies the quarry stone. In the upper part of the quarry the stone is soft, but near the base the quality is good, and it shows the usual characteristics of the Anamosa beds in this locality. There is very little machinery used except a derrick and horse power hoist, and only two or three men are employed. The land is owned by James Joslin, but the quarry is at present leased and operated by James Lawrence. About fifty cars have been shipped during the two years that the quarry has been in operation.

STATE QUARRY.

In 1884 the present State quarry, or Penitentiary quarry, was opened. Formerly the stone for the penitentiary buildings at Anamosa was obtained from what is now known as Champion quarry No. 2. In the year named the state bought property on Buffalo creek, in the southwest quarter of section 33, Cass township, and began operating the present quarry. The quarry is worked altogether by convict labor. Above the stone is a bed of loess and drift varying in thickness from a few inches to ten or twelve feet. Below the drift there are a few feet of decayed and broken "shell rock" belonging to the upper part of the "white stone" of the Anamosa stage. Lower in the quarry the ledges present the same features as in corresponding parts of other exposures. The exposure of Le Claire limestone at the east end of this quarry and the strong dip assumed by the beds in accommodating themselves to the uneven upper surface of the Le Claire have been already noticed. Most of the work at this quarry is done by hand. There are seven large derricks for handling the stone, but they are all operated by hand power. The stone is shipped over a spur of the Northwestern railway, which runs up the valley of the Buffalo and accommodates all the quarries in this part of the Anamosa stone basin. About 15,000 cars have been shipped since 1884.

JOHNELLEN QURRRY.

The Johnellen quarry lies west of the State quarry, in the Sw. ¼ of the Sw. qr. of section 33, Cass township. It is owned by Hon. J. A. Green, who began operations at this point in 1887. The stripping in this quarry consists of loess, drift, residual clays and decayed fragmentary rock, having an aggregate thickness of from ten to twenty feet. There is a great deal of ferruginous residual clay mixed with the fragmentary stone near the top of the exposure. The same clay has worked down into crevices almost or quite to the top of the "gray stone." The lower beds, or "gray stone," are here of very excellent quality, firm, compact, of pleasing neutral color, and capable of resisting the weather indefinitely. This quarry is not operated on a large scale. The present equipment and force are represented by three derricks, two horse power hoists and half a dozen men. The thickness of the serviceable quarry stone, which exceeds that of any other exposure in this region, the quality of the product, and the fact that the beds extend under several hundred acres belonging to the same owner, make it certain that in the near future the Johnellen will become one of the most extensive and important shipping quarries in this upper portion of the Mississippi valley. About 7,000 car loads of stone have already been shipped from this opening.

OTHER QUARRIES OF THE STONE CITY BASIN.

The quarries enumerated above are the only ones shipping stone by rail from the Stone City basin. There are, however, a number of exposures of Anamosa limestone in the bluffs of the small creek that flows through sections 7 and 8 of Fairview township, and some quarrying has been done on the lands of L. B. Parsons and R. M. Peet. The stone is hauled out by wagon and supplies the demand throughout a large and wealthy farming community between the Wapsipinicon river and Mount Vernon. Only the simplest processes are used in these quarries, and, while exact statistics are not at hand, the amount and value of the stone produced here is by no means inconsiderable.

ANDREW RUMMEL QUARRY.

Mr. Andrew Rummel owns and operates a quarry near Olin, in Rome township. (Tp. 83 N., R. III W., Sec. 24, Ne. qr., Se. ¼.) (Fig. 8.) The quarry is opened in the low bluff on the west side of the valley of Sibyl creek. The stone belongs to the Anamosa stage, and except that it is buff in color, it corresponds well with the "gray stone," or lower portion of the formation as seen near Stone City. There are no definite bedding planes, but the rock cleaves readily along any of the planes of lamination. The surface of the laminæ are not so smooth and true as they are at the corresponding horizon near

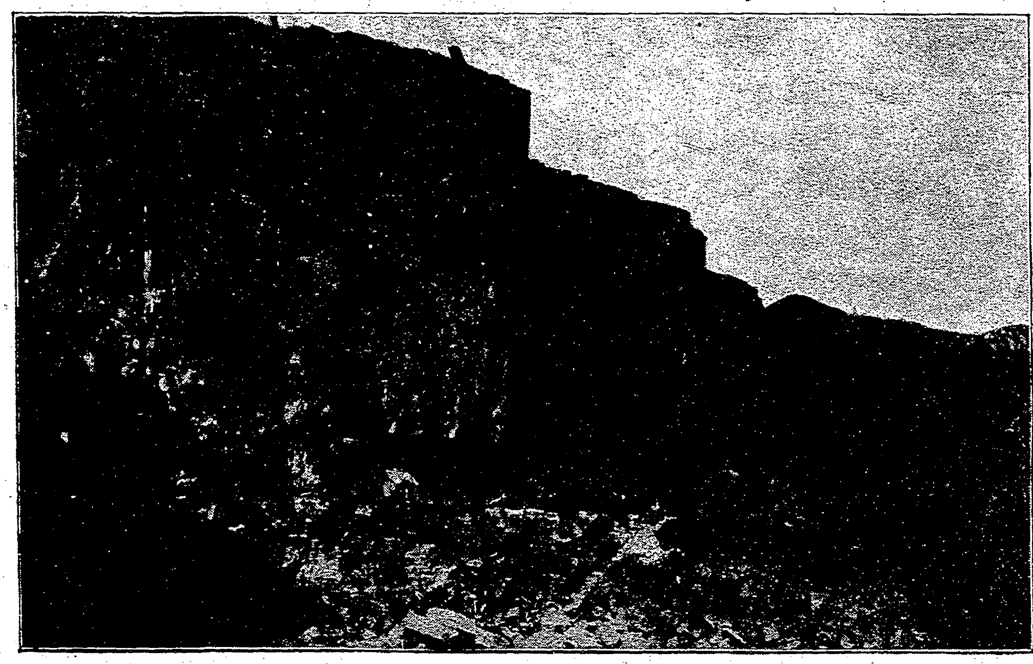


FIG. 8. View in Rummels' Quarry, near Olin.

Stone City, but are irregularly indurated, apparently as a result of wave action at the time the beds were forming. The strata dip southeast at an angle of 5°.

In quarrying, only the simplest tools are used. Drills, crowbars, wedges, picks, shovels and wheelbarrows make up the equipment, From two to four men are employed, and the annual output amounts to about 1,200 perch. Some stone is hauled to Olin and shipped abroad, but the market is largely local. Very little stripping is necessary. The soil or clay overlying the stone is only a few inches in thickness. For two or three feet below the soil the beds are broken into chips or spalls by weathering. With better means for quarrying, the greater part of the exposure would furnish marketable stone. The present method of quarrying, however, involves the use of large quantities of powder in a single blast. Drill holes are made six inches in diameter and twelve feet deep. These are filled, or nearly filled, with powder, and the firing of such a blast loosens up great masses which are further separated and removed with pick, crowbar and sledges. The firing of these great blasts shatters the stone badly, rendering much of it worthless, and leaving even the best of it in condition suited for use in only the cheaper grades of masonry. Were the demand such as to justify the expense of putting in improved machinery, stone of high grade for many purposes might easily be obtained.

A. J. DOLBY QUARRY.

East of the Rummel quarry, in Hale township (Tp. 83 N., R. II W., Sec. 19, Nw. qr., Sw. ¼), there is a quarry on land belonging to Mr. A. J. Dolby. The beds at present worked in the Dolby quarry lie above those of the Rummel quarry and correspond to the upper half, "white stone," of the Anamosa stage at Stone City. The bedding planes are more obvious than in the Rummel quarry, and chert nodules characteristic of this upper horizon are very common along certain planes. The rock here comes almost to the surface, there being only an inch or two of soil. The usual effects of weathering are seen for a few feet below the upper limit of the strata. A derrick operated by hand power is used for hoisting, but there is no other machinery beyond the hand drills and other inexpensive tools used in ordinary quarrying. It is likely that, by working down to a lower level, a better quality of stone than now taken out would be obtained.

SHOPE QUARRIES.

There are two small quarries on the land of Mr. E. Shope, in the forty acres east of the Dolby quarry. One of these is continuous with the Dolby quarry, the two quarries together having a combined front of 300 feet in length. The characteristics of the stone are the same as already described in connection with the quarries of this region.

CARTER QUARRY.

About a fourth of a mile north of the Dolby quarry, and in the same section, Mr. William Carter has taken out stone from beds of the Anamosa stage. This quarry has not been worked except on a small scale. With facilities for shipping, this, as well as all the other quarries of the region, is capable of furnishing unlimited amounts of high grade stone.

HALE QUARRY.

Near the center of section 11, Hale township, three-fourths of a mile east of the village of Hale, a quarry has been worked for some years in beds of the Anamosa stage. The north end of this quarry is owned by Murray Brothers, while the south end is on land belonging to Mr. E. Horton. The stone in the Hale quarry is finer than that in the quarries near Olin, but it resembles the Olin stone in the uneven, wave-marked surface of the several beds. The stone comes practically to the surface, there being only a few inches of soil overlying the upper beds. For about six feet at the top of the quarry the stone is much broken and disintegrated, as a result of weathering. Below the weathered portion the rock is solid and shows the characteristic lamination of this horizon. Partings between the beds are inconspicuous. The flexures of the beds and the dip in all directions (quaquaversal dip) forming a low dome near the north end of this quarry, have already been noticed. The quarry supplies local trade only.

JOHN CLAY QUARRY.

The John Clay quarry is located on the south side of the river, near Hale, a short distance east of the center of section 15. It has been worked on only a small scale to supply a limited demand. The quality of the stone is good, and were there better facilities for shipping, quarrying might be carried on here on a scale that would be limited only by the conditions of the market. The quantity of excellent stone is unlimited.

BALLOU QUARRY.

The Ballou quarry lies east of Clay's, in section 14. The quality of stone is the same as is found generally in the Anamosa stage of this region. While there is an unlimited supply, the demand that can be met by the present conditions of transportation is small. This, like other quarries of the region, is operated intermittently.

OTHER QUARRIES IN THE ANAMOSA LIMESTONE.

East of Ballou quarry is a small opening that has furnished a considerable amount of stone. In sections 26 and 32 of Jackson township there are small quarries to which reference has been made in the description of the typical exposures, and the opening in section 10 of Oxford township has also already been noted.

LIME.

Lime is not made on a commercial scale anywhere in Jones county, although beds suitable for its manufacture occur abundantly in the Delaware and Le Claire stages. Lime was formerly made at points near Anamosa, Stone City, Olin, Clay Mills and Hale. There are Le Claire beds near the quarries on the Buffalo, and there are others near Anamosa and Stone City capable of furnishing material for manufacture into lime of the highest excellence. At the points named the facilities for shipping are good. There are many other equally good exposures of lime burning stone, but they are less favorably situated with reference to easy access to markets.

CLAYS.

The clays of Jones county which are available for use in the manufacture of economic products are loess and alluvium. Both occur in unlimited quantities. The clay products are at present limited to common structural brick and drain tile. Nearly all the brick made in the county are manufactured from loess; for making drain tile the fine alluvial clays are used exclusively.

OLIN TILE & BRICK COMPANY.

The most important clay-working establishment in the county is that of the Olin Tile & Brick Co., located at Olin, in Rome township. The clay used is obtained from beds of alluvium in the low plain a short distance south of the works. It is blue in color, tough, tenacious, and gives best results when mixed with about one-fifth its bulk of sand. During 1894 the factory turned out about 40,000 brick and 400,000 drain tile. The plant consists of the necessary building to accommodate the machinery and workmen in producing and handling the output, steam-heated drying sheds, and three down draft kilns in which the product is burned. An H. Brewer & Co. No. 6 A machine is used in making both brick and tile. The sizes of drain tile range from three to ten inches inclusive. The markets are largely local, but shipments are made by rail, both east and west, for a distance of forty or fifty miles.

MONTICELLO TILE & PRESS BRICK COMPANY.

The Monticello Tile & Brick factory is owned by Mr. John Gibson. It has been operated for fourteen years. The product consists of drain tile and end-cut, steam re-pressed brick. The present annual output amounts to 300,000 brick and 250,000 tile. Formerly 800,000 brick were made annually. Seven sizes of tile are made, the smallest being 2½ and the largest 8 inches in diameter. The machinery used includes a thirty horse power steam plant, a Brewer & Tiffany tile machine with a capacity of 10,000 daily, and a Mackenzie brick machine of nearly equal capacity. The brick are dried in the open air and the tile in a steam heated drying shed. The drying shed has a capacity of 50,000 tile. It is two stories in height, a Jeffery elevator being used to lift the tile dried in the second story. Mr. Gibson has a very ingenious and convenient system of tracks and switches on which to handle the cars that carry the product from the machine to the drying shed. The clay used in making brick is a stratified loess. or loess-like alluvium. The bed is ten or twelve feet in thickness. Its location is about twenty feet above the level of the Maquoketa river, at the edge of an old flood plain where the alluvium blends with the true loess. The clay is dug within a few yards of the machine that moulds it into brick.

The tile clay is a true alluvium, blue in color, and has to be hauled from the low plain bordering Kitty creek three-fourths of a mile away.

The clay for both brick and tile needs only to be tempered with water. Both burn to a deep red color. The tile are burned in a circular down draft kiln which has a capacity of 17,000 tile of the smallest diameter. A case kiln is used in burning the brick. The market is chiefly local, though shipments are made by rail to points within a radius of twenty-five to thirty miles.

ANAMOSA BRICK YARD.

Mr. B. F. Smith operates a brick yard at Anamosa. The product at present consists wholly of common, handmade brick. The common, yellow, loess clay is used, tempered with water in the ordinary pug mill. About 600,000 brick is the annual product, and these are all consumed in supplying the local demand.

OTHER CLAY-WORKING PLANTS.

Brick and tile works have been operated intermittently or only for a season or two at other points in the county. The raw material, especially for brick making, is so abundant and so generally distributed that there are few points where some clay product might not be made. A second factory for the manufacture of brick and tile was operated sometime ago at Monticello, but in recent years the works have been idle, and brick were formerly made at a yard, now unused, in Wyoming.

BUILDING SAND.

Bountiful supplies of building sand are found in the sand bars along the streams and in the beds of yellow sand and gravel that were deposited in connection with the yellow clays during the time of ice melting at the close of the Iowan period.

MOULDING SAND.

The sub-loessial sands at Stone City are finer and more argillaceous than usual, and underneath the yellow clay there are from four to six feet of material that has been tested and found to serve excellently as moulding sand.

ROAD MATERIALS.

Outcrops of Niagara limestone are so numerous that few localities are far removed from unlimited supplies of material that may be converted into road metal or macadam. The yellow sands and gravels already mentioned furnish the best of material for the improvement of clay roads, and all sandy stretches of road need only a thin layer of the widely distributed loess clay to render them passable at all seasons of the year.

LEAD.

More or less energy and capital have been expended in Jones county in prospecting for lead ore. The Niagara limestone, which is spread over the entire county, is dolomitic, and the Iowa dolomites are all lead-bearing to a certain extent. The Niagara limestone, therefore, contains some galena or lead sulphide, but there is no evidence to justify the hope that lead ore, in paying quantities, will ever be found in this formation. The ore bodies are all small, aggregating a few hundred pounds at most, and while interesting from a scientific point of view, possess no economic value. Some years ago Mr. James Brown took out 6,000 pounds of ore from a crevice on section 13 of Fairview township, and in the spring of 1895 Mr. W. D. Sheehan obtained 5,000 pounds in section 19 of Jackson township. These bodies of ore are of very unusual size for this formation, and would probably not be duplicated by the most persistent search in many years to come.

WATER SUPPLY.

The streams of the county furnish a plentiful supply of water in the regions through which they flow. The surface wells that furnished water so abundantly some years ago have very generally failed, and farmers and others have found it necessary to sink wells to water-bearing strata at considerable depth from the surface. The well at Mr. Gibson's tile and brick factory is only 46 feet deep, but the supply seems to be unlimited. The well is bored about 26 feet in Niagara limestone. Near the center of Greenfield township it is found necessary to bore 12 to 15 feet into the rock and the wells are from 75 to 150 feet in depth. Near Center Junction water is found in beds of sand and gravel interbedded with blue clay of the Kansan till, at a depth of from 80 to 100 feet. The deep well at Monticello penetrated to the Saint Croix sandstone at a depth of 1,198 feet.

The permanent water-bearing horizons of which the wells of the county furnish evidence are (1) the Saint Croix sandstone, which may be reached anywhere in the county at a depth of from 1,200 to 1,500 feet, (2) the plane of contact between deep beds of till and the underlying indurated rocks, (3) beds of sand and gravel at some depth from the surface in the blue clay of the Kansan drift. The deep well at Monticello gets its supply from the first named source, the wells near the center of Greenfield as well as many others throughout the county draw from the second, and in the region of very deep drift near Center Junction there are examples of wells deriving their supply from the third source.

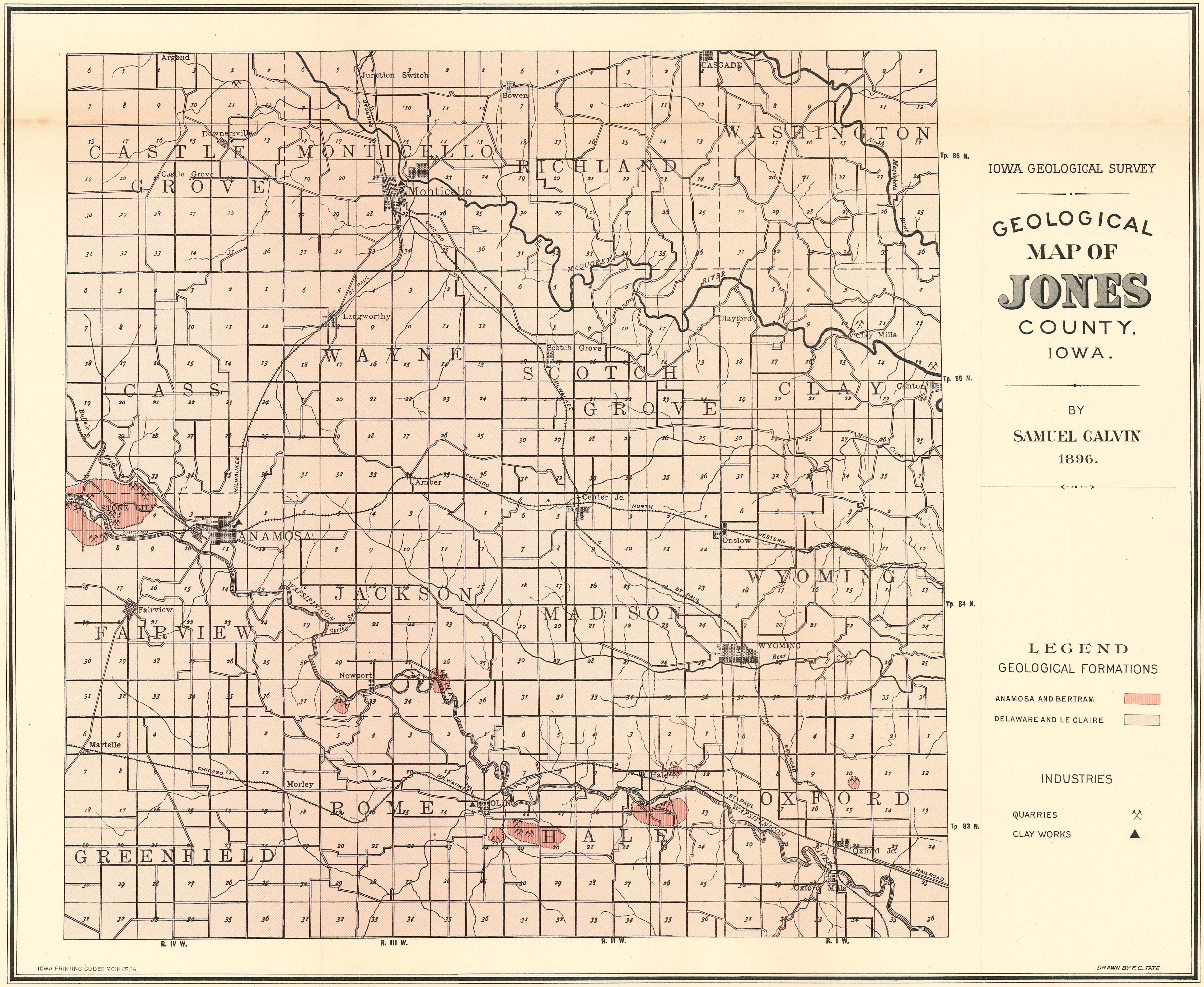
WATER POWERS.

The streams of Jones county furnish abundant water power, but these sources of energy have not yet been utilized as they doubtless will be in the future. The saw mills and grist mills that were important factors during the period of settlement have largely fallen into disuse. On the Wapsipinicon river there are mills at Anamosa, Newport and Oxford Mills. On the Maquoketa the chief water powers are at Monticello and in section 3 of Scotch Grove township. Walnut creek once furnished power to a mill at Olin. At Clay Mills there was a water power on Farmers creek, and the same stream supplied the power for a small saw mill northeast of Temple Hill, in section 28 of Washington township. These smaller streams, however, have recently been dry during the greater part of the year and the mills operated at all have had to resort to steam power.

The water powers at Anamosa and Monticello are now used chiefly in producing electric energy, and it is in this direction that in the future the permanent water powers will all find profitable employment.

ACKNOWLEDGMENTS.

In collecting the data for this report important and valuable assistance has been received from a great number of individuals. The writer would especially acknowledge the helpful service of John Gibson of Monticello, A. E. Myrick of Anamosa and Hon. J. A. Green and Frank Dearborn of Stone City. In addition to much generous assistance in the field work, Mr. Green carefully compiled and furnished the historical facts and statistics of shipments relating to the quarry industries of the Stone City basin.


IOWA GEOLOGICAL SURVEY
GEOLOGICAL MAP OF JONES COUNTY, IOWA.
BY SAMUEL CALVIN 1896.
LEGEND
GEOLOGICAL FORMATIONS
ANAMOSA AND BERTRAM
DELAWARE AND LE CLAIRE
INDUSTRIES
QUARRIES
CLAY WORKS
Tp. 86 N.
Tp. 85 N.
Tp. 84 N.
Tp 83 N.
R. IV W.
R. III W.
R. II W.
R. I W.
CASTLE GROVE
MONTICELLO
RICHLAND
WASHINGTON
CASS
WAYNE
SCOTCH GROVE
CLAY
FAIRVIEW
JACKSON
MADISON
WYOMING
GREENFIELD
ROME
HALE
OXFORD
Argand
Junction Switch
Bowen
Cascade
Downersville
Castle Grove
Monticello
Langworthy
Clayford
Clay Mills
Scotch Grove
Canton
Amber
Center Jc.
Stone City
Anamosa
Onslow
Fairview
Wyoming
Newport
Martelle
Morley
Olin
Hale
Oxford Jc.
Oxford Mills
Maquoketa River
Wapsipinicon River
IOWA PRINTING CO DES MOINES, IA.
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GEOLOGY OF WASHINGTON COUNTY.

BY

H. FOSTER BAIN.

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INTRODUCTION.

LOCATION AND AREA.

Washington county lies well towards the southeastern corner of the state, being twenty-five miles west of the Mississippi river and fifty miles north of Missouri. The Iowa river forms a portion of its northeastern boundary, but with that exception the county has no natural limiting lines. Iowa and Johnson counties lie north of it, and the latter, with Louisa county bounds it on the east. On the south it is bounded by Henry and Jefferson counties, while Keokuk county lies immediately west.

The area of the county is 570 square miles, being disposed in the form of an approximate square having sides twenty-four miles long. Within this area there is a considerable variety both in topographical and geological detail.

PREVIOUS GEOLOGICAL WORK.

One of Owen's field parties under Mr. C. B. Macey in 1849 ascended the Iowa river, but no special observations seem to have been made in the county. Worthen* in 1856 made a geological survey of the county which was necessarily of a preliminary nature only. White† referred to the presence of coal measures in the county, but did not review Worthen's work. Calvin‡ has published an account of the deep well bored at Washington, and J. Gass and W. H. Pratt§ in 1882 called attention to the discovery of a mammoth skeleton within the area.

Since the survey carried on by Hall and Worthen a number of new outcrops have been discovered and considerable change has been made in the classification of the rocks exposed within the limits of the county. It was thought that the relations between the Devonian and the Carboniferous could be well studied within this county, and the hope of

*Geology of Iowa, vol. I, pp. 239-248. Albany, 1858.
†Geology of Iowa, vol. II, p. 273. Des Moines, 1870.
‡American Geologist, vol. I, pp. 28-31 Minneapolis, 1888.
§Proc. Davenport Acad. Nat. Sci., vol. III, pp. 177-178. Davenport, 1882.

obtaining information upon this point was one of the principal reasons for taking up its study at this time.

PHYSIOGRAPHY.

TOPOGRAPHY.

The topography of Washington county is in the main of the type known as the "loess drift." It is characterized by long, low swells with broad-bottomed, shallow, grass-covered swales between. Near the large streams the country becomes decidedly rougher. The slopes are covered with loess, which merges more or less into the alluvium. Along English river, Crooked creek and a few other streams, sharp rocky bluffs are sometimes found. The bottom lands are usually broad. Both along the major streams and the smaller tributaries the present cutting is confined usually to sharp, narrow channels running through the alluvium. Cutting in the hills along the rivers is, on the whole, exceptional. The slopes are usually gentle and are grassed over.

Away from the streams the normal drift plain topography is common. Northeast of Washington, around Keota, and near Wyman, this type of land form is excellently developed. The flat, almost even surface, the straight highways, the black roads and the occasional, but on the whole very rare boulders, are all characteristic. The streams, if it be proper to call them such, which cross such areas show very little if any cutting. Where Long creek runs over the drift plain northeast of Washington, it can scarcely be recognized as a distinct landscape feature. Only a low, gentle swale, marked by bunches of marsh grass and occasional sloughs, indicates the beginning of the stream. Where the country roads cross its course the bridges stand up above the surrounding surface and are reached by long, low dirt embankments.

These drift plains form flat-topped divides of considerable breadth between the rivers. Occasionally the minor streams have pushed back so far into the inter-stream areas that little semblance of a plain remains. The general elevation of the upland is about 800 feet in the north and west, and varies from that to about 750 feet in the south and east.

The broad flood plain of the Iowa and Mississippi rivers which forms so marked a physical feature of Louisa county to the east, does not extend far into this county. Indeed the Iowa river here flows against its west bank, which is a series of abrupt drift bluffs 100 to 120 feet high.

The elevations of the principal towns as well as a number of other points are shown in the following table.

STATION.	Altitude.	AUTHORITY.
Ainsworth	704	C., R. I. & P. Ry.
Brighton	752	C., R. I & P. Ry.
Brighton quarries	700	Survey.
Cedar creek, near Verdi	713	C., R. I. & P. Ry.
Crooked creek, west of Washington	684	C., R. I. & P. Ry.
Crooked creek, south of Washington	673	C., R. I. & P. Ry.
Dayton	823	Survey.
East county line	658	B. & N. Ry.
East county line	749	C., R I. & P. Ry.
East county line	668	B., C. R. & N. Ry.
English river, Kalona bridge	650	Survey.
Havre	733	B. & N. Ry.
High land between Verdi and Skunk river	738	C., R. I. & P. Ry.
Iowa Junction	649	B., C. R. & N. Ry.
Iowa River station	638	B., C. R. & N. Ry.
Iowa River bridge	633	B, C. R. & N. Ry.
Kalona	665	B., C. R. & N. Ry.
Keota	803	C., R. I. & P. Ry.
Nira	770	B., C. R. & N. Ry.
North county line	645	B., C. R. & N. Ry.
Northeast corner of county, on high lands north of English river	710	U. S. G. S.
Northwest corner of county, on high lands north of English river	810	U. S. G. S.
Riverside	648	B., C. R. & N. Ry.
Skunk river, north of Brighton	613	Survey.
Stream southeast of Crawfordsville	668	B. & N. Ry.
South county line	703	C., R. I. & P. Ry.
Verdi	673	C., R. I. & P. Ry.
Washington	769	C., R. I. & P. Ry.
Wassonville mill	706	Survey.
Wellman	730	B., C. R. & N. Ry.
West Chester	784	C., R. I. & P. Ry.
West county line	772	B., C. R. & N. Ry.

In the above table the elevations credited to the United States Geological Survey are taken from the topographic atlas sheets of that organization. Those credited to the different railways are from the engineer's profiles. The elevations credited to the survey itself are corrected barometric observations connected with the nearest known point. While not wholly free from error, they may be relied upon as approximately correct.

A comparison of these elevations gives some interesting results. Dayton, it is seen, lies on the high ridge between English river and Smith creek, and is 117 feet above the former stream and 93 feet above the latter. Wellman is in the valley of Smith creek. Kalona, Riverside, and Iowa Junction are built on the flood plain of English river. Keota, while scarcely more than a mile distant from Crooked creek, is yet built upon the high land, while West Chester, at the same or slightly greater distance from the creek, lies on land which has been degraded a few feet. Washington is built upon a tract of land lying thirty-five feet below the general upland level and eighty-five feet above Crooked creek. Ainsworth is in the valley of Long branch. Havre and Crawfordsville are on the ridge forming the watershed between the Iowa and Skunk river systems. Verdi, Brighton, and Coppack are all within the influence of the Skunk river erosion, while Noble and Wayland Crossing are built in the valley of Williams creek.

DRAINAGE.

The drainage of the county belongs to two systems, the Iowa and the Skunk. The former drains the northern and northeastern portion of the county, while the southwestern half, approximately, is drained by the Skunk river tributaries.

The Iowa river itself does not flow within the county, but forms a portion of the northeastern boundary. Its immediate drainage basin is, in this county, very inconsiderable; the main portion of the water which reaches it coming rather from a series of long, non-branching tributaries which flow almost at right angles to its own course. Of these latter, English river, Davis and Goose creeks are typical, while Long creek belongs to a slightly different category.

English river is formed near the northwest corner of the county by the junction of North and South English. It flows almost directly across the county, with but slight deviation from its general easterly course. It is remarkable for its considerable length in proportion to the width of its drainage basin and for the small number of its tributaries. Of

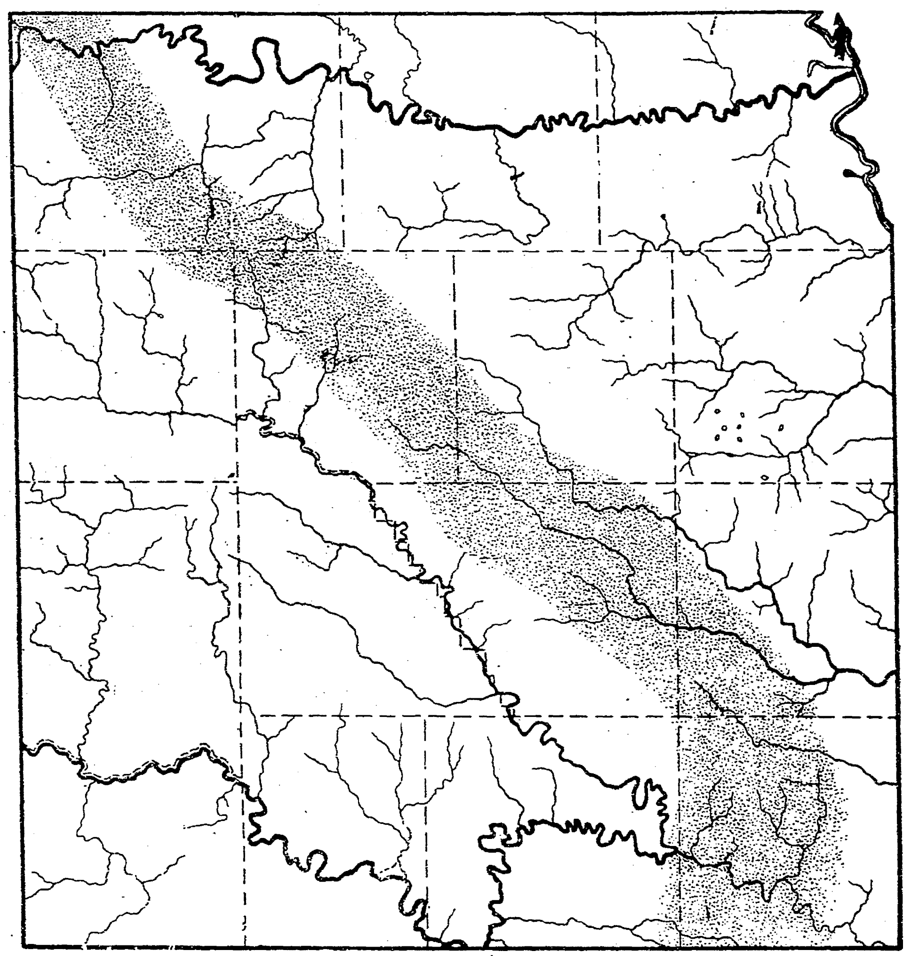


FIG. 9. Drainage of Washington County.

these latter, Smith creek, joining it a few miles below Wellman, is the most important. It is a representation in miniature of the larger stream. English river, at the point where the north and south branches unite, is about 700 feet above sea level. Its mouth is nearly 80 feet below this point, so that within the county it has an average fall of about 3.3 feet to the mile. As has been noticed by McGee, the steeper slopes and higher bluffs are on the south bank of this stream. With but one important exception the rock outcrops are confined to the southern slope.

Davis creek, which in its upper portion is called Continue creek, rises in Jackson township, flows northeast, then east to Iowa river. It is a narrow stream, with few tributaries, and has at only one or two points succeeded in cutting through the drift.

Goose creek rises in Highland township and flows southeast to the county line, within a mile of which it is joined by Whisky run. These streams have cut from seventy to ninety feet below the upland level, but only expose the indurated rocks at wide intervals. In general character they resemble English river markedly.

Long creek with its two branches, north and south, flows southeast, reaching the Iowa river near Bard in Louisa county. It belongs, rather, to the class having many widely branching affluents.

The Skunk river system includes within the county, the Skunk river itself, with its immediate tributaries, and the subordinate system formed by Crooked creek and its branches. The Skunk enters the county about six miles north of the southwest corner, and flows east of south to Coppack, where it makes an abrupt turn due south and leaves the county. It is a stream of considerable size and has an average fall of about two feet eight inches per mile. It has a wide valley, with broad bottom lands, and has cut its channel nearly 200 feet below the general plateau level, the last seventy feet or more being channelled through the limestones below the drift.

This stream, a short distance after it enters the county, receives Richland creek from the south. A mile or more below, a second small stream, also from the south, flows into the larger river. The principal stream flowing into Skunk river from the north is Dutch creek, which has a course almost directly south for some six miles.

Crooked creek enters the county near Keota, and flows southeast to about two miles north of Noble; here it turns directly west, but after flowing five miles in this direction it turns due south and joins Skunk river near Coppack. In its upper portion the south bank is the better defined, most of the tributaries flowing in from the north. In its lower portion the reverse is true. Near Washington, Clemons and Cedar creeks flow in from the west. At the point where Crooked creek makes its abrupt change, north of Noble, it receives the East Fork of Crooked creek. This is a small stream flowing in a rather large valley, which is a direct continuation of the main valley of Crooked creek. At one time Crooked creek probably flowed on up the valley now occupied by its east fork and over the low divide north of Marsh into Otter creek, through which it had a direct course to the Iowa. At the bend north of Noble it then received a tributary from the west. Near Coppack the Skunk received a similar tributary from the north, which does not seem to have been a large stream at that time, but had the advantage of a more rapid descent and worked its way back till it captured the stream flowing into Crooked creek. Since the Skunk river is nearly sixty feet lower than Crooked creek where they are parallel, the new channel thus opened up afforded a short cut, and what is now the west fork of Crooked creek began to flow up its tributary and across the divide, marked now by a cut in the limestone, into the small branch of Skunk river. The increase of volume caused the stream to cut down rapidly into the underlying limestones, and so we have here a stretch of valley which is not relatively wide, but which is cut well down into the indurated rocks. In the adjustment, a part of the lower portion of Crooked creek was reversed and became what is now the East Fork. This change in the course of Crooked creek was probably due in part to the incursion of the ice from Illinois, though there is good grounds for the belief that it would ultimately have occurred in any event. This incursion is represented in Iowa by a moraine, traced by Mr.

Frank Leverett, which crosses the former course of Crooked creek, and forms the present divide between the East Fork of that stream and Otter creek near Morning Sun. This later cutting gives then, a measure of the stream erosion occurring after the incursion of the Illinois lobe.

These adjustments were the more easily accomplished as the region near the great bend is drift covered and easily cut through. The stream is now wearing on its west bank which is here composed entirely of drift, and sooner or later it will find a channel across the narrow neck of unconsolidated deposits.

Williams creek is a small stream flowing into Crooked creek from the east. It has a narrow valley and in the lower part has cut some twenty feet into the limestone.

ORIGIN OF THE DRAINAGE SYSTEM.

The drainage system of the county seems to have had its origin in or immediately succeeding glacial times. The explanatian given by McGee* for English river, that it flows along the southern edge of a gently sloping plain, seems in a general way to be also applicable to the upper portion of Crooked creek. These streams would then have had their origin subsequent to the deposition of the drift.

Skunk river is a large stream and seems to have had a longer history. In general direction, and in the presence of the abrupt turn at Coppack, it simulates the Iowa, Cedar and other rivers farther north. It seems probable that its history may have been much the same as that of those rivers. Though drainage lines evidently existed in this region previous to the ice invasion, the evidence at hand does not show any very close connection between the two. Indeed, some of the present streams cross almost at right angles the older valleys. There is, at some points on Williams creek and Skunk river especially, some evidence of the present valleys being in part drift-filled, but by far the greater portion of

*Eleventh Ann. Rep. U. S. Geol. Sur., pt. 1, pp 412-413. Washington, 1892.

stream erosion must clearly have taken place between the deposition of the drift and the loess. In crossing the country exposure after exposure may be seen where the sides and bottoms of the small valleys are covered by a thin veneer of loess. The latter is not usually thick on the upland. Indeed, it can scarcely be said to occur over the drift plains. East of Bethel church, in Highland township (Tp. 76 N., R. VI W., Sec. 30), the wagon road crosses a number of small ravines which have the relations indicated by figure 10. The drift may be seen in the cutting at the side of the road in both

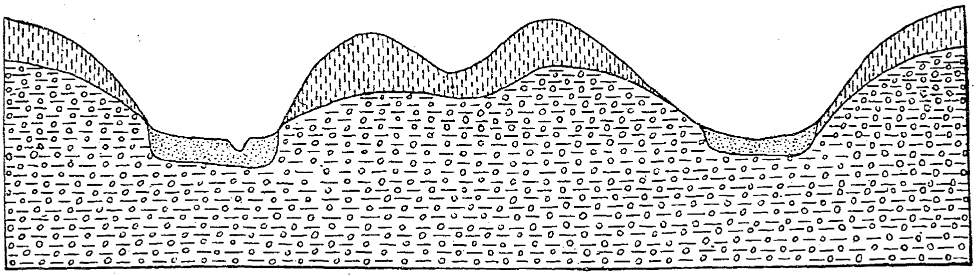


FIG. 10. Relations of present to preglacial drainage.

of the outside ravines. The loess follows right down the slope, veneering the drift. In the middle ravine the road cuttings have not been deep enough to expose the drift. Similar relations between the drift and the loess may be seen north of Riverside and at very many other points. One can not escape the conviction that the streams made their present valleys, even in the case of the minor tributaries, before the loess was deposited, and that the amount of erosion since that time has been comparatively insignificant. If the correlation of the loess with the later or Iowan ice be correct, it would follow that the stream erosion took place in interglacial or Aftonian time, and the relative amount of stream action before and after the loess would be a strong argument for the great length of interglacial time as compared with postglacial.

While the divides of the county are, as has been said, flat-topped, and there are regions of immature drainage, the general impression which one gains from a study of the streams of the county is one of relatively great age. As contrasted with the areas farther north, now covered by the drift of the Iowan and Wisconsin ice sheets, the amount of erosion is great. As has been said, there is but little evidence that this erosion was accomplished in preglacial time. It has been largely, if not wholly, effected since the drift of this region was laid down—in post-Kansan time. Apparently but little of the erosion has taken place in post-Iowan.

STRATIGRAPHY.

General Relations of Strata.

The geological formations comprised within the county belong entirely to the Carboniferous and the Pleistocene. The classification of the strata is shown in the following table.

Classification of Formations.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.		Alluvial.
		Glacial.	Iowan.	Loess.
			Kansan.	Drift.
Paleozoic	Carboniferous.	Upper Carboniferous.	Des Moines.	
		Mississippian.	Saint Louis.	Pella beds. Verdi beds. Springvale beds.
			Augusta.	(Keokuk?) Burlington.
			Kinderhook.	Wassonville limestone. Maple mill shale. English river grit-stone.

STANDARD SECTIONS.

The following sections may be taken as representative of the different geological formations of Washington county. Together they form a general section of the indurated beds.

MAPLE MILL SECTION.

(Tp. 77 N., R. VIII W., Sec. 4, Se. qr., Nw. ¼.)

	FEET.	INCHES.
4. Limestone, ferruginous, arenaceous in places, fine-grained, red, containing numerous casts of fossils and with thin chert layers 2 to 8 inches thick, also fossiliferous	10	
3. Sandstone, or gritstone, very fine-grained, white to buff, very fossiliferous	18	
2. Limestone, fine-grained, non-fossiliferous		2
1. Shale, argillaceous, dark blue to drab, becoming almost black in places	12	

The whole of this section may be referred to the Kinderhook. Numbers 1 and 2 represent the Maple Mill shales, number 3 the English river gritstone, and number 4 the Wassonville limestone. The upper member (No. 4) may be readily traced up the river to the Wassonville mill where it is somewhat thicker. At this latter place the Augusta limestone is seen to lie above it, but is better seen in the following section on Crooked creek.

ECKELS QUARRY SECTION.

(Tp. 75 N., R. VIII W., Sec. 2, Sw. qr.)

	FEET.
3. Loess	12
2. Local drift	6
1. Limestone, coarsely sub-crystalline, blue, gray and white in color, running in ledges from 3 to 20 inches	20

The stone here belongs to the Augusta, or more specifically to the Burlington layers of that formation. The top of the formation is not seen at this point, nor indeed is the contact between it and the next upper member, the Saint Louis, found at any point in this county, though it may be examined at a number of exposures in Keokuk county immediately west, The Saint Louis is excellently shown near Brighton, all the members being present. The whole formation, however, and each of its subdivisions, is much thinner than usual, the greatest diminution being in the middle member or Verdi beds. A complete section along the small ravine running north from Brighton to the river is as follows.

BRIGHTON SECTION.

(Tp. 74 N., R. VIII W., Sec. 29.)

		Feet.	Inches.
17.	Clay, purple to brown; full of Saint Louis fossils, and with irregular pieces of Saint Louis limestone but no erratics; 8 inches to 3 feet	2	
16.	Limestone, gray		8
15.	Limestone, fine-grained, compact, ash-gray in color	1	8
14.	Limestone, as above	1	6
13.	Limestone, gray	3	
12.	Limestone as above	3	
11.	Sandstone, with irregular shaly limestone, the two replacing each other in whole or in part at intervals	8	
10.	Limestone, fine-grained, ash-gray, compact	1	6
9.	Limestone, as above	2	6
8.	Limestone, as above, water worn and cavernous, the face covered in part by stalactitic matter	7	
7.	Limestone, as above, water worn	7	
6.	Clay, blue to drab	3	
5.	Unexposed talus, of brecciated limestone and sandstone	20	
4.	Limestone, soft, brown, earthy	2	
3.	Unexposed	6	
2.	Clay, blue to green, soft	4	
1.	Limestone, above, thin-bedded, ash-colored, sandy, non-fossiliferous; below, in bed of river, hard, black, with obscure fossils	8	

This whole section may be referred to the Saint Louis, with the possible exception, as will be noted farther on, of the lower member which may represent the upper Keokuk or

Warsaw layers. Numbers 17 to 13 inclusive may be seen in the Martin quarry; numbers 13 to 7 inclusive are shown in the Chicago, Rock Island & Pacific quarry now abandoned; number 6 is not exposed, but was at one time encountered in working the latter quarry; numbers 5 to 1 inclusive are shown in the bluff on the Skunk river at the Brighton mill.

The lower four members belong to the series recognized in neighboring counties as the Springvale beds, but are not typical. The upper six members represent the Pella beds, while the intervening layers are referred to the Verdi. The latter series of beds is typically developed about two and a half miles north of here and has probably a much greater total thickness. The two heavy limestone ledges, numbers 7 and 8, do not appear to extend much north of the railroad quarry. In their place, as seen at the mill, is the talus, which thus probably, in part at least, represents them instead of being wholly beneath as given above.

As has been stated, there are within the country a few small coal measure outliers. None of these now exhibit complete sections. At the time of Worthen's visit coal was being taken from the outlier west of Verdi. The following section is given by him.*

LIEBS MINE SECTION.

(Tp. 74 N., R. VIII W., Sec. 5, Ne. qr., Ne. ¼.)

		FEET.	INCHES.
5.	Clay, shaly	3	
4.	Coal	3	6
3.	Coal, slaty	2	3
2.	Sandstone, quartzose, ferruginous, partly exposed	?	
1.	Limestone, concretionary	10	

The upper four members belong to the Des Moines formation (coal measures) while the lower is the Saint Louis. The surface of the limestone is exposed some fourteen feet below the coal and the interval is probably filled by the sandstone.

*Geology of Iowa, Vol. I, p. 242. Albany, 1858.

DEEPER STRATA.

Our knowledge of the strata lying below the Kinderhook of this county is derived entirely from a deep well put down at Washington, the record of which has been interpreted by Calvin.

The strata passed through may be summarized as follows.

FORMATIONS.	THICKNESS.
Drift	350
Kinderhook, shales	82
Devonian limestone	68
Niagara limestone	170
Maquoketa shales	91
Galena limestone	160
Trenton limestone and shales	132
Saint Peter sandstone	100
Oneota, blue shales	?
Saint Croix sandstone	?

Geological Formations.

The areas covered by each of the different formations exposed within the county may be seen by reference to the accompanying map. It will be noticed that in general the older rocks are in the northeast; each later formation outcropping successively to the southwest. An exception to this rule is seen in the coal measures outliers which overlap the earlier beds. The considerable erosion which has taken place since their deposition is evidenced in the small size of the remnants of this formation.

The limits as indicated on the map are not considered absolutely correct at all points as the mantle of drift which conceals the beds makes considerable error possible.

MISSISSIPPIAN SERIES.

With the exception of the few areas covered by the Des Moines formation the indurated rocks of the county belong exclusively to the Mississippian or Lower Carboniferous series. They are of considerable interest, since within the county all three of the major divisions of that series found in Iowa, the

Kinderhook, the Augusta and the Saint Louis, are well exposed. The Mississippian rocks have heretofore been most extensively studied along the river from which the series takes its name, and the typical outcrops of the major as well as the minor divisions are found along its banks. There are few points in Iowa at least, where the whole series may be found at a distance from the main river. The rocks of Washington county form an independent section which might be called the Central Iowa section of the Mississippian. It is of considerable interest to find how closely this section may be correlated with that previously studied.

The Washington county section of the Mississippian series has been studied from an independent standpoint, and the results reached are not due to simply tracing into the area formations already recognized in the southeast. Rather, such correlation as has yet been attempted, has been made by working in the contrary direction and the general agreement arrived at is therefore the more interesting and valuable.

KINDERHOOK.

The beds of this formation which are exposed within this county, and which here form a stratigraphic unit, are well shown in the Maple Mill section previously given. The exposures are entirely confined to English river and its tributaries with the exception of one or two small outcrops on Goose creek and Whisky run.

The members of the section exposed at Maple Mill may be recognized at several points farther up the river. On the opposite side of the river at the head of the big bend (Tp. 77 N., R. VIII W., Sec. 6, Sw. qr.) the limestone forming the upper member (No. 4) of the Maple mill section has been quarried. The old opening shows the following.

		FEET.	INCHES.
10.	Limestone, earthy, arenaceous, red, fossiliferous	12	
9	Chert, in thin layers from 2 to 4 inches thick; very fossiliferous		4

		Feet.	Inches.
8.	Limestone, as above	10	
7.	Chert, as above		3
6.	Limestone, as above	1	6
4.	Limestone, as above	2	6
3.	Chert, as above		2
2.	Limestone, as above	4	
1.	Unexposed to water	4	

The above section is typical of this portion of the Kinderhook. The lower beds are not seen here, though they are imperfectly exposed on the opposite side of the river at the Wassonville mill (Tp. 77 N., R. IX W., Sec. 12, Se. qr.). Worthen's section of this point is as follows.*

		Feet.	Inches.
5.	Slope with outcropping masses of quartzose sandstone	6	
4.	Burlington limestone	3	4
3.	Massive, brown, arenaceous, limestone	2	
2.	Ash-colored gritstone	2	2
1.	Buff-colored gritstone	6	6

The lower portion of this section is now largely covered, but enough can be seen to prove the presence of the gritstone, which corresponds to number 3 of the Maple mill section. At the latter place the two beds (numbers 3 and 4) are not sharply separated, but seem to merge slightly along the line of contact. It is of interest to note that at Wassonville a blue argillaceous shale, similar to number 1 of the Maple Mill section, at one point occurs interbedded with the limestone. In general the massive brown limestone is similar to that in the section on the opposite side of the river already given. The presence and thickness of the chert layers is the same. The thickness of this bed as exposed at the mill is considerably less than Worthen's estimate; not more than twenty-four feet being exposed. The Burlington limestone is not seen at the mill but is exposed in some quarries farther back on the ridge. A careful search has failed to reveal the coal measure sandstone, though at one point a huge boulder,

*Op. cit., p. 245.

lithologically identical with the sandstone seen at Leib's mine and elsewhere, was found. Further up the river the Kinderhook appears from beneath the drift at two points, both on the north side of the river (Tp. 77 N., R. IX W., Sec. 1, Sw. qr., and Sec. 3, Ne. qr.). On the south side it may be traced nearly a mile.

Near Wellman, in the valley of Smith creek, and twenty-four feet higher than English river at Wassonville, the Augusta is exposed. At one point west of town (Tp. 77 N., R. IX W., Sec. 24, Nw. qr.) the Kinderhook was struck in a well, at a depth of eighty-five feet. Southeast of Wellman the creek soon cuts through the Augusta into the Kinderhook. In section 19 (Tp. 77 N., R. VIII W.) the latter was encountered in the base of a quarry on a level with the stream.

In the old Burlington, Cedar Rapids & Northern railway quarry (Tp. 77 N., R. VIII W., Sec. 16) the limestone layers as exposed are twenty feet thick, with the base twenty feet above the bridge on Smith creek. The stone is of the usual earthy magnesian character and runs in ledges two to four feet thick, separated by thin layers of chert. The Augusta is reported to occur immediately above the top of the quarry, though it is not now exposed.

On the river, south of Kalona (Tp. 77 N., R. VII W., Sec. 16), there is an interesting Kinderhook exposure. Near the river the lower shale member (Number 1 of the Maple mill section) is exposed with a thickness of twelve feet. In a small tributary stream a half mile back from the river the following is seen.

	FEET.	INCHES.
5. Limestone, earthy, soft, reddish-yellow	4	
4. Chert		4
3. Limestone, as above	1	4
2. Limestone, as above	1	8
1. Limestone, softer, shaly	4	

The beds seen here seem to lie immediately beneath the drift over a considerable portion of Highland township, out cropping at several points along the streams (sections 21, 33 and 34.) The heavy drift accumulations prevent exposures along Iowa river and the lower part of Davis creek.

An examination of the preceding sections shows that we have here three different beds, or series of beds, which are referred to the Kinderhook. They are from the top downward:

(1) Wassonville limestone:—An earthy magnesian limestone in places becoming arenaceous, itself fossiliferous, and with thin chert bands also containing fossils.

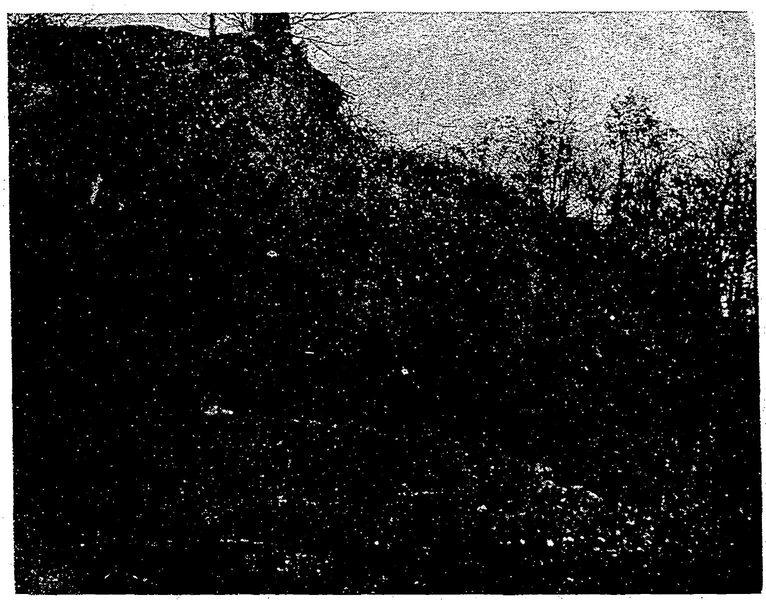


FIG. 11. Wassonville limestone on English river opposite Wassonville mill.

(2) English river gritstone:—A fine-grained sandstone, or gritstone to use Worthen's name, also well characterized by fossils. This bed, at all observed points, merges into the bed above lithologically, though it is quite distinct within a few feet of the contact. The gritstone is thickest toward the west and northwest and thins out, finally disappearing, towards the southeast.

(3) Maple mill shale:—A bed of argillaceous shale which is at one point sharply separated from the gritstones above, while at others it is interbedded with them. The shale itself is non-fossiliferous, and its base is not exposed. In the

Washington well a shale very closely resembling this was penetrated at a depth of 350 feet to 432 feet. At 458 feet a light-colored magnesian limestone was encountered containing the typical Devonian fossils *Atrypa renticularis* Lin., and *Athyris vittata* Hall*.

The Wassonville limestone and the English river gritstone are both fossiliferous. In the gritstone the fossils occur as molds and, while numerous, are badly preserved so that identification is difficult if not impossible. A collection made at the typical locality, the Maple mill northwest of Wellman, included the following forms as determined by Professor Calvin.

Allorisma, Sp.
Aviculopecten, Sp.
Bellerophon bilabiatus Wh. & Whf.
Chonetes fischeri N. & P.
Chonetes, Sp. nov.
Edmondia, Sp.
Othothetes inequalis Hall.
Orthis, Sp.
Orthoceras heterocinctus Winchell(?).
Productus burlingtonensis Hall.
Productus concentricus Hall.
Rhynchonella opposita Wh. & Whf.
Rynchonella pustulosa White.
Spirifera, Sp.
Straparollus, Sp.
Terebratula, Sp.

The Aviculopecten is the of type *A. fasciculatus* Keyes, but is a different species. The Orthis is closely related to *O. impressa* Hall. The Spirifer is doubtless the ancestral form of *S. grimesi* Hall. There are two species of Straparollus.

The Maple mill shale has, within the limits of this county, proven to be non-fossiliferous, and its age must be determined

*Calvin, Op. cit, p. 29.

by its relation to the other beds. It is significant that near Kalona it is found interbedded with the gritstone, the latter containing the same species of fossils that are found at the typical exposure of the English river gritstone, and that at Wassonville a thin bed of gritstone strata is at one point interbedded with the limestone.

The beds which, in southeastern Iowa, are now referred to the Kinderhook, were first studied by Owen. By him and his immediate successors they were recognized as of Carboniferous age. Later, in deference to the published opinion of Prof. James Hall, they were referred to the Devonian, and were correlated with the Chemung. It was in accordance with this idea that Worthen referred the Wassonville section to the Chemung*.

Later Meek and Worthen† proposed the name Kinderhook to include all the strata lying between the Burlington limestone and the black slate of the Devonian, and called attention to the Carboniferous affinities of the beds. Among the localities given by them as typical for the new formation was Burlington.

The rocks found at this point which are referred to the Kinderhook are described by Keyes‡ as follows.

		FEET.
6.	Rather soft, buff limestone, probably somewhat magnesian, apparently sandy locally	5
5	Gray oölite	4
4.	Soft, fine-grained, yellow sandstone; highly fossiliferous	6
3.	Gray, impure limestone, fragmentary, with often an oölitic band below	9 to 13
2.	Soft, fine-grained bluish or yellowish clayey sandstone passing into sandy shales in places	20 to 30
1.	Blue clay shale, fossiliferous, shown by borings to extend 50 to 100 feet or more below the water level; exposed	50

* Op. cit., 245.

Am. Jour. Sci., (2), Vol. XXXII, p. 228. 1861.

Bul. Geol. Sec. Am., Vol. III, p. 285. 1892.

The Kinderhook, as found at Burlington, has been traced along the foot of the Mississippi escarpment to the northern edge of Des Moines county. About two and a half miles north of Huron (Tp. 72 N., R. II W., Sec. 22, Se. qr., Nw. ¼), it is exposed as follows.*

		FEET.
2.	Sandstone, friable, argillaceous	20
1.	Shale, blue, reported from well	4

In Louisa county the Kinderhook may be traced along the bluffs, being exposed north of Morning Sun at several points on Otter creek. It is here a massive, arenaceous, soft, earthy limestone, of brownish-yellow color and is underlain by the usual blue shales. These exposures have not been directly traced to the Washington county outcrops, but the presence of Burlington limestone on Long creek, southwest of Columbus City, renders it probable that the brief intervening gap may be bridged. There can, however, be no doubt as to the equivalency of the two sections.

The upper members of the Maple mill section (numbers 3 and 4) may be considered as the equivalents of all the layers above the blue shale at Burlington (numbers 2–6) referred to the Kinderhook. Worthen considered the magnesian limestone at Wassonville (No. 4) as the equivalent of the oölitic layers. The English river gritstone occupies the same relative position as the yellow sand layer (number 2) at Burlington, and the fauna shows close affinities. Number 2 of the Maple mill section is of local occurrence only. The shale at both points is undoubtedly the same. Number 6 of the Burlington section has been correlated† with the Chouteau limestone of Missouri, and numbers 2 to 5 are considered to represent the buff sandy shale exposed immediately below the Chouteau at Louisiana, Missouri, and forming the upper portion of the Hannibal shales (Vermicular shales and sandstones of Swallow). The blue shale at the base of the Burlington section represents the green shale at the base of the Hannibal shales as seen at Louisiana, Missouri.

*Geology of Des Moines county, Iowa Geol. Surv., Vol. III, p. 425. Des Moines, 1895.
†Keyes: Bul. Geol. Soc. Am., Vol. III, pp. 285-286. Rochester, 1892.

The exact thickness of the lower bed (Maple mill shale) is unknown. There is in Washington county a maximum exposed thickness of about forty feet. At Burlington borings have shown it to have a thickness of at least 160 feet. In the deep well at Sigourney 229 feet of shale, which may be referred to this horizon, were penetrated. A comparison of the levels of the outcrops on English river with the base as revealed in the Washington well, allowing for a slight southerly dip, gives a thickness of at least 200 feet.

An interesting question arises as to the base of this lower member. The exact relations between the Carboniferous and Devonian have not been definitely determined in Iowa. Meek and Worthen in defining the Kinderhook included all the strata between the Burlington limestone and the black shale which has been found at many points in the Mississippi valley and which frequently contains Devonian forms. This shale does not occur in Iowa, unless the Lime creek shale described by Calvin be its representative. Instead we have at the base of the Kinderhook a heavy shale which in Missouri is underlain by a third member, the Louisiana or lithographic limestone. The Louisiana limestone is supposed to be of Kinderhook age, though evidence has recently been produced* suggesting that it may be Devonian. In the Washington well the shales recognized as Kinderhook were found resting directly upon limestone from which typical Devonian forms were obtained. The Devonian outcrops nearest to the Kinderhook shales of Washington county are found in the vicinity of Iowa City and Muscatine. The intervening territory is heavily drift covered so that the exact relations can not be observed. It is possibly significant that the country between the mouth of English river and the Muscatine outcrops is a low level bottom land and represents exactly the lateral enlargement in the Mississippi channel which would take place during a long period of erosion where the country rock was a soft shale. There is no topographic

*Keyes: American Geologist, vol. X. pp. 300-384. 1892.

indication of any hard beds intervening between the shale and the Cedar Valley limestones of the Devonian. While the different members of the Devonian have not yet been definitely differentiated for the whole state, making it difficult to say just what is its uppermost limit, the Lime creek shale constitutes the highest member known. Apparently then we have on the one hand at the top of the Devonian a series of shales containing Devonian forms, and on the other hand at the base of the Carboniferous an exactly similar shale interbedded at the top with gritstones containing Kinderhook forms.

In Washington county the Maple mill shales have not been found to contain fossils. The beds at Burlington which may be correlated with it do, however, contain certain forms. Collections made at the Granite Brick works at Burlington by Mr. E. H. Lonsdale have been recently investigated and shown to include forms with Devonian affinities.

The sandstones of Muscatine county, which were at one time correlated with the yellow sand layer at Burlington, have been shown by Calvin to be of Devonian age, and it seems not improbable that ultimately a considerable portion of the beds now recognized as Kinderhook may be proven to be pre-Carboniferous. Some of the evidence at hand supports the belief that the shale at the top of the Devonian and that at the base of the Carboniferous is the same. The difference in the fossils in that case would be due to geographic causes. According to this view, while the Lime creek beds, which contain a prolific Devonian fauna, were being laid down, corresponding sediments were being deposited 120 miles away to the southeast. The conditions of life at the latter point seem not to have been favorable, and most of the fauna which wandered so far from the shore perished. The few which survived became modified in important regards. Among them is *Orthis iowensis* Hall var. which shows a marked change in the muscular scars. In time new Carboniferous forms were introduced and in the succeeding deep sea deposits became supreme.

AUGUSTA.

In Washington county, as also in Keokuk county, the limestones composing the Augusta formation, and which elsewhere are known by individual names, are not separable. There are slight differences in lithology, more marked, however, between the exposures of Louisa and Washington counties

FIG. 12. Augusta limestone on Rock creek in Keokuk county.

than between any within the immediate limits of this county, and a few forms occur at some points which have not been found at others. The greater number of fossils found belong to the Burlington fauna, though a few Keokuk forms occur. The formation is however, as a whole, a distinct, well marked, stratigraphic unit for the region studied. It is neither advisable nor possible to divide it into formations which could be separately mapped. It underlies the county in a broad irregular band stretching from the northwest to the southeast as shown on the map. The area covered by the Augusta narrows somewhat towards the east. There is also an area toward the northwest where the Augusta has been cut out by preglacial erosion and the Kinderhook is shown by well records to underlie the drift. This is also true of Washington. These areas are, however, too imperfectly known to be represented on the map.

The best exposures of the Augusta are seen on Crooked creek northwest of Washington. The Eckles quarry section at this point has already been given. Sections from the quarries in this vicinity exhibit two facies: (1) a hard, heavily bedded, light gray to brown, sub-crystalline limestone, with abundant Burlington fossils, and (2) a buff, sandy rock containing small calcite geodes. The main portion of the rock belongs to the first type.

Farther up the creek an imperfect exposure may be seen north of West Chester (Tp. 76 N., R. VIII W., Sec. 20, Sw. qr.) where the presence of layers similar to those just described is shown. In the region around Keota the limestone immediately underlies the drift and is usually encountered at a depth of about sixty feet. In the northern portion of Keokuk county the Augusta appears at one point on English river (Tp. 77 N., R. IX W., Sec. 16). In Washington county the most northwesterly outcrop is at the Whitstine quarry near Dayton (Tp. 77 N., R. IX W., Sec. 13, Ne. qr., Ne ¼). This is a small local quarry located on the ridge between English river and Smith creek. The following layers are shown.

		FEET.
3.	Limestone, buff arenaceous	5
2.	Limestone, brown, coarsely crystalline, fossiliferous	½
1.	Limestone, blue-gray, fine-grained, sub-crystalline, fossiliferous	4

The fossils found at this point are Burlington forms, and in character the layers agree closely with those found at the Eckles quarry.

Directly southeast of Wellman on Smith creek (Tp. 77 N., R. IX W., Sec. 24), similar layers are exposed in the bed of the creek and have been quarried locally. The buff, arenaceous layer is here only one foot thick; the white or light drab layers beneath are seen at intervals down the stream to the old railway quarry (Tp. 77 N., R. IX W., Sec. 16), where, as already stated, they cap the Kinderhook with a thickness of about four inches. East from this point the Augusta has not been seen along English river. Exposures, however, occur four miles south of Riverside on Davis creek (Tp. 77 N., R. VI W., Sec. 31, Sw. qr., Se. ¼). The stone is seen at this point in Wingler's quarry; a small opening supplying the local stone trade. The rock is a white to light drab, coarsely crystalline, fossiliferous limestone, similar to that seen elsewhere in the county. Only one ledge is exposed. This has a thickness of 3½ to 4 feet and is covered by 20 feet of drift. The stone is exposed along the creek for a short distance only. About four miles still farther southeast similar stone is exposed on Goose creek (Tp. 76 N., R. VI W., Sec. 20).

On the ridge between Goose and Whiskey creeks the Augusta seems to have been eroded, and the Kinderhook immediately underlies the drift. Stone belonging to the Augusta formation is quarried in Louisa county at a number of points southwest of Columbus Junction on Long creek.

As has been said, the Augusta is in this county a stratigraphic unit. The divisions found elsewhere can not here be traced. The main portion of the stone shows a closer affinity with the Burlington layers, though there are beds which contain fossils suggestive of the Keokuk and the Warsaw.

The actual contact between the Augusta and the Kinderhook has been nowhere observed within the county, though such a contact was formerly exposed in the old railway quarry near Wellman. At one or two points on Smith creek yellow magnesian layers, answering in description to the Kinderhook, have been penetrated in taking Augusta stone from the bed of the creek. There seems to be no doubt that the coarse, crystalline limestone of the Augusta rests directly upon the earthy magnesian rock of the Kinderhook without transition beds. The upper limits of the Augusta are even more poorly defined. On Crooked creek, between the outcrops of lowest Saint Louis and highest Augusta, a drift interval of nearly five miles intervenes, and there are no outcrops by which it may be bridged. As a result the line between these two formations can only be drawn on the map approximately and without detail.

SAINT LOUIS.

The rocks of the Saint Louis stage cover the southern and southwestern portions of the county. It will be seen from the Brighton section already given that they are composed of limestones, brecciated beds, clay shales and sandstones. These different beds are shown more in detail in the following sections taken from a number of different points in the field.

A section on Crooked creek, three miles south of Washington, at the crossing of the Wayland road (Tp. 74 N., R. VII W., Sec. 5, Ne. qr.), gives the following.

	FEET.	INCHES.
6. Drift	30	
5. Shale, blue to green, calcareous	4	
4. Limestone, earthy, brown		10
3. Shale, similar to No. 5	3	
2. Limestone, earthy brown as above	2	
1. Shale, imperfectly exposed to water	4	

These beds may be correlated with the beds below No. 5 of the Brighton section. They may be traced up the stream something more than a mile, and are exposed, though not so perfectly, near the upper bridge (Tp. 75 N., R. VII W., Sec. 32, Sw. qr.). Down the stream they may be traced by frequent imperfect outcrops on both sides, showing the presence of similar stone, though not apparently continuous with the layers given, nearly two miles. At one point (Tp. 74 N., R. VII W., Sec. 4 ?), the shaly member is seen to be covered by the usual brecciated beds, imperfectly exposed and rising thirty-five feet above the stream. Around the big bend in the stream there are no exposures, the country being deeply covered with drift.

Almost directly south of the last mentioned exposure (Tp. 74 N., R. VIII W., Sec. 21, Nw. qr.) limestone is again found on Crooked creek. The exposure here shows:

		FEET.
2.	Shale, arenaceous, with thin bands of earthy limestone	12
1.	Limestone, heavily bedded, dark blue, fossiliferous; to water	4

A mile or more farther down the stream is the following.

		FEET.
1.	Shale, blue, clayey and arenaceous; exposed to water's edge	12

About half a mile east of Coppack, in a cut on the Burlington & Western railway, the following section is exposed.

		FEET.
4.	Shale, arenaceous, with interbedded sandy limestone layers 2 to 4 inches thick, showing slight, irregular deformations	8
3.	Shale, arenaceous, green	12
2.	Limestone, soft, earthy, red	1
1.	Limestone, soft, earthy red; to track	2

The base of this section is about fifteen feet above Crooked creek, the interval not being well exposed but apparently being made up of beds similar to number 4 of the above section. A quarter of a mile up the stream these beds are seen to be covered by four to five feet of limestone, similar to that occurring in the brecciated beds, and with thin layers of oölitic material interbedded.

With the exception of the limestone just mentioned, all the beds of these sections belong to the lower portion of the Saint Louis and are below number 5 of the Brighton section.

In the hill above the Coppack mill the beds of the brecciated division (Verdi) appear. South of Coppack both these beds and the lower division (Springvale) are exposed at intervals along the Skunk river. An excellent section* is exposed near the mouth of Crooked Creek (Tp. 73 N., R. VII W., Sec. 6, Nw. qr., Ne. ¼) in Henry county.

*Measured by Mr. Arthur C. Spencer.

		FEET.
4.	Loess	15
3.	Sandstone and limestone, irregularly alternating (Verdi beds)	25
2.	Shale, light blue, argillaceous (Springvale beds)	26
1.	Limestone, white, unfossiliferous; seen in bed of creek	6

Between Coppack and Brighton on the Skunk river there are numerous points at which the Saint Louis outcrops, but few good clear exposures occur because of the easy disintegration of the beds. Near a spring in section 27 (Tp. 74 N., R. VIII W.) a blue calcareous shale is seen at the head of a bend in the river. Only a foot or two is exposed, lying about ten feet above the water. Above the shale are four feet of thin-bedded fine-grained limestone over which lie sixteen feet of impefectly exposed limerock and sandstone. The former is earthy and of a brown color. Fenestella and other obscure fossils occur in blocks of limestone in the talus. The shale, and possibly a portion of the beds above, apparently represent the Springvale beds, while the higher beds probably belong to the Verdi.

A somewhat similar, though better exposed section occurs about a mile farther up the stream (Tp. 74 N., R. VIII W., Sec. 28, Nw. qr., Nw. ¼).

		FEET.
2.	Slope, talus of brecciated limestone and sandstone	10
1.	Shale, blue, argillaceous, non-fossiliferous; to water	12

Between the Brighton mill and the west county line, limestone crops out at a number of points on Skunk river and its branches, but few good exposures are found. The following section is one of the best. (Tp. 74 N., R. IX W., Sec. 9, Sw. qr.).

		FEET.
5.	Drift	15
4.	Limestone, hard, black, nodular	2
3.	Shale, blue, calcareous	4
2.	Limestone, hard, black, nodular	2
1.	Shale, blue, calcareous; to water	10

The entire section may be referred to the Springvale beds. The same beds are again seen above the wagon bridge in section 9 (Tp. 74., R. IX W.) where the usual shaly beds are exposed for a thickness of twenty feet above the water.

About five miles north of Brighton, near Verdi station, the middle member of the Saint Louis is excellently exposed. As seen here in an old railway quarry, it is made up of very irregularly interbedded limestone and sandstone. The limestone is the usual fine-grained, ash-colored, compact variety

FIG. 13. Irregular beds of limestone in the Saint Louis; Verdi quarry.

found in the upper layers. In parts of the quarry the brecciated phase of the rock is particularly well developed. The sandstone bands are as much as five feet thick and are in part fine-grained and white, while in part, particularly in a bed at the top of the quarry, they are coarse and red. The quarry abounds with apparent unconformities. The sandstone rapidly thickens and thins and contains great blocks of the limestone, occasionally as much as four feet long and six inches thick, standing at various angles, some as high as 30 degrees, such as is shown in figure 14.

Since the origin of the brecciation in these beds is a matter not yet fully explained, it is of interest to note that at this locality all the phenomena seen are exactly similar to what is found now at the base of any high cliff on a sea shore.

In Washington and the neighboring counties the Saint Louis has been differentiated into three members called the

FIG. 14. Limestone block resting on sandstone bands; Verdi quarry.

Springvale, Verdi and Pella beds. All three members of this series of beds occur in Washington county.

The Springvale beds derive their name from the exposures near the old Springvale mill south of Delta in Keokuk county, and form the lowest member of the formation. In Washington they are most typically shown in the exposure on Crooked creek at the crossing of the Wayland road in the section already given. Their lithological character is well shown in the various sections which have already been referred to them. It is noticeable that in this county the shaly character becomes the more prominent, while to the west the division is more generally represented by brown, earthy limestones. The maximum thickness is usually in the neighborhood of twenty-five feet. Where the base can be seen the beds invariably rest directly upon the coarse, crystalline limestone of the Augusta.

The Springvale beds cover the entire southern portion of the county. In the middle eastern portion a few feet of thin yellowish limestone is frequently encountered in drilling wells. This is never of any great thickness and immediately overlies the heavy limestones of the Augusta. On Long creek near Ainsworth there has been quarried on a small scale a stone which greatly resembles the Springvale beds and not improbably represents an outlier. The beds are usually non-fossiliferous; the few forms which have been found are imperfectly preserved and are valueless for purposes of correlation. The determination of the age of the beds in this region must for the present rest upon their stratigraphic position alone. The lowest portion of the formation as seen at Brighton was referred by Worthen to the "Argillaceous marlites of the Geode bed"* and the layers above were correlated with the magnesian portion of the formation as exposed elsewhere. The only fossil noted by him was *Lithostrotion canadense* Cast., though it is not quite clear from which layer it was collected, nor does it appear upon just what decisive evidence his correlation was based.

Gordon has recently traced throughout southeastern Iowa a bed apparently occupying the same stratigraphic position as the Springvale, and strikingly like it in lithological character. This formation he has called the Arenaceo-magnesian bed* and it is characterized by the abundant presence of *Lithostrotion canadense*. The affinities of the Arenaceo-magnesian bed seem to be with the Saint Louis and to that

*Op. cit., 243.

*Geology of Van Buren county, Iowa Geol. Surv., vol. IV, p. 215, 1895.

formation it is referred. It seems probable that the Springvale beds may be correlated with the Arenaceo-magnesian bed, though careful search has failed to reveal at any point the characteric fossil.

The only fossils which so far have been collected from the Springvale bed came from limestones in the bed of the river at the Brighton mill, and in the bluff at the spring mentioned above as located some distance farther down the river. Apparently the fossil-bearing limestone at the mill was not exposed at the time of Worthen's visit.

None of the forms found are sufficiently clear to allow a definite correlation to be based upon them. The close relation existing between the shale found along the Skunk river, in Washington county, and the arenaceous earthy limestone more generally present at the same horizon in Keokuk county, is in this region apparent. On Crooked creek, south of Washington, they are interbedded. In Keokuk county they pass by lateral transition into each other; everywhere it is evident that they belong together and are simply phases of a variable sedimentation.

This series of beds seems, in this immediate region, to be intimately related to the Saint Louis, and to that formation they have been referred, while the possibility is recognized that ultimately it may be necessary to refer them in part to lower formations. In accordance with the usage of the survey, they have been given a local name, Springvale, for immediate purposes.

The Verdi beds lie immediately above the Springvale. Their character is sufficiently shown by the sections described and is particularly well exhibited in the old Verdi quarries from which they are named. It has been customary where this middle member of the Saint Louis has been differentiated to refer to it as the brecciated beds. The name does not seem applicable for the reason that, while the brecciated beds occur in this formation they are only one phase of it. In the counties lying farther west of Washington, the outcrops are more frequently of alternating layers of sandstone and limestone, as seen at Atwood and many other points in Keokuk and Mahaska counties. The sandstones often become very important. At points in southeastern Mahaska county single beds are twenty-five to thirty feet thick. The brecciation, while usually present, is not always found, and at many points, well-bedded limestones of considerable thickness ocur.

The Verdi contains the record of a time of considerable disturbance. Shore formations and open sea deposits succeed each other in rapid alternation. Huge blocks of the previously-formed limestone were torn from their beds and buried in the sands, apparently at the foot of a series of cliffs; or they were beaten upon each other and reduced, in part, to fragments of varying degrees of coarseness, and in part to finest powder that eventually cemented the fragments together. Considering the turbulent conditions under which the beds were formed, it is not strange that fossils are rare. Such as occur are found usually in the limestone and are the brachiopods and kindred forms which become so prominent in the succeeding quieter times when the Pella beds were deposited. The reference of the brecciation in the formation to coral-reef structure is untenable by reason of the practical absence of corals in the region studied. The very few specimens collected from these beds were found in the compact limestone and belong to species which are most abundant in the succeeding strata where there are no signs of brecciation. Furthermore, they are not reef-forming species.

The Pella beds form the upper member of the Saint Louis, and are marine deposits made in the quiet waters succeeding the stormy Verdi. They have only been preserved from erosion in the immediate neighborhood of Brighton, in the bottom of what is probably a broad, shallow synclinal. They are well represented in the quarries, and the stone taken out here comes from these beds. As elsewhere, they consist of compact, fine-grained, ash-colored limestone, breaking with a distinct conchoidal fracture, and lying in ledges separated by thin beds of clay marl completely filled with fossils. The stone is itself fossiliferous, but only sparingly so as compared with the interbedded clays. The fauna found is not so noticeable for the large number of species as for the abundance of individuals.

UPPER CARBONIFEROUS.

The beds of the Upper Carboniferous series occupy but a small portion of the county and belong entirely to the lower division or Des Moines formation.

DES MOINES.

The deposits of this stage within the county occur in the form of small outliers. The only one which has yielded coal to any extent is about one mile west of Verdi. A section of the strata here, as exposed at the time of Worthen's visit, has already been given. A quartzose ferruginous sandstone, red to yellow in color, is found on Goose creek (Tp. 76 N., R. VII W., Sec. 21), lying above the Kinderhook. It is probably of Des Moines age. A similar stone is found on Davis creek over the Augusta.

On Whiskey Run (Tp. 76 N., R. VI W., Sec. 34, Ne. qr.), a thin coal seam occurs and was at one time mined a little. It varied in thickness between six and twenty-two inches; it was covered only by drift and apparently rested on clay. In some of the wells near here a sandstone similar to that on Goose creek has been encountered, though it apparently does not occur at the old mine workings. A similar sandstone has been reported as occurring near Wassonville, and clay shales similar to the "slate" of the coal regions have been reported from Clay township about two and one-half miles west of Brighton.

It must be remembered that this region suffered profound erosion both previous to the deposition of the coal measures and during later periods. The first erosion trenched the surface deeply and prepared a series of basins for the subsequent deposition of the coal. Later the coal measures were cut away except only in the most favored of these previously formed basins. It may even perhaps be doubted if the coal-bearing strata ever covered the whole of Washington county. Certain it is that they now cover only a very small fraction of the territory. Whether this is altogether the expression of the profound erosion to which they have been subjected, or whether it is in part the expression of the original conditions of deposition is not known. There are some reasons for the belief that the outliers between the main portion of the Iowa and Illinois field were developed in small independent basins.

PLEISTOCENE.

The Pleistocene deposits of Washington county include the Kansan drift, the loess, certain stratified gravels and sands, and the modern alluvial deposits. Together they form a mantle of unconsolidated beds which spread over and very largely conceal the indurated rocks. The thickness of this mantle varies from nothing to as much as 350 feet. The minimum is found only along lines of present drainage, while the maximum marks lines of former stream action. Over the smooth, upland drift plains the depth to rock is not always the same. Near Keota it is usually about sixty feet, this, seemingly, being less than usual. Near Wellman rock has been encountered at a depth of about eighty-five feet. The drift covering the plain around Wyman has been penetrated by numerous wells. Usually the rock is encountered at a depth of seventy-five to 100 feet. The Edward Umphrey well, on a level with the railway station, is 120 feet deep, with 100 feet to rock. The Uriah Beachman well, west of town, is 180 feet deep, with 100 feet to rock. Near Havre the drift is sixty-five feet thick. Northeast of Washington, within the limits of the Washington channel, the drift is more than 300 feet thick. Near Crawfordsville a well 70 feet deep failed to reach the indurated rocks.

KANSAN DRIFT SHEET.

The drift plains of the county are covered by a very few feet, two to six, of "overwash" loess-like material. Below this are the heavy till beds of the Kansan drift. There are here, as elsewhere, two phases of dirt. The upper is excellently shown on Williams creek, on the north side of the stream, at Wayland crossing. It is a deep, reddish-brown color, and contains numerous pebbles including large quantities of local material. The rocks are very frequently subangular and planed. A large proportion are striated. Granitic types are common, though greenstones are not infrequent. All of the material, with the exception of local chert pebbles from the Augusta, is badly weathered. Large boulders are not present. The only noticeable exception is a light-gray granitic boulder, two and a half feet in diameter, lying at the foot of the hill.

North of this exposure between Wayland crossing and Washington, the streams have frequently cut into the drift. It is quite uniformly of the character just described; at some points the color is a bright yellow beneath the reddish-brown. At one point (Tp. 74 N., R. VII W., Sec. 27, Ne. qr.), small lime concretions were found in the till; at the same point the underlying blue clay in a weathered condition is exposed.

South of Riverside on Goose creek (Tp. 77 N., R. VI W., Sec. 35), the blue clay is shown in a much fresher condition; it is here sharply separated from the yellow clay as shown in the following section:

		FEET.
3.	Sand, coarse, yellow, alternating with fine gravel	25
2.	Yellow clay with pebbles	½
1.	Blue clay, plastic, few small pebbles	12

The contact between the two clays is here marked by a row of springs. The presence of the heavier blue clay throughout the county is attested by well borings, though the clay is not frequently seen at least in a fresh condition in exposures. Its relation to the yellow clay can not be definitely stated further than that it is always beneath, and shows considerable difference in the variety and character of the contained pebbles. The two clays evidently represent quite different conditions of deposition, but it does not seem clear that they must be referred to two separate ice sheets.

No well defined forest bed which can be traced from point to point has been found. In the Washington well pieces of wood and twigs of trees were encountered at a depth of 115 feet. Among the remains were a few small cones of the spruce *Abies nigra*. The significance of these facts, however, as indicating a well defined forest bed, is impaired by the fact that the Washington well did not go through the normal undisturbed drift sheets, but rather encountered an unusual phase of the drift.

Above the yellow clay at the Goose creek exposure is a series of stratified sands and gravels. Similar beds were at one time exposed in a stripping at Brighton. Here they rested directly upon the limestones and were covered, apparently unconformably as shown in figure 15, by loess-like material. The age of these sand beds is open to doubt.

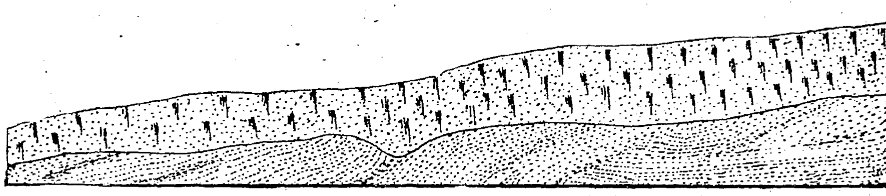


FIG. 15. Sub-loessial sands; Washington.

The loess-like material found at Brighton is of no great thickness, and apparently merges above into black soil and below into pebbly clay. It should probably be looked upon as of different origin from the more typical loess found in other parts of the state. In the Martin quarry a section of the drift deposits shows the following phases.

		FEET.
5.	Soil, black, fine	½
4.	Clay, gray, loessial	2 to 2½

		FEET.
3.	Clay, yellow and gray irregularly mingled, sandy in part; small pebbles throughout, upper and lower limits more distinctly gravelly; larger erratics more frequent at the base	14
	Unconformity.	
2.	Clay, purple to brown, full of Saint Louis fossils and limestone blocks	1 to 3
1.	Limestones, Saint Louis	4+

The clay found here immediately above the limestone is very similar to the clays and marls found in the upper layers of the Saint Louis upon which it rests. It has, however, a much darker color, and may, perhaps, be not improperly considered as being to a certain extent residuary in origin. It cannot be of glacial origin since it never contains foreign pebbles, and under it the limestone shows no marks of glaciation, though where it is absent such marks are found. The pebbly clay lying above it represents well the general character of the yellow clay. It shows a more or less complete merging into the loess clay above.

Glacial striæ have been noted at two points in the county. The first of these is at Brighton, where they appear upon the upper surface of the Saint Louis limestone. The striations are frequently half an inch deep and ten feet or more long. They take the directions (corrected) south 4° east and south 6° east. One shorter irregular groove varied from south 6° west to south 4° east. It was not so well marked as the others. The planing action of the ice is even better shown in the Eckel's quarry on Crooked creek, where, in 1894, a surface was exposed showing characteristic ice planing. The direction of the ice planing at this point was south 67° east (magnetic).

THE LOESS.

While the true nature of the loess-like material occurring at Brighton is open to some doubt, there are many exposures in the county which show material which can be definitely correlated with the loess of the counties farther north. Indeed the loess of Johnson county may be directly traced from the thick fossil-bearing beds at Iowa City south into Washington county. Along English river and indeed over the greater portion of the county the loess is normally found veneering the earth forms cut into the drift before its deposition.

The loess of Washington and neighboring counties shows important differences from the loess of the Missouri river. It is not porous, but rather the opposite. It does not stand long in vertical faces, but crumbles readily; it is stiffer, more plastic, freer from lime concretions, and while better adapted for use in the clay industry, is not so good a soil material. It apparently bears definite relations to the Iowan ice of Johnson county and probably represents fine water-laid material washed out from the front of the ice. It is not improbable that it has been in some regards modified since laid down, and because of this possibility and on account of the wide difference between it and more typical loess deposits it has been previously spoken of as the "altered loess," a name which is perhaps not strictly applicable on account of implying too much.

THE ALLUVIUM.

Alluvial deposits have been developed along the major and most of the minor streams. They are of the usual black loam character and resemble in appearance the black soil of the drift plains.

Geological Structure.

The general geological structure of the county is simple. The rocks have a slight prevailing dip to the southwest, and have been practically undisturbed. No regular series of anticlinals, similar to those traced in neighboring counties, has been found. With the exception of one very broad, shallow synclinal the rocks follow the prevailing dip. There are, however, two great erosion unconformities and one overlap known. The latter exhibits no marked signs of unconformity.

CROSS SECTIONS.

Skunk River Section. (Plate iii, figure 1.)—The section along the Skunk river is valuable in showing the general absence of all undulations in the strata. A short distance west of the county line the Augusta is exposed above the river at Manhattan mill, a thickness of forty feet being shown. These beds do not, however, appear at any point along the Skunk river in Washington county, though the lowest member of the Saint Louis is exposed along the entire distance, and the Augusta can not be very far below the level of the water. Brighton lies in the base of a very broad and very shallow synclinal to which fact may probably be due the preservation there of the Pella beds, while the underlying Verdi forms the surface exposures over so much of the county both west and north. The preservation of these beds is also largely due to the local thinning of the Verdi, allowing the Pella to be deposited at a level considerably below its outcrops elsewhere.

Cotters to Keota. (Plate iii, figure 2.)—A section made along the line of the Chicago, Rock Island & Pacific railway, from Cotters to Keota, shows excellently the variation in the topography produced by stream action. The abruptness of the change from upland to stream bed is greatly disguised, since the railway necessarily follows the easiest grade. That the upland forms one general plain is, however, evident. The level country from Keota west to Crooked creek, is indicative of the small amount of erosion accomplished by the tributaries of that stream since, for the greater part of the distance, the railway is within a mile of the main stream.

Brighton to Washington. (Plate iii, figure 3.)—On the line from Brighton to Washington the deep channels of the Skunk river and Crooked creek are crossed as well as the high lands between these streams.

English River Section. (Plate iii, figure 4.)—The best east and west section across the county is exhibited by the exposures along English river. This does not, however, show very well the dip of the strata as it runs at only a slight angle with the strike. South of Riverside the Maple mill shale of the Kinderhook is seen to be covered by the Wassonville limestone. At Kalona, the English river gritstones begin to intervene. At Maple mill they attain their maximum thickness. At Wassonville they have thinned and largely passed beneath the river, while the Augusta appears over the Kinderhook. Two miles west the strata are cut out, and there intervenes a broad, deep valley filled in with drift. Some distance beyond, the Augusta again appears.

EXPLANATION OF PLATE III.

Geological cross-sections in Washington county.

Figure 1. Skunk river section (a-b).
Figure 2. Cotters to Keota (c-d).
Figure 3. Brighton to Washington (e-f).
Figure 4. English river section (g-h).
The numbers refer to the formations as follows:

Drift	8
Saint Louis—	
Pella beds	7
Verdi beds	6
Springvale beds	5
Augusta	4
Kinderhook—	
Wassonville limestone	3
English river gritstones	2
Maple mill shales	1

DEFORMATIONS.

No deformations of any importance occur within the county. The series of small parallel undulations which are so well developed in Keokuk county, and which show traces in Mahaska county, can not be recognized in this area. This is more interesting as the series show a gradually increasing intensity toward the east. Apparently the culmination was reached in the Manhattan anticlinal.

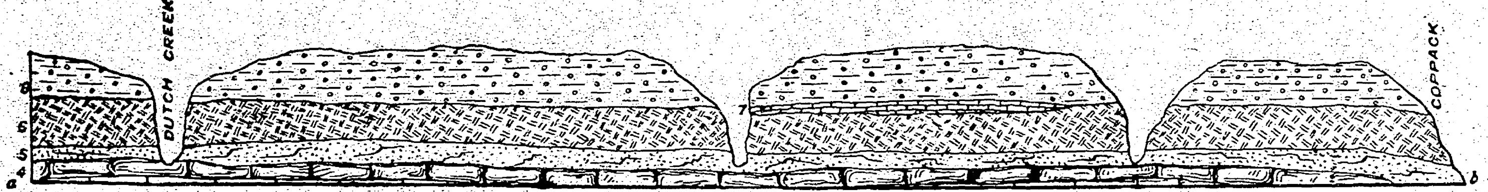
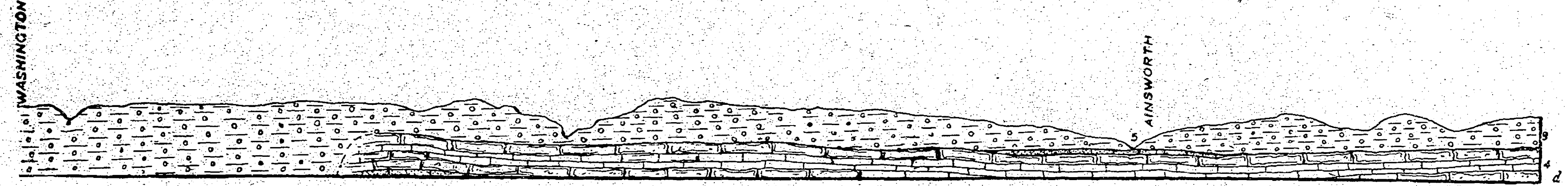


Figure 1



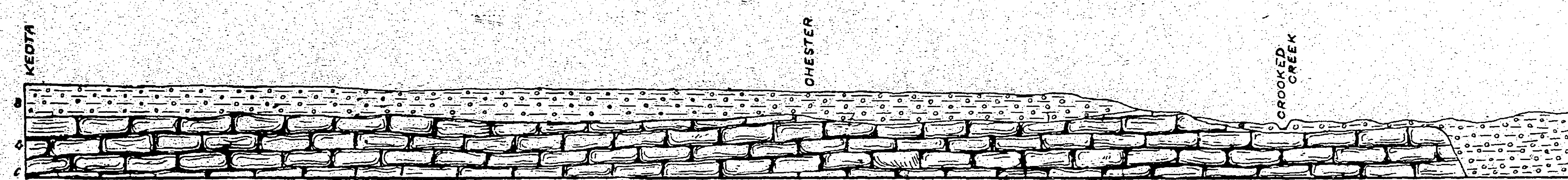


Figure 2

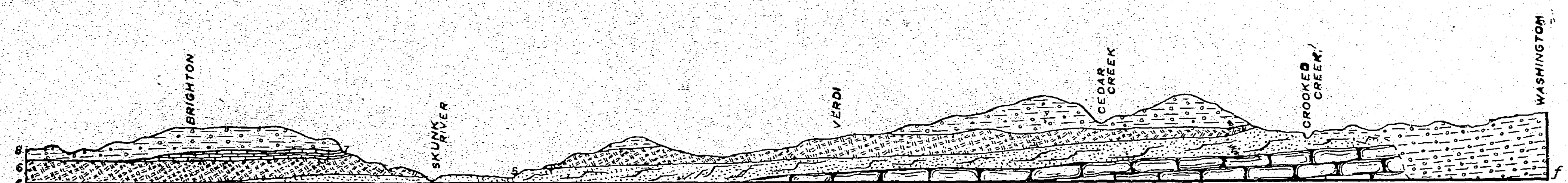
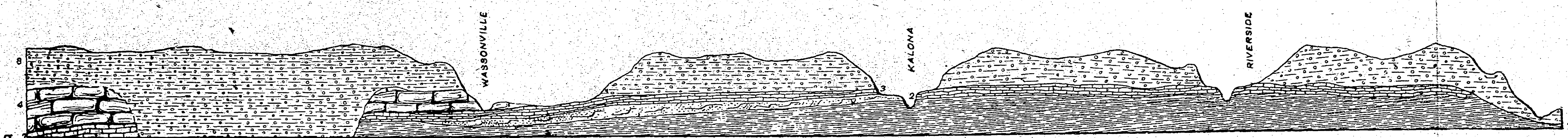


Figure 3



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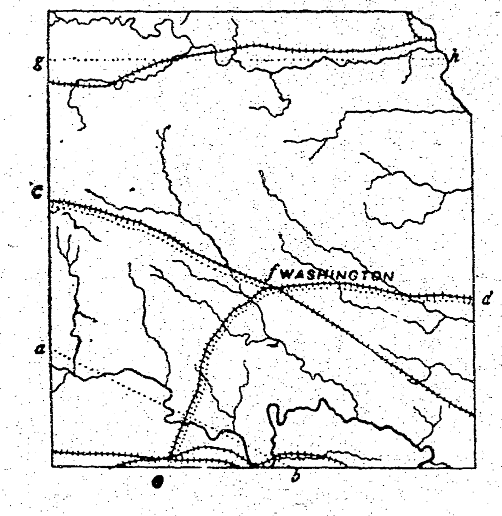


Scale Vert. 100 FEET
Hor. 1 MILE

GEOLOGICAL CROSS-SECTIONS IN WASHINGTON COUNTY.

UNCONFORMITIES.

UNCONFORMITY BETWEEN DRIFT AND INDURATED ROCKS.

The general unconformity between the indurated rocks and overlying unconsolidated beds is particularly well shown in this county. Just what had been accomplished by the preglacial streams in their efforts to base level the country is not definitely known. A reasonably even surface of rock seems to underlie the drift at a present elevation of 700 feet. At Keota it is 743 feet which seems higher than usual. If, however, such a surface at one time obtained there is abundant evidence that at some time preceding the ice age, probably but a short time before, it was elevated and attacked by vigorous erosion. Calvin in 1888 called attention to the remarkable thickness of drift at Washington and interpreted it as evidence of a preglacial channel. The drift here is 350 feet thick, and the channel in which it lies is cut down nearly through the Kinderhook, or 285 feet below the nearest outcrop of limestone at Eckle's quarry on Crooked creek, and 324 feet below the higher limestone farther west. The width of this old valley, which has been called the Washington channel*, is not however known.

In the northwestern corner of the county similar evidence of profound erosion is found. The valley of English river here shows a remarkable expansion on its southern side. The river has built up a flood plain south of the river a mile and one-half wide for a distance of nearly six miles. On the south this plain is bounded by gently rounded hills of drift, such as are more common on the northern side of this stream elsewhere, rising sixty to seventy-five feet above the flood plain, or to an altitude slightly below 800 feet. At its eastern limit the plain is abruptly cut off by sharp-contoured hills of rock capped by drift. Similar phenomena are seen on the northern side of the river, but are not so noticeable, and the limits of the expansion in the valley appear a little west of that described. It was not a surprise to find here that

*Proc. Iowa Acad. Sci., vol. II, p. 23. Des Moines, 1895.

borings on the hills south of the river had failed to reach rock, though carried to depths of 170 to 212 feet, or more than 100 feet below the water level of the stream. There is an old channel here which has cut down at least 150 feet into the rock and probably much deeper. Near Deep River in Poweshiek county, northwest of this point, a channel has been located cutting 250 feet below the level of the adjacent rock.

Southeast from Washington evidence of this channel is again seen. It has been noted that on Crooked creek there are no exposures of rock close to the great bend north of Noble, while west of the bend the exposures begin to appear at about the same point on both the upper and lower courses. Near the bend the deepest borings carried on, some going to a depth of 200 feet, fail to strike rock, though carried much below the nearest outcrops and much below what can be fairly attributed to any filling in by the present stream.

In the counties still farther southeast there are traces of similar channels, but as yet the one found in Washington county has not been connected with them. The location of the Washington channel is approximately shown in the sketch map of the drainage of the country. (Figure 9.)

The depth of this ancient channel gives a measure of the amount of the elevation of this region preceding the ice period. It has been exactly measured at Washington only, where the stream had cut down to 419 feet above present sea level. The exact figures at Deep River are not known, but they evidently agree quite closely with these. In Des Moines county, near Kossuth, a buried channel has been encountered which was believed to have cut down to 274 A. T. More recent evidence renders it probable that these figures may not be quite reliable.

It has been shown by Gordon* that, preceding the ice invasion, the Mississippi had cut down to about 350 feet above sea level in the region near Keota. Into that river the stream

*Iowa Geol. Survey, vol. III, p. 248. 1895.

following the Washington channel probably flowed. The small amount of fall which it must have had between these points accords well with the equally slight grade between Deep River and Washington, and indicates that the stream, when it was overwhelmed and buried, was engaged in widening its channel. This agrees well with the surface indications of a considerable width near Wellman, though there is some reason for believing that near Deep River the valley could not have been wide. A glance at the sketch map will show that the present drainage has no close connection with this ancient system. English river flows directly across it while Crooked creek, after reaching its former channel, turns abruptly aside and attacks the hard ledges of the Saint Louis.

UNCONFORMITY BETWEEN THE DES MOINES AND SAINT LOUIS STAGES.

The unconformity between the coal measures and the underlying rocks, which has such weighty economic import in the counties to the west, loses here its significance. The general absence of the coal measures is due, perhaps, most largely to the vigorous erosion succeeding the period of deposition. The erosion occurring in the long period between coal measure deposition and the ice invasion cut down far below the previous plane of drainage, and, while the erosion between the close of the Saint Louis and the beginning of the coal measures must have largely influenced the deposition of these beds, their probable originally limited extent, and subsequent almost complete removal, reduce greatly the relative importance of the pre-coal measure erosion.

UNCONFORMITY BETWEEN THE SAINT LOUIS AND AUGUSTA.

White* in 1870 called attention to the overlap of the Saint Louis upon the underlying rocks. It is of some interest to study this question in Washington county, as it must have been about here that the retreat of the sea southward was checked and the advance of the line to the north began. As has been shown, in Washington and Keokuk counties the

*Geology of Iowa, vol. II, p. 225. 1870.

Keokuk is not recognizable as a distinct formation. It has become so merged with the Burlington that its distinctive characters are lost. The greater portion of the Augusta seems more closely related to the Burlington, though at a few points Keokuk forms are found.

Over the Augusta lies the series of shales which show everywhere close stratigraphic relations with the Saint Louis. Between these shales and the Augusta limestone there are no certain evidences of unconformity, though at the contact near Ollie in Keokuk county, certain obscure phenomena might be so interpreted.

In the Brighton section the lower member shows close relations with the Saint Louis, and yet the fossils while obscure, have a Keokuk facies. On the whole it seems now probable that in this region there is no unconformity of erosion, but rather that sedimentation was continuous, though very slight, during the time that the main portion of the Keokuk and what has been called the Warsaw were being deposited farther south.

ECONOMIC PRODUCTS.

COAL.

As has been shown, there are at present no productive coal areas in the county, though in the past two at least have yielded supplies of the much coveted mineral. All the known coal territory in the county has been worked out. While it is possible that other outliers may occur, the probability is hardly great enough to warrant prospecting. The discovery of such beds, if they be present, must be left to chance. So far, the small outliers seem to have cost as much as they have been worth. The reported presence of coal measure sandstone near Wassonville led to the sinking of a shaft eighty feet deep, in part through the Augusta. Slightly bituminous shales probably belonging to the Kinderhook were encountered. Altogether a considerable sum has at various times been spent in this county in prospecting, with practically no return.

Even if the coal measures ever covered any considerable portion of the county, a conclusion not wholly free from doubt, the very great erosion to which the area has since been subjected precludes the possibility of more than limited outliers remaining.

CLAYS.

CHARACTER AND DISTRIBUTION.

Of the five formations exposed in this county three, the Kinderhook, the Des Moines, and the Pleistocene, may be considered as clay producers. At present the latter furnishes all the clay used.

The lowest formation exposed within the county is the Kinderhook. Its distribution and the divisions of which it is composed have already been given. Of the three divisions present, the lower, or Maple mill shale, is the only one important as a clay producer. This shale exists in large quantities and is at several points conveniently located for working. It is suitable for both paving and building brick, and probably could also be used for sewer pipe when wisely mixed with other clays which are more highly refractory and which have a lower shrinkage.

So far as known, the formation resting upon the Kinderhook, the Augusta, does not yield clays of any value within the limits of Washington county. The Saint Louis, which in turn overlies the Augusta, is not usually a clay producer. In the southwestern part of this county the middle and lower portions of the formation contain some shale, though, so far as observed, it has too large a proportion of sand and other impurities to be available.

The coal measures, which farther west and south furnish such a variety and abundance of clay shales, are here almost entirely absent. As yet but three small outliers have been located. These are three miles west of Brighton (Tp. 74 N.,

R. IX W., Sec. 27), one mile west of Verdi (Tp. 74 N., R. VIII W., Sec. 4) and five miles northeast of Ainsworth (Tp. 76 N., R. VI W., Sec. 34). At each point the formation has been at some time worked for coal, at which time the presence of the usual fire clay was demonstrated. These deposits are not now of any economic importance.

All the clays at present used are derived from the later or Pleistocene deposits. Alluvium, loess and drift are here present and available. The drift is made up largely of pebbly clays in two well marked divisions—an upper yellow clay, and a lower blue clay. The latter is freer from impurities and better adapted for use, though hardly likely ever to be of much value in this connection. The loess deposit described elsewhere is found covering nearly all the county; it is the clay most largely used at present and differs in no regard from that in adjoining counties, showing the same disposition to check upon drying. The alluvium is as usual developed along the large streams. In the valley of English river it seems to be closely connected with the loess.

CLAY INDUSTRIES.

KALONA.

The Farley Brothers' plant is located on the hills south of English river. A drift clay is used and the section is as follows.

		FEET.
3.	Yellow, soil-like clay	3½
2.	Sand	2½
1.	Clay, drab, plastic, clean	3

The upper and lower clays are mixed together and then tempered and moulded on a Freese side-delivery machine. Both brick and tile are made; the ware is dried under closed sheds and gives very little trouble from checking; only cased kilns are used in burning. The ware is smooth, hard and of good color. Experiments show that a hard burned brick suitable for paving can be made from the clay, though the Kinderhook shale outcropping near by could probably be used for this purpose to better advantage.

RIVERSIDE.

R. L. Swift & Company operate works located in the valley of the English river south of town. The clay used, which is carted from a neighboring field, seems to more nearly resemble the loess than alluvium. It is run through a Brewer crusher and moulded on a Brewer No. 6, new style, side-delivery machine. The ware is dried in part under open sheds, and in part in a steam-heated dry house which has a capacity of 22,000 brick, and in which the moisture is driven off in forty-eight hours. Two round and one oblong down drafts, and one cased kiln are used. Coal slack is mixed with the clay—two-thirds of a bushel to 1,000 brick, and a considerable saving in the cost of burning is thereby effected.

WASHINGTON.

James Eckels owns a tile factory four miles northwest of Washington. This factory has been in operation several years. The loess is used, being moulded on a Brewer machine and dried under closed sheds. Considerable care must be exercised in drying to avoid cracking. The ware is burned with wood in a single kiln.

The F. W. Swift plant is located in the southwestern part of Washington. The common altered loess clay is used; it is run through a Brewer crusher and moulded on a Brewer side-delivery machine. The brick are cut slightly curved so that in drying they become straight. Closed sheds are used for summer drying, but for winter use there is a large dry house having steam pipes under the floor. The clay checks as usual and must be dried slowly. In burning, three round and one oblong down draft, and two patent up draft kilns are used. Both brick and tile are made.

BRIGHTON.

Andrews Brothers formerly manufactured brick and tile at Brighton, using the loess and having a well equipped plant. Work has not been carried on since 1893.

WAYLAND CROSSING.

The plant of the Morris Brick, Tile & Lumber Co. is located directly north of the station in the valley of Williams creek. The section of the pit shows:

		FEET.
5.	Soil, black	$\frac{1}{2}$
4.	Soil, ash-colored	2
3.	Gumbo	2
2.	Clay, yellow, some pebbles	4
1.	Sand, yellow	

The clay is moulded on a Kells & Son machine, dried under closed sheds and burned in two cased kilns. The plant is new. No tile has yet been made, although the manufactured brick show that the clay might readily be used for this purpose.

WAYNE.

The Brown Brothers' tile factory is situated in the west half of section 34, Crawford township, about a mile and a half north of Wayne, a station on the Burlington & Western railway. Ware was first made on a Penfield plunger, then a No. 5 Brewer was put in and recently a No. 6 A of the same make has been substituted. The material is run through a Bennett smooth-roller crusher. Heretofore the output has been exclusively drain tile from threes to eights, but to meet an urgent demand the firm recently turned attention to the production of brick. The clay used is a yellowish-red loess-like deposit, from two to five feet thick, and a blue drift clay of the same thickness. This grades into a more sandy clay lying above twenty feet of quite hard sand. The exhaust steam pipes run under the dry shed floor and assist in drying the green ware. Checking occurs when any considerable portion of the blue clay is used. Tightly closed sheds are used to prevent this loss. The yellow clay is ordinarily preferable on account of the ease with which it is handled. Two round down draft kilns are used in burning and from three to four days are required.

BUILDING STONE.

Stone of suitable quality for building purposes may be obtained from any one of the three major geological formations. The sandstone of the Des Moines formation is not altogether unsuitable, but its limited quantity throws it out of consideration.

SAINT LOUIS.

The Saint Louis affords the greater portion of the stone now taken out. The ledges quarried belong to the upper portion, and the stone presents the usual lithological characters which mark it throughout the region. The sandstone of this formation is not now used, though at the old railway quarries near Verdi some was at one time taken out. It is, however, too irregular in bedding to be of value for anything but ballast, and is too soft to be of much value for that.

The limestone of the Saint Louis formation are mainly quarried in the vicinity of Brighton. It is here covered by from two to twenty-three feet of drift, below which there are two ledges, quarried principally for bridge and dam rock, and two of which furnish paving flags. Below these latter layers are the heavy beds once worked in the old Chicago, Rock Island & Pacific railway quarry. These lower ledges are more or less water coursed, frequently badly so. It was this difficulty which led to the abandonment of the quarry.

The vicinity of Brighton affords a number of openings. The Faber quarry, on the west side of the Chicago, Rock Island & Pacific railway, immediately north of town, shows the following layers:

		FEET	INCHES.
6.	Stripping; drift	5 to 15	
	Calcareous marl	2 to 4	
5.	Shell rock		8
4.	Bridge stone	1	3
3.	Bridge stone	1	11
2.	Paving flags and rubble stone		3
1.	Paving flags and rubble stone		3

The Martin quarry, on the opposite side of the railway, shows slightly different thicknesses.

		Feet.	Inches.
6.	Stripping: Drift	23	
	Calcareous marls 8 inches to	2	
5.	Range and rubble stone		8
4.	Bridge stone	1	8
3.	Bridge stone	1	6
2.	Paving flags		3
1.	Paving flags		3

This quarry is worked principally for the bridge stone, and supplies considerable quantities for railway use. Equivalent ledges are worked at a number of neighboring points. The Morris quarry is immediately south of the Martin. The Wood quarry is one and a half miles east; the Lloyd and Emery the same distance northwest of town (Tp. 74 N., R. VIII W. Sec. 28, Nw. qr., Ne. ¼), and the Slater, two miles northeast (Tp. 74 N., R. VIII W., Sec. 28, Nw. qr., Ne. ¼). At the latter point the stone is shipped by means of a switch from the Burlington & Western railway. Both compact and finely brecciated layers are represented at the quarry; the ledges being six to twelve inches thick. The output is small.

The stone quarried in this region is fine-grained, compact, breaks with a conchoidal fracture, and is of a pleasing ash-gray color. It is of fairly good quality but limited in quantity, as only the few ledges noted are workable. Below, are the disturbed beds of the Verdi. Formerly the stone was burned, and made a clear-white, mild lime. No stone is now used for this purpose.

Near Verdi, S. Richardson operates a local quarry (Tp. 74 N., R. VIII W., Sec. 5, Nw. qr., Ne. ¼); also in the Saint Louis. The old railway quarries, near this place, have been long since abandoned.

About three miles southeast of Washington on Crooked creek is the Jacobs quarry at which stone is taken from the lower or magnesian portion of the Saint Louis (Springvale beds). This quarry is worked for local trade only. In the southeast portion of the county there are no quarries, though tone is obtained in the adjoining portion of Henry county north of Winfield.

AUGUSTA.

The Augusta formation furnishes the best quarry stone obtained within the county and to it must any great expansion in the quarry industry be due. This stone is well shown in the Eckels quarry section, already given. In addition to the Eckels quarry there are two similar openings in the same vicinity which supply rock. These are the Thompson (Tp. 75 N., R. VIII W., Sec. 2, Sw. qr.) and the Humpston.

In the Thompson quarry there is an exposed face of about six feet. The stone is a hard, heavy bedded, light gray to brown, sub-crystalline limestone with abundant fossils. In the Humpston quarry the rock is, at least in part, coarser. It is interbedded with a poorer grade of buff sandy stone containing small calcite geodes. Chert bands run through the rock at both points. This group of quarries supplies considerable stone for local trade, nearly all the foundation stone at Washington coming from here. Near Dayton (Tp. 77 N., R. IX W., Sec. 13, Ne. qr., Ne. ¼) there is a small quarry in the Augusta. At this opening, the Whetstine quarry, the following layers occur.

	Feet.
3. Limestone, buff, arenaceous	5
2. Limestone, brown, coarse, sub-crystalline, fossiliferous	½
1. Limestone, blue to gray, finely sub-crystalline, fossiliferous	4

This stone very closely resembles that found in the Crooked creek quarries. Similar stone has been taken from the bed of Smith creek immediately southeast of the Wellman, and extends down the stream some distance. It has been opened up at several points. The Augusta is also quarried at the Wingler's quarry on Davis creek south of Riverside (Tp. 77 N., R. VI W., Sec. 31). The ledge opened up is three and one-half to four feet thick and covered by twenty feet of drift.

KINDERHOOK.

The upper magnesian layers of the Kinderhook (Wassonville limestone) are available over a part of the county but are not extensively quarried. South of Riverside, stone has been taken from these layers and used in the construction of a mill (Tp. 77 N., R. VI., Sec. 18, Sw. qr.) and the beds have also been opened up a little for local purposes on Goose creek (Tp. 77 N., R. VI W., Sec. 21, N. ½). Southeast of Wellman (Tp. 77 N., R. VIII W., Sec. 16) the Burlington, Cedar Rapids & Northern railway formerly quarried considerable stone. A working face 150 feet long was opened up.

Near Wassonville there are many local quarries which obtain stone from these layers. Immediately at the mill is the Yoder and Pfeil quarry from which stone was taken for the piers of the bridge and the foundation of the mill. At present a small amount of stone is sold. It is used for foundations, wells, window sills and wall rock. The stone is rather soft but frequently is better than first appearance seems to indicate.

SOILS.

The soils of Washington county belong to two general types; the loess soil and the alluvial soil. There is a close connection between the two in character, properties and origin. Both are black, loamy, soils of great fertility, both are water deposits, and both consist of fine silt-like beds laid down in quiet water. Indeed, the alluvial soil is at present receiving direct addition from the loess by the simple process of wash from the uplands and re-deposition over the bottom lands. There are, however, important differences between the two soils. The loess soil is formed *in situ* from the underlying loess by changes in that deposit. Its subsoil is, therefore, always the loess, which is usually of considerable thickness. Over some regions it is thin, and then the drift itself acts, to some extent, as a second subsoil.

The alluvial soil is not formed *in situ* but is derived from other ready-made soils and may overlie anything. It is usually of considerable depth, so that the subsoil is the same as the soil itself, except that it may be coarser. This is not, however, necessarily true, as the soil covering may be thin and may have any kind of a subsoil. The relations between the two types are quite close, and they are in the main adapted to the same kind of culture.

WATER SUPPLY.

In common with the other counties of the region, Washington is well supplied with surface waters. The English and Skunk rivers, with their tributaries, contain an abundant supply for general farm use, which is readily available throughout the greater part of the county.

Good wells are rarely difficult to obtain. The drift contains here numerous lenticular bodies of gravel and sand, interbedded with more impervious clays, which thus form natural basins for the collecting and storing of water. Such layers are found throughout the county, usually within 100 feet of the surface, though not always so. Immediately above the indurated rocks is a good water-horizon. In the underlying rocks water may also be usually obtained. In Des Moines and Louisa counties the Augusta frequently yields good water along the planes between the heavy limestone bands. West of here the Saint Louis is water-bearing in the middle member and might be found to yield water in the southwestern portion of this county.

In the deep well at Washington a good supply is obtained at a depth of 1,611 feet. It probably comes from one of the upper layers of the Saint Croix, or from one of the sandstones of the Oneota. The water stands forty-four feet one inch below the top of the casing and has a temperature of 74°. It has a slight mineral taste, but is well liked. It is pumped at the rate of ninety-five gallons per minute, the smallest casing being four and one-half inches in diameter.

WATER POWER.

The power afforded by the streams of this county is used at only four points. Two mills are located on English river, one at Wassonville and one at Riverside, and two on Skunk river at Brighton and Coppack respectively. These mills use an aggregate of 150 to 200 horse power and there is considerable room for expansion.

ROAD MATERIALS.

The materials which are here adapted to the purpose of road making consist of gravel, clay and stone. The first occurs in greater or less quantity throughout the drift, but it is only at a few points that it has accumulated in sufficient quantity and purity to be readily available. These points are along the larger streams. At Coppack there is a gravel terrace from which considerable material has been taken by the Burlington & Western railway and used for ballast along its line. The gravel is rather fine and is mixed with considerable sand. The output has been decreasing.

The number of cars loaded of recent years has been as follows:

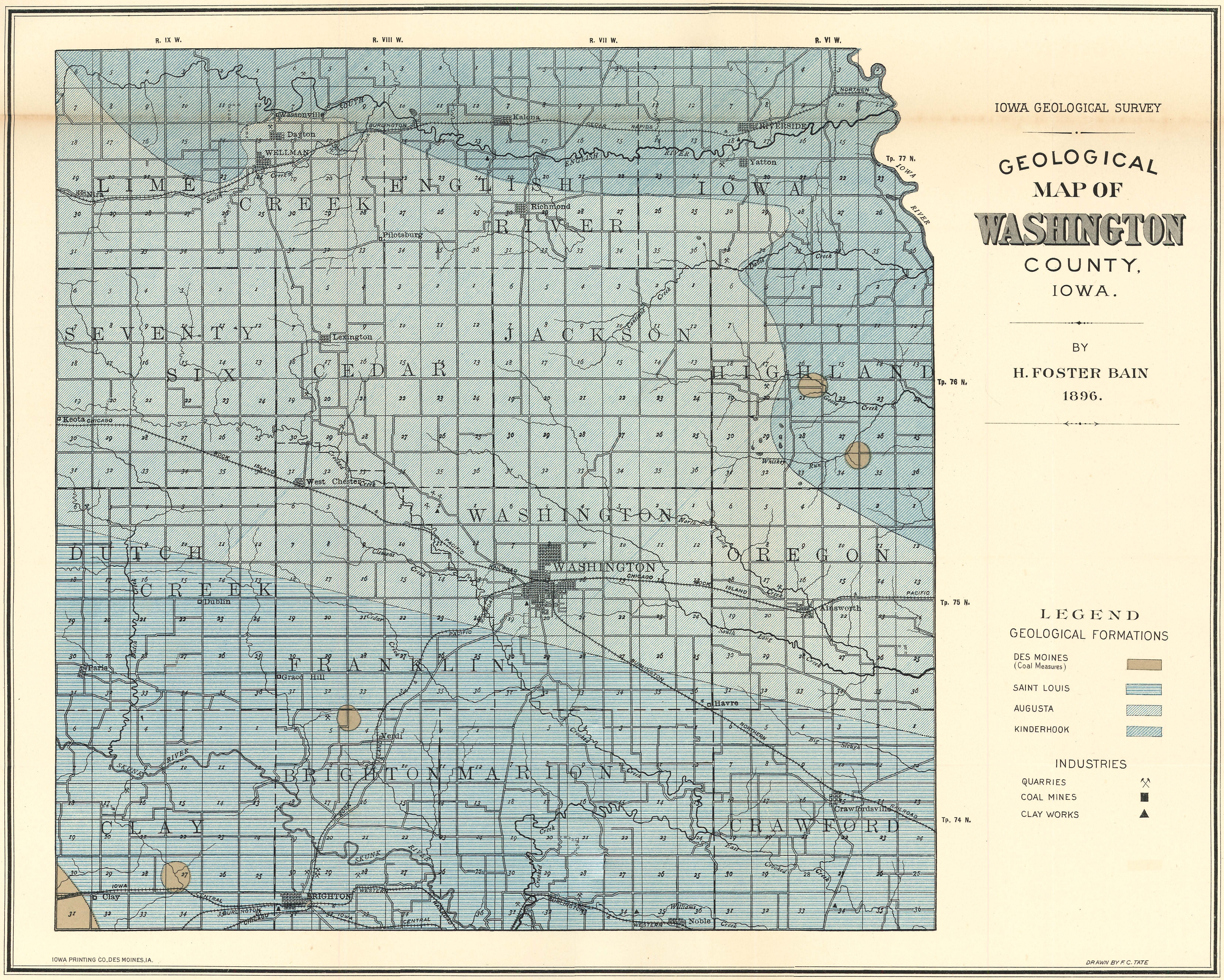
1892	2,100
1893	400
1894	100

Clay of good quality, such as is elsewhere burned for ballast and road materials, is everywhere present but has not been used for these purposes.

Rock suitable both for ballast and general road purposes occur in all formations. The Saint Louis has been used to some extent for the former purpose by the Chicago, Rock Island & Pacific railway, and the Kinderhook has been used by the Burlington, Cedar Rapids & Northern. Rock has not been used on the common country roads except at local points. It is of excellent quality for such purposes and readily available.

ACKNOWLEDGMENTS.

The author wishes to acknowledge the important aid received in the preparation of this report from the citizens of the county. The hearty co-operation of the quarry owners and brick makers has been especially helpful. To Professor Calvin and Dr. Keyes he is indebted for many valuable suggestions and for identification of fossils.


IOWA GEOLOGICAL SURVEY
GEOLOGICAL MAP OF
WASHINGTON
COUNTY,
IOWA.
BY
H. FOSTER BAIN
1896.
LEGEND
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KINDERHOOK
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QUARRIES
COAL MINES
CLAY WORKS
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R. VIII W.
R. VII W.
R. VI W.
Tp. 77 N.
Tp. 76 N.
Tp. 75 N.
Tp. 74 N.
LIME CREEK
ENGLISH RIVER
IOWA
SEVENTY SIX
CEDAR
JACKSON
HIGHLAND
WASHINGTON
DUTCH CREEK
OREGON
FRANKLIN
BRIGHTON
MARION
CLAY
CRAWFORD
Wassonville
Dayton
WELLMAN
Kalona
RIVERSIDE
Yatton
Richmond
Pilotsburg
Lexington
Keota
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WASHINGTON
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GEOLOGY OF BOONE COUNTY.

BY

SAMUEL WALKER BEYER.

GOELOGY OF BOONE COUNTY.

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INTRODUCTION.

SITUATION AND AREA.

Boone county forms one of the middle tier of counties, lying immediately to the west of the center county, Story, of the state. It comprises an area of approximately 576 square miles.

PREVIOUS GEOLOGICAL WORK.

Like that of many other counties of the state, the literature pertaining to its natural resources is extremely meager. The first published account of observations made on the geological structure of the county appears in a report of a geological survey of Wisconsin, Iowa and Minnesota, and incidentally of a portion of Nebraska territory, by David Dale Owen.* This description deals mainly with the general features of the county, and is accompanied by a sketch of the Des Moines river and vicinity, with several sections illustrative of the strata in the southern half of the county. It is based on an excursion up the river between the Raccoon and Lizard forks during the summer of 1849, the primary object being to determine the delimitations of the Iowa and Illinois coal area.

In 1856 A. H. Worthen made a general geological reconnoissance of the Des Moines valley†, and incidentally gives detailed sections of the strata occurring at Elk Rapids and Milford, which, with some slight modifications, may be considered as fairly typical for the southern and middle portions of the county respectively. White in his second annual report, and again in his final report‡, speaks of the coal industry and definitely refers the strata of the whole county to the coal measures.

*Report of a Geological Survey of Wisconsin, Iowa and Minnesota, and incidentally a Portion of Nebraska Territory. By David Dale Owen. Pages 123-125. Washington, 1852.

†Geology of Iowa, vol. I, part 1, pages 172-173. 1858.

‡Geology of Iowa, vol. II, page 259. 1870.

PHYSIOGRAPHY.

TOPOGRAPHY.

The surface configuration of the county belongs to McGee's third type, the "Drift Plain" topography*. Under this general type three sub-types may be distinguished: the inter-morainal, morainal and extra morainal portions. The area lying within the moraine comprises a narrow tract in the northern part of the county, characterized by an extremely flat surface broken only by occasional small eminences and depressions. The moraine is composed of a chain of interlocking hills having a north of west trend and running three-fourths of the way across the county. The belt varies from one to two or three miles in width, and is the most prominent topographic feature in the region. The extra-morainal area comprises by far the greater portion of the county. The general surface of this area is undulating and slightly inclined toward the south. The land bordering the principal streams is much broken, and as a rule supports a vigorous growth of timber. The inland portions present a billowy appearance, the general trend of the corrugations being northwest to southeast.

The watershed between the Skunk and the Des Moines river has an average altitude of nearly 1,200 feet, this being the most elevated divide in the county. That between the Beaver and the Des Moines is about seventy-five feet lower. The subjoined table, based upon railroad profiles, gives the altitudes of some of the most important points.

Table of Elevations.

STATION.	Altitude above sea level.	AUTHORITY.
Angus	1028	M. & St. L. Ry.
Beaver Station	1031	C. & N-W. Ry.
Boone	1143	C. & N-W. Ry.
Dayton (Webster county)	1090	C. & N-W. Ry.
Madrid	1006	C., M. & St. P. Ry.

* Eleventh Am. Rep. U. S. G. S., page 367.

Table of Elevations.

STATION.	Altitude above sea level.	AUTHORITY.
Midway	1086	C. & N-W. Ry.
Moingona	909	C. & N-W. Ry.
Ogden	1098	C. & N-W. Ry.
Pilot Mound	1220	M. & St. L. Ry.
Stratford (Hamilton county)	1120	C. & N-W. Ry.
Summit between the Beaver and Des Moines	1111	C. & N-W. Ry.
Summit between the Skunk and Des Moines	1186	C. & N-W. Ry.

DRAINAGE.

The streams in this region belong to McGee's* second class, and their homologues in northeastern Iowa have been well described by that writer as follows: "The most striking characteristics of all these streams is their great length in proportion to their volume, and the striking characteristic of the basins is their length and slenderness. Moreover there is a dearth of small tributaries, and so occasional lakes and ponds, swamps, and extensive sloughs are common." As has been mentioned, the general surface inclines gently toward the south and a natural inference would be that the principal water courses flow in the same direction. This is true in the main, the streams in the northeast portion of the county being the exception. The streams belong to two river systems; a major, comprising the Des Moines river with its tributaries, all flowing nearly due south with the surface incline and draining the southwest three-fourths of the county; a minor, drained by tributaries of the Skunk river, the general trend of which is nearly at right angles to the surface incline. As a rule all the larger channels of both systems have deeply incised the county through which they flow. This is particularly the case with Squaw creek and the Des Moines river with its short branches.

* Ibid, p. 359.

DES MOINES RIVER.

The Des Moines river enters the county about two and one-half miles west, and leaves it a little more than three miles east of the median line, thereby dividing the county into two almost equal east and west halves. The valley formed by the river varies from a half mile to two miles in width. The present flood plain comprises about one-third of the area, though, during periods of ultra high water, at least one-half of the valley is inundated. The stream meanders from side to side of its flood plains, but very rarely impinges upon its restraining bluffs. It has cut through the drift and deep into the coal measure strata throughout its course in the county. The valley is included between precipitous bluffs, deeply lain with glacial debris, and the continuity of its walls is broken only by the incursions of its numerous side branches. These mural walls vary in height from rather more than 100 feet at their entrance into, and exit from the county, to a maximum of 200 feet west of Boonesboro.

Terraces.—Terraces marking distinct stages in the development of the river are characteristic features in this region. The most prominent and persistent terrace appears about fifty feet above low water and, in the main, marks the limit of the present flood plain. The valley farms are largely located on this bench, and amply testify to the value of its soil for agricultural purposes. Another terrace of less pronounced character may be observed, at various points, at an elevation of about 100 feet above the river.

The Des Moines basin proper is extremely narrow. The tributaries which become confluent within the confines of the county are extremely short. The watersheds between the Skunk and Des Moines, on the east, and the Beaver and Des Moines, on the west, average scarcely nine miles apart and might be crossed and re-crossed without their presence being suspected. The valleys of the short lateral branches of this system partake of the general canyon-like character of the parent stream, and give a very broken aspect to the river belt. They possess steep declivities and become torrential during seasons of high water, but very few flow in extended periods of drouth. The majority, although they may be creeks of some importance in their upper reaches, lose themselves entirely in the sands of the river flood plain. The principal tributaries are Mineral, Honey, Peese and Hull creeks from the east, and Bluff, Bear, Caton and Preston creeks from the west, all of which tend to parallel the greater stream.

Age of the Des Moines river.—Sufficient data is not at hand to definitely determine the age of the river; but several significant facts, all of which point toward the youthfulness of the system, may be noted. (1) The extreme shortness of its tributaries, taken in conjunction with their high grades, are indicative of brief careers. (2) The river itself has done comparatively little lateral corrasion. Only in rare instances does it impinge on the limiting walls of its valley, and "truncated salients," which form such a prominent feature in the topography of the Mississippi valley, are almost unknown. (3) According to data derived from coal mines and well sections the position of the stream appears to be out of harmony with the topographic features of the older formations; i. e. the Des Moines is a superimposed stream, younger than the glacial deposits.

Beaver creek.—Beaver creek, with its long meandering branches, drains the western tier of townships and belongs to the greater Des Moines system. It is essentially a prairie stream of low grade. In fact the northern ten miles of its course might be more properly denominated a system of prairie sloughs and ponds which become almost impassable during prolonged periods of rainy weather, but do not persist during the dry season. As might be expected from the low declivity of the stream ways, and the transient character of the waterflow, the streams have done but little work in channeling or in valley formation. Only in the southern portion of the county, after the several branches have become confluent, is there a well defined valley. At no place is the superimposed drift sufficiently removed to reveal the older formations.

SQUAW CREEK.

Squaw creek, a tributary of the Skunk, with its long sinuous branches, amply drains the northeastern fourth of the county. Unlike the Beaver, this system possesses a higher declivity, and the several components have cut for themselves well defined valleys. Furthermore, small lateral branches are more numerous, and sloughs and ponds less common. The streams with their flood plains are from fifty to eighty feet below the general level of the surrounding country. Like the Beaver, these streams seldom persist throughout the entire year.

STRATIGRAPHY.

General Relations of Strata.

The geological formations represented in Boone county may be referred to two systems, an older, the Carboniferous, comprising the indurated rocks of the county, and a younger, the Pleistocene, including the non-indurated beds. The relative rank of the individual formations is shown in the subjoined table.

Classification of Formations

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.		Alluvium.
		Glacial.	Wisconsin.	Upper till.
			Kansan.	Lower till.
Paleozoic.	Carboniferous.	Upper	Des Moines.	

Boone county, so far as now known, lies wholly within the region of the lower coal measures, or Des Moines formation. For many years it has been one of the most important coal producing counties of the state. The Lower Carboniferous formations, while present at no great depth below the surface, as evidenced by numerous well borings both within the limits of the area and also in the adjoining counties of Story and Hamilton, are nowhere exposed within Boone county. The Saint Louis limestone occurs in typical exposure about two miles from the eastern boundary of the county, on a tributary of the Skunk river. This is the only outcrop of the Mississippian series in the vicinity. The drift is everywhere present, varying from fifty to more than two hundred feet in thickness. It entirely conceals the subjacent formations, save along the Des Moines river and a few of its tributaries; and even here talus slopes and landslides of glacial debris largely conceal the country rock. Inland, there are no natural sections of importance; but, fortunately, certain public spirited citizens have been instrumental in preserving careful records of several artificial excavations which give reliable information not only concerning the coal measures, but concerning the deeper lying strata as well.

TYPICAL SECTIONS.

The following sections taken from various parts of the county illustrate the lithological character of the formations present.

Traversing the county from south to north along the Des Moines river a considerable number of sections may be observed, which may be considered fairly typical of the coal measure stratigraphy of the region.

On Preston branch, about one mile from its confluence with the Des Moines, the following sequence of strata may be observed.

SECTION I.

(Tp. 82 N., R. XXVI., Sec. 33, Ne. qr.)

		FEET.	INCHES.
11.	Drift	20	
10.	Shale, blue	2	
9.	Sandstone in which plant impressions are numerous	2	
8.	Shale, somewhat bituminous below	3	

		FEET.	INCHES
7.	Coal		2
6.	Sandstone, fine-grained; argillaceous in the lower portion	15	
5.	Shale, bluish-buff; containing numerous interesting concretions near the top and one or two hard bands toward the bottom	18	
4.	Coal, not persistent		4
3.	Shale, interstratified with irregular, friable, sandy bands toward the top	15	
2.	Sandstone, ferruginous, concretionary		6
1.	Shale, blue	2	

The base of the section is at the bottom of the creek. To show the great variation in details, even in closely situated exposures, the outcrop on the side of the bluff, about 200 yards to the northeast, may be considered.

SECTION II.

		FEET.	INCHES.
7.	Soil and drift	10 to 50	
6.	Shale, light blue, iron mottled		3
5.	Shale, compact, brittle; strongly calcareous and highly fossiliferous, containing a marine fauna	1	6
4.	Shale, blue; carbonaceous and fissile below	3	
3.	Coal ("coal blossom" of miners)		1 to 4
2.	Sandstone, calcareous, deeply bedded.	6	
1.	Shale, blue (exposed)	1	

The lowest member visible at this point is about seventy feet above low water in the Des Moines river. No. 2 comprises a heavy-bedded calcareous sandstone, only the lower portion of which is thoroughly cemented. The upper layers take on a variegated appearance due to the anomalous distribution of ferric oxide. This portion contains an abundance of plant remains, which may have been instrumental in the removal of calcite and a redistribution of the iron constituent. False bedding, on a small scale, is not uncommon, yet the sands must have been laid down with extreme gentleness, for in many instances the Lepidodendron stems retain their leaves extended, in presumably perfectly natural position.

In the south central part of the county, the older Carboniferous formations have been cut out and replaced by a younger massive sandstone. A casual observer traversing the river valley cannot but notice the sudden change in topographic form, when this sandstone is reached. The rounded salients of the coal measure shales and argillaceous sandstones, give place to mural escarpments and bold buttresses of the "Ledge" sandstone, amply testifying to the change in stratigraphy. This terrain is typically exposed near the mouth of Peese creek, a tributary of the Des Moines entering from the east. The section exhibited at this point is as follows.

SECTION III.

(Tp. 83 N., R. XXVI W., Sec. 33, Sw. qr., Sw. ¼.)

		FEET.
4.	Drift	80 to 100
3.	Sandstone, fine-grained; very friable and of a brownish color; iron-stained	50
2.	Sandstone, heavy bedded; containing numerous ferruginous and quartzitic (?) concretions	35
1.	Sandstone, thinly bedded; often showing false-bedding	5

The base of the section is but little above the river level. The creek valley is extremely narrow and walled in by vertical cliffs, often overhanging ledges; hence the name of the formation.

Examples of water sculpture are numerous and beautiful. The ridges and less precipitous slopes support a luxuriant vegetation. In short, the inorganic and organic worlds have conspired to make this one of the most picturesque spots in the region. This formation presents many interesting lithological variations, the manifestation of which, in all probability is due to, or at least has been accentuated by, the weathering processes. The second member contains numerous ferruginous concretions varying in size from a few inches to many feet in the direction of their greater dimension. Others take an almost quartzitic facies and are so hard that they will strike fire with steel. These nodules are commonly lens-shaped or spherical, but in some instances are cylindrical. By reason of their relatively greater refractoriness, they often project beyond the softer matrices, and closely simulate the trunks of trees, and they are currently known as such.

FIG. 16. Ledge sandstone on Des Moines river.

To make the delusion more complete, these pressed cylinders weather concentrically and have a striking resemblance to the truncated bodies of exogenous trees of gigantic proportions. The lower bed of the section shows in many places cross-bedding the appearance of which is intensified by the differential corrasive and corrosive effects of the present stream. This sandstone is known to have a thickness of upwards of 100 feet and has been represented in the section as occurring in three stages.

The divisions are arbitrary rather than real; the external differences being due to accidents of weathering rather than to variable conditions during sedimentation. The ledge sandstone may be considered as a geological unit representing a period of continuous deposition. As in most deposits of its kind it is of limited extent. It thins out rapidly both to the north and the south. At Bear creek half a mile down the river it is reduced to forty feet, and two miles in either direction from its typical exposure it entirely loses its identity, giving place to alternating sands and shales. One mile and a

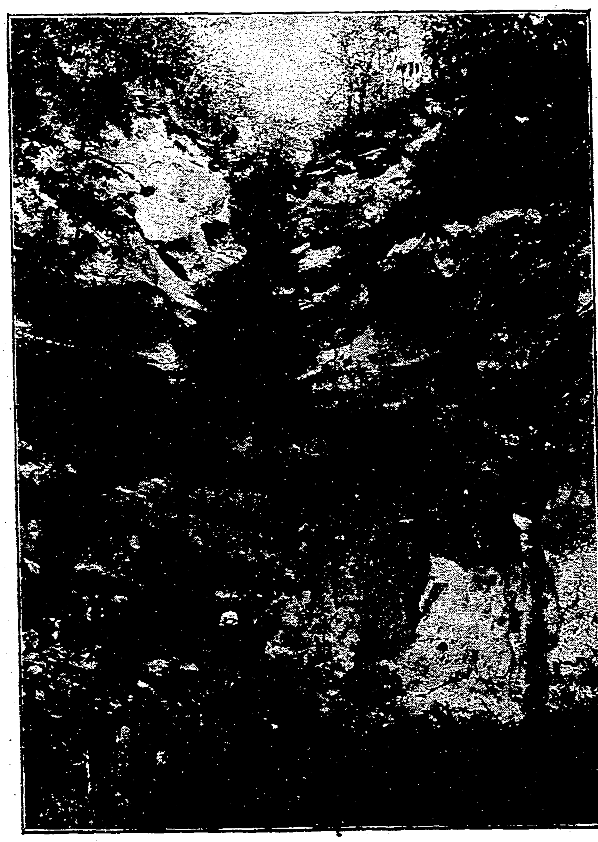


FIG. 17. Differential weathering of the ledge sandstone.

half toward the source of Peese creek the older measures pass uncomformably under the ledge sandstone. Approaching from the south about one mile below the mouth of the Bear, two seams of coal are easily seen outcropping along the river bank, the lower being twenty feet above the water. Where first observed these coal beds are separated by a considerable thickness of shale and clay. Proceeding northward the intervening strata gradually disappear, and before reaching the mouth of the creek the veins themselves end abruptly, and the ledge sandstone comes into view. Both stratigraphically and lithologically the ledge sandstone seems to have its homologue in the massive sandstone exposed in Marion county and currently known as the "Redrock sandstone." *

The Redrock sandstone is indicative of a considerable oscillation of the shore line during Carboniferous times, by which the land in that vicinity was elevated, profoundly eroded and then submerged by gradual tilting of the surface on an axis more or less parallel to the shore line. This was a period of vigorous erosion on land and of rapid sedimentation in the area in question. The ledge sandstone was laid down during this time and was followed by re-elevation.

The four following sections may be considered representative for the central coal-producing area of the county.

SECTION IV.

Honey creek section (Tp. 83 N., R. XXVI W., Sec. 7, Se. qr., Ne. ¼).

		FEET.
8.	Drift containing an abundance of selenite crystals near the base	40+
7.	Shale, compact, brittle, calcareous and highly fossiliferous	2
6.	Shale, bituminous	2
5.	Coal	2
4.	Fire clay and alternating shales and argillaceous sandstone	50
3.	Shale, black, containing many clay-ironstone concretions—nigger heads	2
2.	Coal	2
1.	Fire clay to bottom of creek	1

No. 7 is lithologically and faunally very similar to No. 6, in Section II. Both terrains have about the same altitudes and it is highly probable that they belong to the same horizon. The following species have been identified from this stratum.

Athyris argentea Shepard.

Discina nitida Phillips.

*Iowa Geological Survey, vol. I, pp. 99 et seq. 1893.

Productus costatus Sowerby.
Rhynchonella uta Marcou.
Spirifer (*Martinia*) *lineatus* Martin.
Aviculopecten, Sp.
Clinopistha radialis Hall.
Pleurotomaria grayvillensis Norwood & Pratten.
Pleurotomaria illinoisensis Worthen.
Soleniscus newberryi, Stevens.

The iron nodules, which occur so abundantly in No. 3, often contain well preserved specimens of gasteropods.

SECTION V—MOINGONA.

Coal measure strata exposed about one-half mile northwest of the town of Moingona, along the Chicago & Northwestern railway, are as follows.

		FEET.	INCHES.
11.	Drift, in the main, a light blue, gritty clay, with numerous small lime concretions, extends about fiften feet below the road bed	50	
10.	Sandstone, shaly, alternating with sandy shales; predominantly ash-gray in color and calcareous	12	
9.	Shale, blue	4	
8.	Sandstone, shaly and sandstone, compact	4	
7.	Shale, black	2	
6.	Coal		3
5.	Fire clay and shale	7	
4.	Shale, containing many ferruginous concretions and stems of Lepidodendra	4	
3.	Shale, blue-black, containing *Lingula umbonata* Cox, in places	2	
2.	Coal	2	
1.	Fire clay, exposed	2	

This section extends to the water level in the river. According to data derived from the coal shafts in the vicinity, a soft sandstone underlies the fire clay at the base of the section. About one mile north of this point the following sequence of strata may be observed.

SECTION VI.

(Tp. 83 N., R. XXVII W., Sec. 1, S. ½, Se. ¼.)

		FEET.
7.	Drift and displaced material	40
6.	Sandstone, compact ledge	1
5.	Sandstone, ash-colored, clayey and somewhat fissile; state of induration very variable, pockets of fine sand occur in the upper portion while the lower part takes on a concretionary structure	45
4.	Shale, blue-black	2
3.	Coal	2
2.	Fire clay	3
1.	Sandstone, exposed	3

Numbers 2, 3 and 4 are undoubtedly the same as 1, 2 and 3 in Section V. Above this point on the river the country rock is rarely exposed and in no case can more than a partial section be observed.

At Milford the following section may be made with some degree of accuracy, the partial natural exposure being supplemented by shafts in the vicinity.

SECTION VII—MILFORD.

		FEET.
8.	Drift	100
7.	Sandstone, alternating with shaly sandstone	60
6.	Shale, bituminous; containing Lingula and Lepidodendra	10
5.	Coal	1
4.	Fire clay, sandy shale and shale	20
3.	Coal at water level	2
2.	Fire clay and shales, the latter often containing septarian nodules	10
1.	Coal	1 to 4

The correlation of the strata at this point with those of previous sections cannot be definitely made. It is highly probable that numbers 2, 3 and 4 are the equivalents of 2, 3 and 4 in Section VI. No. 1 in this section may be present at Section VI, but it has been proved to be absent at Moingona as the numerous coal shafts in that vicinity attest. Proceeding northward there is an exposure on the west bank of the river opposite Wilson's mine (Tp. 85 N., R. XXVII W., Sec.

22, Se. qr.). Six feet of a micaceous fissile sandstone appears along the roadside, about thirty feet above low water. A workable vein of coal is found about ten feet below the bed of the stream as evidenced by the mine across the river. The last outcrop of coal measure strata in the county may be seen on the Se. qr. of Sec. 10, same range and township as the preceding. A twelve-inch seam of coal appears about four feet above the water in the river and is capped by a bituminous shale which is followed by a shaly sandstone. This vein is peculiar in that it contains a persistent clay parting.

Away from the Des Moines river and its immediate tributaries natural exposures of the coal measures are wholly wanting. Our present knowledge of the stratigraphy of the inland regions of the county is almost entirely based on drillers' records. It is very generally admitted that the record of a well that has been dug, or of a shaft that has been sunk, when not accompanied by sample drillings, soon becomes a matter of legend. Notwithstanding the somewhat unreliable character of the data derived from such sources, when minor details are concerned, the general fact has been quite clearly demonstrated that the Des Moines strata underlie the entire county. Of the sections away from the Des Doines river the well record at Ogden is instructive in giving the depth of the drift and the general character of the coal measures for the western part of the county. In sinking the city well the following strata were penetrated.

SECTION VIII—OGDEN.

		FEET.	DEPTH OF SAMPLE.
8.	Soil and drift clays	108	108
7.	Sand and gravel, water-bearing	2	110
6.	Shale, light-colored, sandy	7	117
5.	Shale, black; more or less concretionary, and containing some coal at the base	8	125
4.	Fire clay	2	127
3.	Shale, bituminous	---	228
2.	Shale and sandstone mixed at	---	256
1.	Coal, penetrated at	---	270

This section gives the thickness of the drift as 110 feet and shows the presence of coal under a good roof within a workable distance of the surface. The amount of coal penetrated at this point would not seem to warrant the sinking of a shaft, but the presence of at least two coal horizons is established, and further prospecting may develop the fact that coal exists in sufficient quantity to be economically important.

SECTION IX—BOONE WELL.

One of the most important artificial sections in the state is that afforded by the deep well put down in the city of Boone.* Here, a magnificent section of 3,000 feet is presented for inspection. The following sequence of strata, based on drillings taken at short intervals is appended.

		DEPTH OF SAMPLE.
110.	Clay, yellow, sandy, variegated	10
109.	Clay, light-blue; mixed with angular gravel which gives it a gritty character	24
108.	Clay, light-blue; gravel more conspicuous	34
107.	Clay, yellowish-gray; slightly arenaceous and containing fragments of wood, closely resembling red cedar; gravel still persists, but is less angular	45
106.	Clay, gray-blue, more even in texture than the preceding, but still containing a considerable percentage of arenaceous material; strongly calcareous	60
105.	Clay, yellow-gray, but gradually changes to yellow at 140; even textured, almost free from gravel, but slightly arenaceous throughout	100, 110, 140
104.	Clay, grayish-yellow, containing angular sand and gravel	150
103.	Gravel, coarse; imbedded in a matrix of blue clay; composition of gravel; quartzitic, cherty and of basic rocks; many of the individual pebbles are faceted	155
102.	Clay, deep brown	165

*The writer desires to express his obligations to Mr. E. E. Chandler, chairman of the committee on water works for the city of Boone, who kindly supervised the collecting of sample drillings. The writer has been the recipient of many helpful suggestions from Prof. W. H. Norton, who also has verified many of the above determinations.

		DEPTH OF SAMPLE.
101.	Clay, blue, massive	175
100.	Sand, quartz, fine uniform grain and containing a few grains of calcareous chert	185
99.	Gravel, coarse, composed chiefly of granite, vein quartz, basic rocks, quartzite and nodules of clay ironstone. The latter two bespeak strongly of a coal measure origin. Many of the constituents, by their rounded forms, bear evidence of prolonged attrition	195
98.	Shale, buff arenaceous; containing a small amount of fine gravel, probably carried down from the overlying strata; slightly calcareous	200, 210, 220, 230, 250
97.	Shale, blue, compact, brittle	270
96.	Shale, blue, containing a small amount of coal	275, 308
95.	Shale, blue, calcareous and slightly arenaceous	325
94.	Shale, light-blue, strongly calcareous and more arenaceous than the preceding	335
93.	Shale, black, bituminous; its fissile character is rendered apparent on exposure	345, 353
92.	Shale, bituminous, mixed with ash-colored fire-clay, coal, iron pyrites and clay ironstone	355
91.	Shale, black non-calcareous, brittle and containing an abundance of iron pyrites	370
90.	Shale, gray blue, slightly arenaceous at 400 but practically non-calcareous throughout	380, 390, 400, 415
89.	Shale, ash-colored, brittle, calcareous	430
88.	Shale, gray, containing a small amount of black shale and a great abundance of flint which partakes the geodetic character; also, some limpid quartz	445, 450
87.	Shale, grayish-black, calcareous and arenaceous	455
86.	Limestone, containing rhombs of calcite	460
85.	Limestone, slightly oölitic	470, 475, 490, 500
84	Shale, blue and strongly calcareous	515, 525, 540
83	Shale, gray-blue, more marly than the preceding	550
82.	Limestone, bluish-gray, close textured, brittle, drillings sharply angular	552
81.	Limestone, drillings show conchoidal or hackly fracture	560
80.	Limestone, an abnormally large amount of chert is present	562

		Depth of sample.
79.	Limestone oölitic facies, slightly quartzitic; drillings not angular	580
78.	Sandstone, friable, fine-grained	590
77.	Shale, greenish-gray, slightly arenaceous	600
76.	Shale, slightly calcareous	610, 620
75.	Shale, more marly	630
74.	Limestone, gray	640, 650
73.	Limestone, gray, marly	660–777
72.	Limestone, blue, compact, brittle	790
71.	Limestone, apparently brecciated	800
70.	Shale, gray	805
69.	Limestone, sub-crystalline, gray	815, 830
68.	Limestone, containing numerous reddish-brown spots, probably due to oxidation and hydration of iron pyrites	840–920
67.	Limestone, magnesian, light-buff	930–1,015
66.	Limestone, more or less argillaceous and containing fragments of a dark colored shale	1,028, 1,040
65.	Shale, slightly calcareous	1,050
64.	Limestone magnesian, similar to 930-1,015	1,065, 1,070
63.	Shale, gray-blue, similar to 1,050; some sand present	1,080, 1,090, 1,100
62.	Shale, arenaceous, containing a considerable number of larger sand grains	1,120
61.	Limestone, gray, dolomitic	1,130, 1,140, 1,150
60.	Limestone, magnesian, buff, saccharoidal	1,160, 1,170, 1,180
59.	Limestone, magnesian with some quartz grains	1,190
58.	Limestone, dolomitic, marly	1,200, 1,210
57.	Shale, greenish-gray	1,220
56.	Limestone, dolomitic; similar to 58	1,240, 1,250
55.	Limestone, more argillaceous	1,260
54.	Quartz, vari-colored, chalcedonic	1,280
53.	Clay, residual, a red ochreous substance, charged with white, calcareous grains	1,282
52.	Sand, quartz, vari-colored	1,290
51.	Limestone, crystalline, purplish; some fissile, green shale present	1,298
50.	Limestone, buff, considerable green shale present	1,305
49.	Dolomite, gray, fine even textured, brittle; reduced to a fine sand by the drill	1,315, 1,325
48.	Shale, green, soft, plastic; but slightly calcareous	1,335–1,385

		Depth of sample.
47.	Shale, black, carbonaceous	1,395
46.	Shale, buff, magnesian	1,405, 1,430
45.	Limestone, argillaceous	1,440
44.	Limestone, gray, magnesian	1,450, 1,480
43.	Limestone, argillaceous, marly	1,490
42.	Limestone, gray, magnesian	1,500, 1,510
41.	Limestone, buff, magnesian, finely granular	1,537
40.	Limestone, slightly cherty	1,545–1,560
39.	Limestone, buff, magnesian; containing flakes of gray limestone and small cleavage plates of gypsum	1,580, 1,590, 1,600
38.	Dolomite, brownish-yellow, marly	1,610
37.	Dolomite, becoming progressively lighter colored	1,620, 1,630
36.	Dolomite, buff	1,640
35.	Dolomite, sacchroidal	1,650
34.	Dolomite, buff	1,660, 1,680
33.	Dolomite, shaly	1,690
32.	Dolomite, bluish-gray, marly, argillaceous	1,700
31.	Dolomite, buff	1,710, 1,720, 1,730
30.	Clay, residual, with some fine-grained quartz sand	1,740
29.	Shale, greenish-gray	1,750
28.	Dolomite, brownish	1,760
27.	Shale, greenish-gray with dolomite sand	1,770
26.	Dolomite, deep brown	1,780
25.	Dolomite, color gradually changes from buff to greenish-gray, and texture becomes shaly	1,795–1,810
24.	Shale, bluish-gray	1,830
23.	Shale, green, non-calcareous	1,835
22.	Shale, bluish	1,840
21.	Sandstone, clear-white; grains well rounded	1,845
20.	Shale, green, with small amount of sand	1,850
19.	Shale, arenaceous	1,860, 1,870
18.	Sandstone, clear-white, even grained quartz sand	1,880, 1,890, 1,895
17.	Shale, similar to No. 19	1,990
16.	Dolomite, gray with fine quartz sand	1,910
15.	Dolomite, greenish-gray, marly	1,915
14.	Dolomite, same as No. 16; sand finer than in No 18 and much more angular	1,940, 1,950
13.	Dolomite, cream-colored, slightly shaly	1,955
12.	Dolomite, gray, shaly	1,975
11.	Shale, red, non-calcareous	2,075

		DEPTH OF SAMPLE.
10.	Shale, buff, highly calcareous, slightly arenaceous	2,165
9.	Shale, green	2,200
8.	Shale, green	2,250
7.	Shale, dark-blue and marl, light-gray	2,310
6.	Sandstone, highly calcareous, buff, fine-grained	2,510, 2,515
5.	Shale, yellowish-green, highly calcareous	2,560
4.	Sandstone, yellowish, fine-grained; mostly sub-angular or rounded, many angular grains	2,585
3.	Sandstone, light-buff, grains fine, mostly angular	2,640, 2,660
2.	Sandstone, calciferous, in the mass brown, fine-grained	2,700
1.	Alternating bands of shale, red marl, and soft-red sandstone, without limestone	2,700-3,000

The total absence of type fossils renders the interpretation of the above section difficult. Fully realizing the somewhat unreliable character of correlations based on lithological grounds only, the following summary is offered tentatively.

Summary of Formations.

NUMBERS.	NAME	SAMPLES.	THICKNESS.	DEPTH.
110-99	Pleistocene	0-200	200	200
98-83	Des Moines	200-460	260	460
82-58	Lower Carboniferous and Devonian	460-1,210	750	1,210
57-49	Upper Silurian	1,210-1,325	115	1,320
48-46	Maquoketa shales	1,325-1,440	115	1,445
45-22	Galena-Trenton	1,440-1,840	400	1,840
21-18	Saint Peter	1,840-1,895	55	1,890
17-7	Oneota	1,895-2,450	475	2,455
7-1	Saint Croix	2,450-3,000	550	3,000

The top of the well has an elevation of 1,140 feet above tide. The drift is apparently 200 feet in thickness. The next seventy feet is most anomalous in character. It has a distinct soil odor and is loess-like in appearance. The gravel present is similar to that in the overlying drift which is undoubtedly its source. The W. D. Johnson shaft, three miles to the westward, penetrates no strata which can be correlated with this terrain. Two hundred feet of coal measure shales follow.

The data at hand does not warrant the separation of the Lower Carboniferous from the Devonian, to say nothing of attempting to delimit the subdivisions of these systems. The material deposited during these periods are predominantly limestones, although interbedded with numerous bands of shale and some sandstone. The oölitic character so well exemplified in the typical outcrops of the Lower Carboniferous strata in central and southeastern Iowa may be noted in 85 and 79.

The Upper Silurian possibly begins with 57, which is followed by a magnesian limestone similar to 58. This formation contains a considerable amount of siliceous material. Sample 54 is composed almost wholly of quartz; the limestone has been removed probably by washing. The residual material may represent a cavern or an old surface. The Maquoketa shales are characteristically developed at this point although reported absent at Ottumwa and Centerville by Prof. W. H. Norton*. The heavy deposits of magnesian limestone and dolomite from 45 to 31 may be referred to the Galena and Upper Trenton formations. Interstratified dolomites and shales comprise the Lower Trenton with an easy passage into the white sands of the Saint Peter. The Oneota and Saint Croix attain great thicknesses in central Iowa, as evidenced by the lower 1,100 feet of the section.

Geological Formations.

CARBONIFEROUS.

DES MOINES STAGE.

As has been mentioned, the lower coal measures completely underlie the county. The Des Moines river has cut into this formation a channel averaging 100 feet in depth, and revealing a series of sandstones and shales with several veins of coal, which are interbedded in a most intricate manner. The following general section, which is to some extent ideal, gives the most important relations of the strata. It is based on

*Iowa Geological Survey, vol. III, p. 209.

the natural exposures along the rivers taken in conjunction with data derived from coal shafts and well sections in the vicinity.

Thickness.—The coal measures have never been entirely penetrated save at a single point within the limits of the county. The Boone deep well section shows a thickness of 260 feet. The drift at this place is 200 feet thick, while the surface altitude is 1,140 feet. Three miles to the westward, the drift is but 100 feet in thickness, while the surface elevation has been reduced but sixty feet. It is probable that the coal measures may reach a thickness of nearly 300 feet at that point. Whether or not there is a gradual thickening to the westward must remain an open question until more data is at hand.

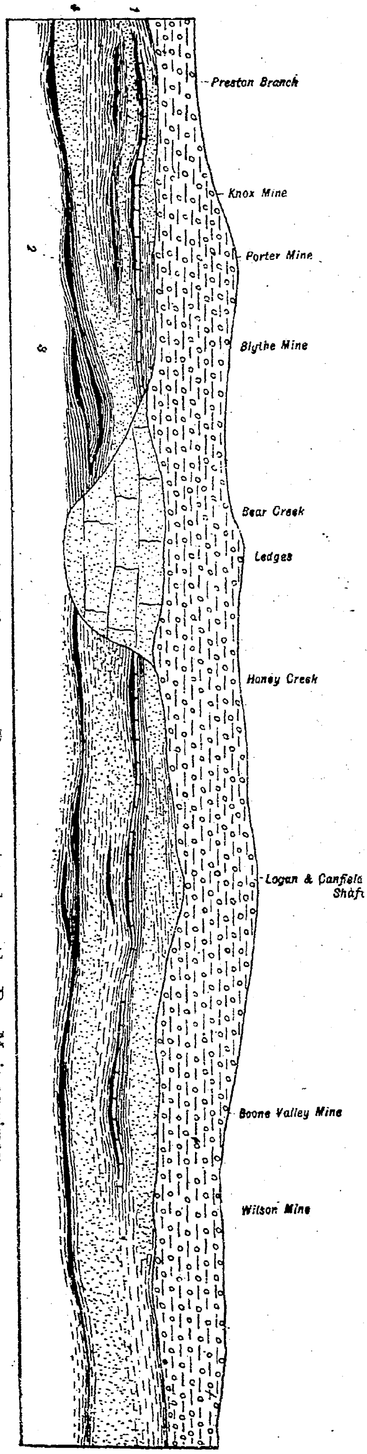


Fig. 18. General geological section across Boone county along the Des Moines river

Lithologically, the coal measure strata consist essentially of sandstone and shales which contain several seams of coal, of greater or less extent. The sandstones and shales are extremely variable, not only in composition, texture and state of induration, but also in their lateral and vertical distribution. The sandstones are composed of fine, rounded quartz grains which are, as a rule, imbedded in a matrix of calcareous, ferruginous or argillaceous cement.

The individual sand grains are often coated with ferric oxide, which indicates that they were not subjected to vigorous or prolonged shore action during the period of deposition and accumulation. In texture, all gradations may be observed from the massive "Ledge sandstone," where a single layer may reach a thickness of twenty feet and is practically a freestone, to fissile sandstones which readily separate into laminæ less than one-tenth of an inch in thickness. The former deposit is indicative of rapid, continuous deposition, while the latter predicates rapidly recurring conditions and, perhaps, slow accumulation.

The state of induration is most anomalous. Sand, friable sandstone and compact sandstone,—almost quartzitic in character oftentimes—rapidly replace one another both laterally and vertically. The prevailing color of the Boone county sandstones is buff, reddish-brown or ash-colored, depending largely as to whether the cement is calcareous, calcareo-ferruginous or calcareo-argillaceous, respectively.

The shales are equally as variable as the sandstones. There are all gradations from argillaceous sandstones to fire-clays. The color varies from a gray or ash-color in the leached fire-clays, through massive blue shales, to the black, bituminous shales, which usually immediately overlie the coal seams.

The state of aggregation varies greatly from the soft, plastic clays, which may be readily molded between the fingers, to the brittle, calcareo-argillaceous rocks which emit brilliant sparks when struck with the hammer. The carbonaceous shales often contain septarian nodules and clay ironstone concretions.

The coal belongs entirely to the variety known as bituminous. As a rule, it is composed of upwards of 80 per cent of oxidizable elements, chief among these being carbon. The coal will be more fully treated in a later portion of this report. In addition to sandstone, shales and coal there are certain bands of argillaceous limestones, which are the most persistent features of the coal measures. Such bands may be observed near Moingona and on the river west of Madrid.

PLEISTOCENE.

Deposits later than the coal measures and usually designated by the general term "drift," completely cover the county save where they have been removed by the present streams. They cover the underlying deposits unconformably and may be differentiated into a lower and upper till and an alluvial deposit. Most of the present topographic forms find expression in the easily molded materials of this terrain. The average thickness of the drift in this area is upwards of one hundred feet. At Zenorsville, in the northeastern portion of the county, it varies from sixty to one hundred and twenty feet; in the city of Boone it is 200 feet thick; at Ogden, 110, and the coal shafts near Angus reveal a thickness of from fifty to one hundred feet. A deduction of the thickness of the drift at certain points from their respective altitudes, along a line from the agricultural college in Story county, by way of Boone, the Logan and Canfield shaft, Milford and Ogden to Beaver station, renders apparent an interesting and

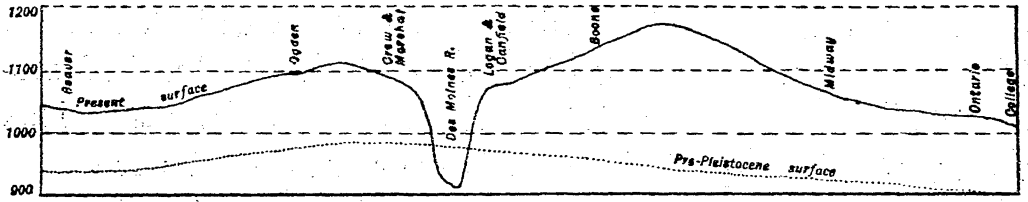
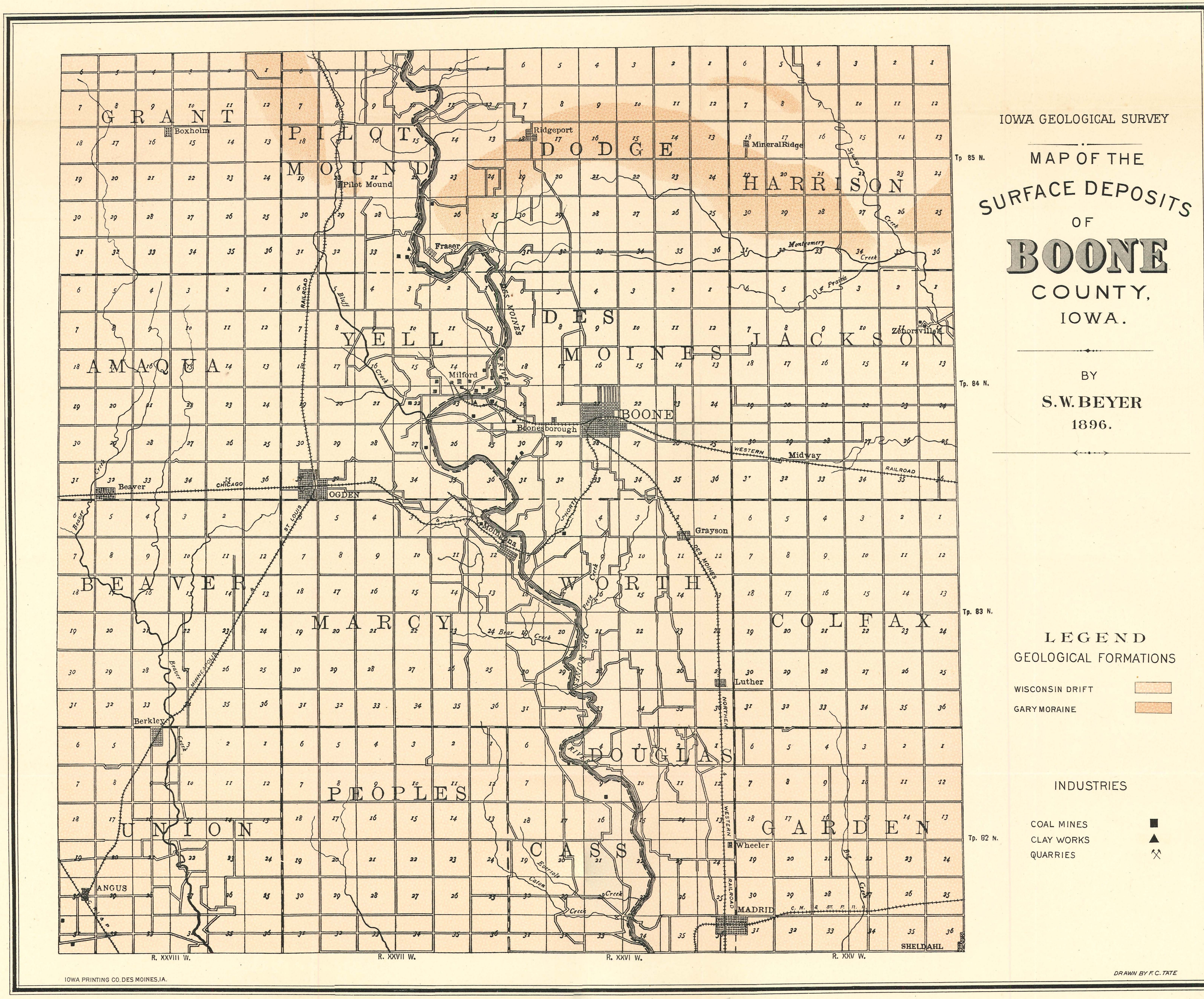


FIG. 19. Relations of the present and pre-Pleistocene surfaces.

important fact. The surface features at the beginning of the Pleistocene must have been less pronounced than at the present time. It would seem that the region had suffered profound erosion during the preceding period and that the area under consideration was practically base-leveled at the beginning of the present epoch. The Des Moines river appears to have the characters of a superimposed stream. Its present position is clearly out of harmony with the older land surface. In fact it is highly improbable that any of the streams of the present drainage systems are coincident with those of pre-Pleistocene times.


IOWA GEOLOGICAL SURVEY
MAP OF THE
SURFACE DEPOSITS
OF
BOONE
COUNTY,
IOWA.
BY
S. W. BEYER
1896.
LEGEND
GEOLOGICAL FORMATIONS
WISCONSIN DRIFT
GARY MORAINE
INDUSTRIES
COAL MINES
CLAY WORKS
QUARRIES
GRANT
PILOT MOUND
DODGE
HARRISON
AMAQUA
YELL
DES MOINES
JACKSON
BEAVER
MARCY
WORTH
COLFAX
UNION
PEOPLES
DOUGLAS
CASS
GARDEN
Boxholm
Pilot Mound
Ridgeport
Mineral Ridge
Fraser
Milford
Boonesborough
BOONE
Zenorsville
Midway
Beaver
OGDEN
Grayson
Luther
Berkley
Wheeler
ANGUS
MADRID
SHELDAHL
Tp. 85 N.
Tp. 84 N.
Tp. 83 N.
Tp. 82 N.
R. XXVIII W.
R. XXVII W.
R. XXVI W.
R. XXV W.
CHICAGO
WESTERN
RAILROAD
DES MOINES RIVER
Montgomery Creek
Squaw Creek
Bear Creek
Beaver Creek
IOWA PRINTING CO. DES MOINES, IA.
DRAWN BY F. C. TATE

No attempt will be made in the present report to delimit the subdivisions of the Pleistocene. According to present data it may be tentatively stated that the county is completely underlain by the two drift sheets.

LOWER TILL OR KANSAN FORMATION.

A yellowish-brown clay appears at several points along the Des Moines, noticeably along road-cuts at about the one hundred-foot level above low water. The deposit is characterized by a predominance of greenstone pebbles and a considerable number of small sized granite boulders, many of which are in an advanced state of decay and readily disintegrate when removed from their matrices. Occasionally, this oxidized deposit may be traced downward into a massive blue clay, of which it is probably the lower unweathered portion. At the Logan and Canfield shaft, the lower till, as above described, shows a thickness of about forty feet for the oxidized portion. The Boone deep well gives forty-five and fifty-five feet for the lower and upper portions respectively.

UPPER TILL OR WISCONSIN FORMATION.

Boone county lies wholly within the outer loup of the terminal moraine which marks the southern limit of the last great ice incursion. This extension of the great continental ice sheet is currently known as the "Des Moines lobe," and is bounded by the Altamont moraine. Upham* has shown the terminal moraine of the Des Moines lobe to be continuous with the Kettle moraine, and Chamberlain† has designated this drift sheet the "Wisconsin formation." An inner or Gary moraine, which marks a stage in the retrogression of the Des Moines ice, crosses the northern portion of Boone county in a north of west, south of east direction. Its most salient topographic forms are in the vicinity of the Des Moines river. The most prominent of these are popularly known as Mineral Ridge and Pilot Mound. The former is a long ridge

*Geol. and Nat. Hist. Surv. of Minn., p. 298. 1880.
†Journal of Geology, vol. III, p. 275. 1895.

rising from fifty to seventy feet above the drift plain, trending in a north of east, south of west direction through the town of Ridgeport, and is cut off by the Des Moines river. Pilot Mound is an isolated spur of the moraine and rises abruptly some seventy feet above the surrounding country. The town of Pilot Mound takes its name from this drift hill. The moraine in this section is rather sharply delimited on its inner edge, but it fades out gradually into a succession of low swells peripherally.

Boulders are everywhere abundant and present a familiar spectacle in fence corners and along roadways. The prevailing types are granites and gneissoid rocks, with a liberal sprinkling of the red Sioux quartzite.

Plate iv shows a large granite boulder in the foreground, with the "inner loup" of the terminal moraine in the background (Tp. 85 N., R. XXVI W., Sec. 2, Sw. qr., Sw. ¼). The boulder is coarse textured, and is composed essentially of quartz, red feldspar and hornblende.

Lithologically considered, the upper till is composed of an incoherent mass of clays, sands, gravels and boulders, which rarely occur singly but are usually intermixed in a most complicated manner. In general, this formation, as also the Kansan, may be subdivided into an upper oxidized and a lower unoxidized portion. According to numerous natural and artificial sections in this county, the basal portion of the Wisconsin drift attains a thickness of from forty to ninety feet. In color it is a grayish-blue, and contains more grit and is less massive than its anologue in the lower till. Fragments of wood are not uncommon. On the Steelworth farm, about two miles south of Boone, large fragments of wood were uncovered through the lateral corrasion of a small stream and the consequent caving of its bank. The specimens have the general character of our common red cedar (*Juniperus virginianus* L.). Although the distribution of woody fragments is general, yet, so far as now known, no well defined forest beds have been observed in this region.

THE GARY MORAINE IN BOONE COUNTY.

It seems highly probable that the erosive agencies were vigorously active early in the Wisconsin age, and the upper portion of the Kansan was thoroughly reworked and incorporated into the younger drift. The oxidized portion of the upper till is light yellow in color and averages from ten to forty feet thick. The Wisconsin formation, as a whole, is characterized by pebbles and boulders of the quartzitic and granitic types, and calcareous concretions are conspicuously present. The boulders are usually much larger than those of the Kansan drift and often present fresh, glassy surfaces.

ALLUVIUM.

Alluvial deposits accompany the principal streams, but they are of little importance away from the Des Moines valley. They consist essentially of black, sandy loam, mixed with the wash from the bluffs. In many instances the humus and river silt has been removed to a large extent, and a yellowish-gray sand results.

ECONOMIC PRODUCTS.

COAL.

Boone county has long been one of the leading coal-producing counties in the state. For nearly half a century coal has been known to exist in this region in quantities of economic importance, and has been long mined to supply local consumption. As early as 1849, Owen, in his excursion up the Des Moines river, noted the fact that the blacksmiths of the county obtained coal along Honey creek. Although coal was thus early known, a score of years elapsed before mining for export was initiated. After the advent of the railroad in 1866, mining operations were pursued with vigor, and the mining industry now ranks second only to that of agriculture.

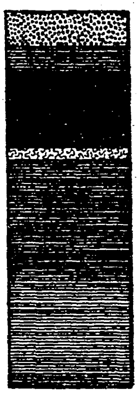
The mining regions of the county may be considered conveniently in three groups; those of the Des Moines valley, the Squaw creek basin, and the Angus region.

DES MOINES VALLEY MINES.

In the vicinity of Madrid local mines have been opened from time to time along the river south and west of the town, but all of these have been operated intermittently and only to supply the immediate neighborhood during the winter seasons. The more important mines are in the north central portion of the county.

MADRID DISTRICT.

Knox Brothers have, for years, operated a mine about four miles northwest of Madrid (Tp. 82 N., R. XXVI W., Sec. 10, Sw. qr. Sw. ¼). The vein worked at this point outcrops in the side of a ravine, some seventy feet above low water in the river. The seam averages about twenty-six inches in thickness, is of fair quality, has a good roof and is readily mined by drifting into the bank. About four miles from the south boundary line of the county is the Porter slope (Tp. 82 N., R. XXVI W., Sec. 8, Ne. qr., Ne. ¼). The section near the coal bed is as follows.



	FEET.	INCHES.
5. Limerock, impure, compact, bituminous "cap-rock"	1	
4. Shale, bituminous		7
3. Coal	2	6
2. Fire clay	4	
1. Shale, black, bituminous	7	

FIG. 20. Coal seam at Porter slope on the Des Moines river. Below Moingona.

The so-called "cap rock" is a black, very compact and brittle calcareous shale, highly fossiliferous and separated from the coal by a few inches of dark fissile shale. The vein of coal is about sixty feet above low water in the Des Moines river. The seam opened up here appears to be the same as that worked in the preceding mine. Two miles beyond, near a short bend in the river, is the Blyth slope (Sec. 5 of the same township and range), where two veins of coal are exposed; the lower one being about three feet above low water in the river and the other about four feet higher up. The lower seam ends abruptly toward the southward, being cut out, and the channel filled with clay. This vein is three feet in thickness, while the "upper" one is two and one-half feet thick. The upper seam especially, has a good roof. Figure 21 shows the above relations.

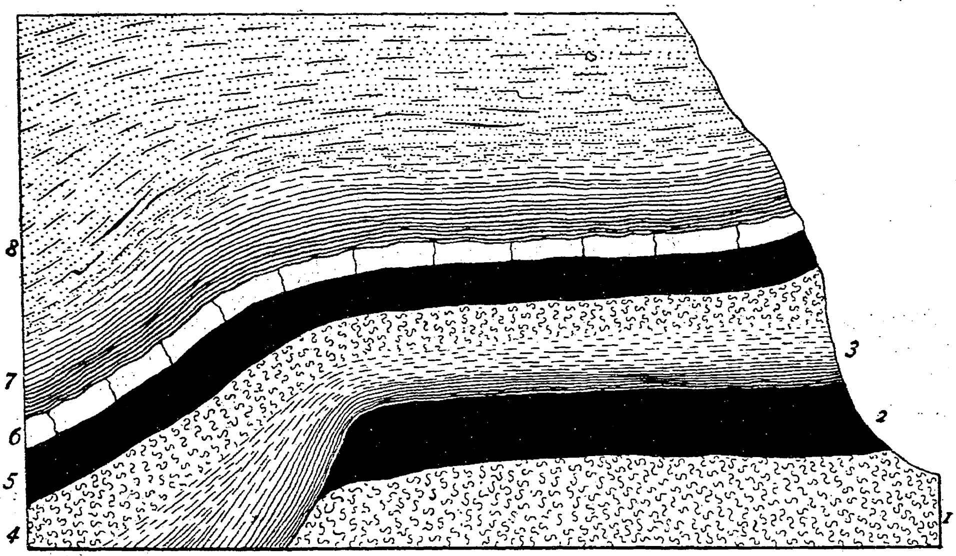
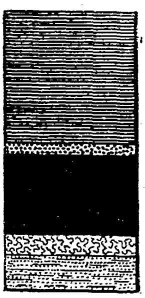


Fig. 21. Coal seams at the Blythe mine.

Continuing northward along the river, there are occasional outcrops of coal on either bank. On section 29 (Tp. 83 N., R. XXV W.), two veins of coal appear on the left bank of the stream. The lower of these is about twenty feet above water level. The seams are separated by a considerable thickness of clay and shale which, gradually thinning northward, finally disappears, the veins coalescing. Near the point of coalescence they are cut out by the Ledge sandstone. Between this point and Moingona the bluffs form high, mural escarpments of sandstone, through which deep labyrinthine ravines have been gouged out by numerous small streams as they approach their embouchures.

MOINGONA DISTRICT.

A mile below Moingona, on the west river bank (Tp. 83 N., R. XXVI W., Sec. 18, Nw. qr., Nw. ¼), is the Highland Chief mine which has been in operation for many years. It is a shaft sixty feet in depth and works the "upper vein" which is here from two to three feet in thickness. Near by is the Moingona Coal Co.'s shaft No. 6, the last mine opened by the company in the neighborhood. In the vicinity of the town coal crops out in many places in the sides of the Des Moines valley, and along the minor streams flowing into the river. Directly opposite the railroad station at Moingona is the White Smoke mine. This is a shaft put down in 1892; it is about fifty feet in depth and reaches the "upper vein," which has a thickness of about two and one-half feet. The section is:



	FEET.	INCHES.
5. Shale, bituminous	4	
4. Limerock, impure, very compact, bituminous, ferruginous		4
3. Coal	2	6
2. Fire clay		7
1. Sandstone (exposed)	1	

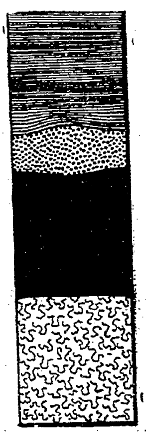
FIG. 22. Vein at White Smoke mine. Moingona.

There are several country banks in the vicinity which furnish considerable fuel for local use. This locality was formerly an important mining region, but at the present time comparatively little coal is being taken out. North of Moingona about one and one-half miles is the Clyde mine No. 2, which is now deserted. Still farther northward is the Ogden (Tp. 84 N., R. XXVII W., Sec. 27, Se. qr., Ne. ¼).

The coal mined at the Ogden mine was encountered at a depth of ninety feet; the mouth of the shaft is about eighty feet above the water level in the Des Moines river. An "upper" vein exists about seven feet above the lower but is not worked. A mile north of the Ogden is the Clyde No. 1, now abandoned. This is the southernmost of the more important mines which are comprised in the Milford area.

MILFORD DISTRICT.

The Rogers & Crow shaft (Tp. 84 N., R. XXVII W., Sec. 14, Sw. qr.), is located on the summit of the bluff and is 206 feet in depth. The drift deposits at this point are 100 feet in thickness. There are two veins of coal, the "upper" being about ten feet above the lower; the latter is on an average three and one-half feet in thickness; it is somewhat irregular, becoming in places considerably thicker and thinner than the measurement given; it is wanting at the base of the shaft, but it was encountered some ten rods distant towards the northeast by a lateral drift. The upper vein is somewhat thinner than the lower, but more uniform in thickness. There is also a third vein, said to be present about forty feet below the "lower vein." This third vein is not at present of economic importance at this point. About 200 yards to the northeastward is the Milford shaft which is located at the base of the bluff. It is 100 feet in depth, and also works in the "lower" vein, which here has a thickness of four feet. At the bottom of the shaft the layers shown are:



		FEET.
3.	Shale, bituminous, with band of impure nodular iron-stone at base	5
2.	Coal	6
1.	Fire clay	4

FIG. 23. Bottom of shaft, Milford mine.

The upper seam is ten to twelve feet above this and is three feet in thickness. Several thin veins were passed through in sinking the shaft before the upper seam was reached. Half a mile southeast of Milford is the Boone Valley shaft which is seventy feet in depth. The coal is three and one-half feet in thickness. A second vein is eight feet higher but only the lower one is mined at the present time.

Directly to the east are several shafts known as the Marshall mines. They are all located on the river bottom and work coal from two and a half to four feet in thickness, presumably the lower vein.

On the opposite side of the Des Moines river a number of mines are in active operation, one of the most important being the Hunt slope (Tp. 84, N., R. XXVII W., Sec. 13, Ne. qr., Se. ¼). Half a mile to the southward is the Marshall slope, which like the preceding, mines the "upper vein."

BOONESBORO DISTRICT.

Occupying the amphitheater in the great bend on the Des Moines river is the Boonesboro area, which immediately adjoins the Milford region on the east and is only separated from it by the river.

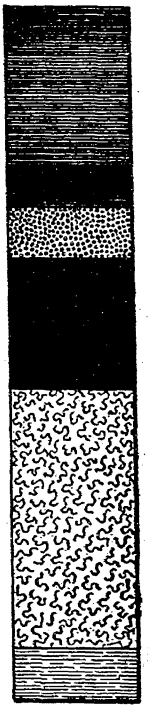
The W. D. Johnson mine is located on the summit of the bluff (Tp. 84 N., R. XXVII W., Sec. 24, E. ½). It is the oldest and

FIG. 24. Top works of the W. D. Johnson mine.

largest mine in the county. It has been operated continuously for more than thirty years. Finch & Company, of Des Moines, formerly operated it, but for more than a quarter of a century the mine has been under its present management. Two workable seams of coal are found, and both are worked by the longwall method. The following section of the shaft was prepared from an examination of small samples obtained by the foreman at the time of sinking.

		FEET.
29.	Soil	5
28.	Clay, yellowish	20
27.	Clay, bluish; considerable grit present	40
26.	Clay, yellowish-brown	40
25.	Clay, massive, blue, jointed	9
24.	Sandstone, ash-colored, shaly, graduates into 23	9
23.	Shale, gray-blue	3
22.	Shale, with ironstone concretions	3
21.	Sandstone, fine-grained, friable	12
20.	Shale, bluish and drab; containing numerous oxidized iron concretions	6
19.	Sandstone, ash-colored	12
18.	Shale, compact, massive	7
17.	Shale, light colored ("soapstone" of the miners)	5
16.	Sandstone, whitish, argillaceo-calcareous	13
15.	Sandstone, more compact and coarser in texture, calciferous	8
14.	Shale, black, bituminous, fissile below	3
13.	Fire clay and light colored shale	9
12.	Shale, hard, blue-black	5
11.	Fire clay	1
10.	Shale, compact, brittle; highly bituminous and often fossiliferous	3
9.	Coal	½
8.	Shale, variegated, arenaceous, calcareous; a parting between 7 and 9	1
7.	Coal, "upper" vein	4
6.	Fire clay	3
5.	Shale, variegated, with numerous ironstone concretions and septarian nodules	4
4.	Coal, "lower" vein	4
3.	Fire clay	3
2.	Shale, light colored; graduating into the strata below	3
1.	Shale, dark, bituminous	2

The "lower" vein is quite variable in thickness, containing many pinches and swells and attaining a maximum measurement of five feet. A half mile to the southeastward is the Heap mine which is a shaft 208 feet in depth. Only the "upper" vein is mined here; the "lower" being absent. It appears to be the same as the "upper vein" in the Johnson mine. The coal is from two to four feet in thickness. A little more than a mile to the southward is the McBirnie shaft 175 feet deep. The coal seam is from two and a half to three feet in thickness and has an excellent roof. The strata shown in connection with the coal at this point are as follows.



		Feet.	Inches
7.	Shale, black, highly bituminous	3	
6.	Coal		7
5.	Shale, bituminous, argillaceous		2
4.	Limerock, impure, shaly, "caprock"	1	
3.	Coal, 2 to 4 feet, averaging	2	6
2.	Fire clay	5	
1.	Shale, exposed	1	

FIG. 25. Section in McBirnie shaft. Boonsborough.

The vein mined probably belongs to the same horizon as the upper vein in the preceding mines. The bipartite character of the seam confirms this view. Opened in the same vein are a number of other mines, though at present they are not in operation. Among these may be mentioned the Flock and Clark mines, and the McBirnie and Nelson shaft. Between the McBirnie shaft and the Johnson mines two or three mines have been opened recently.

The most important of these is a shaft operated by the Zimbleman Coal and Mining company. This shaft is located about one mile from Boonesboro (Tp. 84, R. XXVI W., Sec. 30). The plant is equipped with modern machinery and mining is carried on according to the most approved methods. The seam worked and its including strata are essentially the same as at the Heap and McBirnie shafts.

FRASER DISTRICT.

About three miles north of the Milford area is the town of Fraser, which but recently has become the seat of considerable activity in coal mining. In 1893 the Boone Valley Coal & Railway company opened a mine (Tp. 85, N., R. XXVII W., Sec. 34, Sw. qr.). Several shafts have been sunk in the river bottom and mining operations are being vigorously pushed. The seam worked at this point has a thickness of from two to three feet and is probably the homologue of the "upper" vein represented farther down the river. This seam is popularly known among miners wherever it occurs as the "black jack" vein. This mine is provided with all modern improvements and finds convenient outlet for its products over a spur of the Minneapolis & St. Louis railroad. One mile north of Fraser on the right bank of the river are the Wilson and Zunkle mines (Tp. 85, N., R. XXVII W., Secs. 26 and 27). These are shafts 50 and 80 feet in depth respectively. They reach the same vein, which averages about three feet in thickness, and can probably be correlated safely with the "upper" vein of the Milford-Boonesboro area. The last two mines are only active during the winter months to supply fuel for the immediate vicinity. Although some prospecting has been done to the north of this, no mines have yet been opened within the limits of the county in that direction.

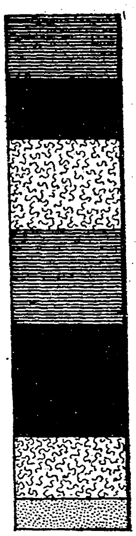
SQUAW CREEK VALLEY.

Considerable mining has been carried on in the vicinity of Zenorsville, in the eastern part of the county. The principal mines are three in number. The Hutchinson No. 1 (Tp. 84, N., R. XXV W., Sec. 12, Se. qr., Nw. ¼) is a shaft 125 feet deep with coal 28 inches in thickness. The section of the shaft is as follows.

		FEET.
11.	Soil, gray and sandy	1
10.	Clay, joint	40

		FEET.
9.	Shale, bluish	53
8.	Shale, light-colored	1
7.	Shale, bituminous; fissile below	2
6.	Coal	2
5.	Fire clay	3
4.	Sandstone, rather soft and friable	2
3.	Shale, lighter colored	4
2.	Shale, dark bituminous	3
1.	Coal	1

Hutchinson shaft No. 2 is located about 300 yards to the northward. It is on lower ground and is 105 feet in depth. The coal is nearly four feet in thickness. There is an upper vein present at this point about six feet above the lower, the latter only being mined. The section at the base of the shaft is shown in the annexed figure.



		FEET.
7.	Shale, bituminous fissile	3
6.	Coal, one to three feet, "upper vein"	2
5.	Fire clay	3
4.	Shale, bituminous	3
3.	Coal, "lower vein"	4
2.	Fire clay	2
1.	Sandstone, exposed	1

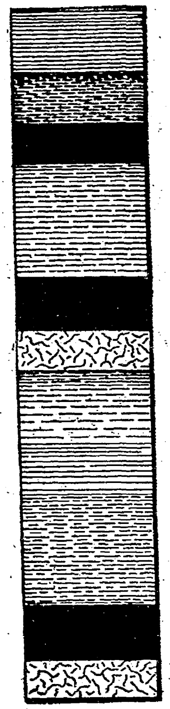
Figure 26. Coal bed in Hutchinson mine, near Squaw creek. Zenorsville.

Northeast of the Hutchinson mine about a quarter of a mile are the York and the Clemens mines, which at the present time are not in operation.

ANGUS MINES.

In the extreme southwestern portion of Boone county is a region which a few years ago was one of the most important mining localities in the state. It forms a part of the district which lies in portions of three counties; Boone, Dallas and Greene. The leading mines, however, were located in Boone. Altogether upwards of a score of shafts have been operated here. At the present time only a few are working, the principal ones running being the Angus and Dalby mines. Considerable confusion exists as to the exact correlation of the coal seams. There is one which is worked in the Angus mine and was formerly worked in the Craig, Ramsey and Panic shafts. Above this is a thinner seam which has also been worked to some extent in the Craig and the Hagger mines. This is the same vein which is said to crop out in the bluffs of the Raccoon river a few miles to the westward, but there is considerable doubt as to the correctness of the correlation. Lower down than the chief bed worked at the Angus mine is another seam which has been opened in the Dalby shaft. Beneath the first mentioned seam there has been reported a third coal bed, which, though not yet worked, has been encountered in borings. Other veins are also known to exist but none have yet been found thick enough for profitable working. The "third" seam is five and one-half feet in thickness according to the best information obtainable, and is located at a depth of ninety feet below the bed opened in the Keystone mine. All the mines are situated southwest of the Angus station. Drillings show that the seams extend beneath the town, but they are somewhat thinner and the roof is poor. A shaft put down east of the place was flooded after working but a short time.

The Angus mine, one of the largest now in operation, is located a short distance from Angus station (Tp. 82 N., R. XXVII W., Sec. 31, Nw. qr., Nw. $\frac{1}{4}$). It is a shaft fifty feet in depth, and is thought to be working in the "middle" seam. The coal is from three and one-half to five feet in thickness, with an average of about four feet. The section shows the following beds.



		FEET.
9.	Shale, light colored; exposed	5
8.	Shale, bituminous, indurated	4
7.	Coal	3
6.	Fire clay and shale	12
5.	Coal	4
4.	Fire clay	3
3.	Shale, bituminous below, light colored above	20
2.	Coal	5
1.	Fire clay	3

Figure 27. Section in shaft in Angus mine. Angus.

The seam is quite undulatory. A few faults have been met with and also several "horsebacks." Half a mile south of the Angus mine is the Dalby. This mine is a shaft 120 feet deep and works in the "lower" vein. The seam is from three to four and one-half feet in thickness; the roof is a hard, black shale and sandstone, but is in some places rather poor; the bed is somewhat undulatory, faults are rare. The bottom of the shaft shows the following beds:

		FEET.	INCHES.
5.	Sandstone, compact, massive; exposed	1	
4.	Shale, black, indurated, "black jack"		5
3.	Coal	3	5
2.	Shale, bituminous		2
1.	Fire clay, exposed	2	

Figure 28. Coal bed in Dalby shaft. Angus.

In several places a soft fire clay is found pressing up into the entry forming "creeps," one of which is represented in the accompanying figure 29.

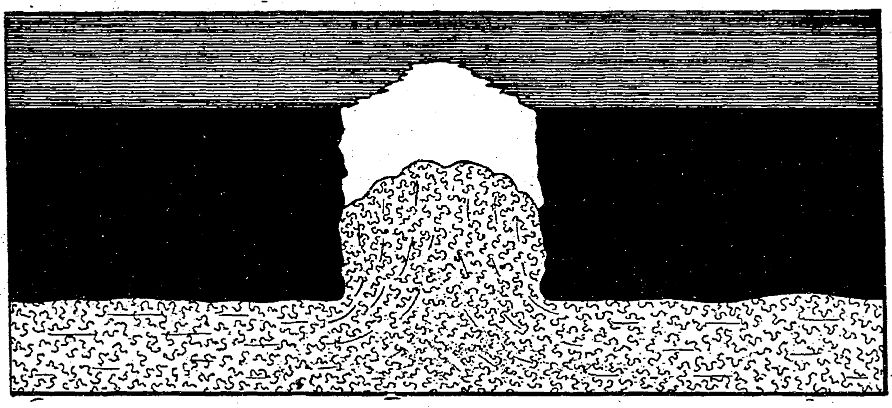


FIG. 29. "Creep" in Dalby mine. Angus

During the summer of 1883 several prospect holes were put down near the Boone county line in Greene county (Tp. 82 N., R. XXIX W., Secs. 10 and 11). The following composite section represents the sequence of strata.

		FEET	INCHES
24.	Soil and yellow clay	14	
23.	Clay, blue	25	
22.	Soil and gravel	6	
21.	Clay, argillaceous, blue below	21	
20.	Sand, water-bearing	1	
19.	Shale, light colored	4	
18.	Shale, dark	5	6
17.	Shale, compact, brittle	8	
16.	Shale, gray, blue; bituminous below	3	6
15.	Coal (coal blossom of miners)		1
14.	Fire clay		2
13.	Shale, ash-colored	7	
12.	Shale, bituminous, fissile below	3	
11.	Coal, somewhat shaly above		6
10.	Fire clay and light colored shale	8	
9.	Shale, black	2	
8.	Shale, brittle, compact	1	6
7.	Coal		7
6.	Shale, strongly bituminous, hard	3	
5.	Sandstone	4	
4.	Shale, ash-colored	3	6
3.	Shale, black, bituminous	6	
2.	Coal	1	
1.	Fire clay	2	

Four seams of coal were penetrated in this area, yet none were of sufficient thickness to warrant the beginning of mining operations.

SUMMARY.

All of the coal beds now mined in the Des Moines valley in Boone county may be referred tentatively to three horizons. The first has an elevation of from fifty to seventy feet above the water in the Des Moines river, and is the bed operated at the Knox and Porter slopes in the southern portion of the county, and the drifts along Honey creek in the central area. This horizon is usually overlain by a "caprock" of hard, brittle, calcareous shale which contains in abundance the remains of a marine fauna—Rhynchonella, Discina and Productus are the more common genera represented.

The second horizon occurs some fifty feet below the first and is the most persistent seam in the county. It is currently known as the "upper vein," or "black jack." The former name is in contradistinction to a lower vein which sometimes accompanies it; the latter name is often applied to it on account of its semi-lustrous jet-black color and somewhat bony character. This seam is operated at the Blyth drift, and in the Moingona, Boonesboro, Milford and Fraser areas. It is usually provided with a good roof and carries its thickness well—two essentials to profitable mining. The roof shale often contains well preserved specimens of the genus Lingula.

The third horizon occurs from four to twelve feet below the second and is usually denominated the "lower vein." The distribution of coal in this seam is somewhat anomalous; the coal usually occurs in lens-shaped masses (pockets) of limited extent. The roof is fairly good, but often contains numerous septarian nodules and clay ironstone concretions, which render mining somewhat hazardous unless due precautions are observed. The product of this vein is much sought for furnace and domestic use and commands the highest market price. At the present time the production of this coal is almost wholly limited to the Boonesboro–Milford area.

The regions away from the Des Moines afford but little data for their correlation with the central region. On lithological grounds, and because of the similarity in association of strata and of elevations, the seams worked in the Squaw creek basin may be referred with some degree of confidence to the second and third horizons in the Des Moines valley, probably being an eastward extension of that basin. Sufficient data are not at hand to attempt a correlation of the beds operated at Angus with those of the above regions.

CHEMICAL ANALYSES OF BOONE COUNTY COALS.

Experience has shown that it is impossible to formulate the criteria upon which the absolute value of a coal depends. Certain properties may not prove detrimental to the use of a coal for one purpose and yet seriously detract from its usefulness for another. Chemically, a coal usually is considered desirable if it contains high percentages of fixed carbon and of hydrocarbons, and low percentages of water, ash and sulphur. The subjoined analyses* may be considered representative of the principal Boone county coals.

	COAL.	H_2O.	Total comb	Ash.	Vol. comb.	F. carb.	Coke.	Sulp.	Sulphate.
1	Angus mine average	8.62	82.75	8.64	38.33	44.41	53.05	2.59	0.08
1a	Dalby mine average	2.84	88.36	8.12	43.08	45.29	54.08	4.33	0.14
2	Boonesboro average	12.37	81.90	5.87	48.24	43.72	49.41	------	------
3	Fraser	14.77	73.71	11.48	37 67	36.05	47.53	2.76	0.19

COAL LANDS.

To say that the entire region under consideration is underlain by the coal measures does not predicate that coal, in workable amounts, is universally distributed throughout Boone county. Sufficient data are not at hand to delimit the known

*Analyses—Nos. 1 and 2 were made by the survey and published in Vol. II, p. 505; No. 2 is taken from White's Report, Vol. II, pp. 390-391; No. 3 was made by the Department of Agricultural Chemistry of the Iowa Experiment Station.

coal basins, but certain it is that they have a much wider range than is suspected at the present time. Systematic prospecting has been confined almost wholly to the Des Moines valley in the north central portion of the county, although the strata have been explored over very limited areas in the vicinity of Angus and Zenorsville. Fully fifteen-sixteenths of the area of the county remains unexplored and offers an attractive field for the prospector. The diamond core drill would be found a valuable adjunct to the equipment of the progressive operator, and a judicious use of this instrument in the further development of the coal mining industry in Boone county would, undoubtedly, be rewarded with adequate returns.

The land now owned or leased by mining companies, and, therefore, properly considered as under development, are indicated on the map accompanying this report. The holdings of the different companies are indicated by numbers corresponding to those in the following list.

1. Boone Valley Coal & Railway Co.
2. Moingona Coal Co.
3. Clyde Coal & Mining Co.
4. Crow & Marshall Coal & Mining Co.
5. Milford Coal & Mining Co.
6. W. D. Johnson Coal & Mining Co.
7. Garden Hill Coal & Mining Co.
8. Zimbleman Coal & Mining Co.
9. James Wilson.
10. Mineral Ridge Coal Mining Co.
11. Joseph York.
12. Hutchinson Bros. & Son.
13. J. Clemmens.
14. W. Zenor.
15. Highland Chief Mine.
16. Riverside Coal Co.
17. W. D. Morgan.
18. Porter Bros.
19. Knox Bros.

1*a*. Excelsior Coal Co.
2*a*. Climax Coal Co.
3*a*. North Angus Town Lot & Coal Co.
4*a*. Angus Coal Co.
5*a*. Standard Coal Co.

BUILDING STONE.

But little has been done to develop the quarry industries of the county. As a rule the soft, incoherent character of the coal measure strata does not warrant the outlay of capital necessary in opening up quarries. At two or three points along the Des Moines river some quarrying has been done from time to time, the product being utilized in the rougher grades of masonry in the immediate vicinity. West of Madrid a calciferous sandstone has been quarried intermittently for more than a third of a century. Some of the stone used in the construction of the old court house in Des Moines is said to have been derived from this source (Section 11, No. 2).

In the central portion of the county the "Ledge" sandstone affords an abundance of constructional material which ought to receive more attention than has been accorded it heretofore. In the main it is a soft, buff to reddish sandstone or freestone, containing large concretions, which are highly refractory and some of which may be quarried advantageously. That even the matrix which holds these ferruginous or quartzitic concretions withstands weathering agencies is abundantly attested by the mural walls which have resisted the elements for thousands of years. This rock, when properly selected, will be found durable for above ground and above water structures, and its somewhat open texture will hold the mortar well.

Although the older strata furnish some valuable stone for constructional purposes, yet this is not the most important source. The great ice incursion made a generous contribution to the building materials of the region. Numerous boulders, some of which are of enormous size, are distributed over most of the county and are especially plentiful in the morainal area. The prevailing types are gray and red granites and red quartzites. An abundance of material suitable for foundations, roads, and monumental purposes is afforded. As a rule the economic importance of these stepping stones to wealth is not appreciated by the inhabitants and but feeble attempts have been made toward their utilization.

LIME AND CEMENT.

There are no limekilns or cement works within the borders of the county. Certain argillaceous limestones are present in the coal measures which might be made into a hydraulic cement of acceptable quality. Such deposits are of limited extent and not readily accessible.

CLAYS.

No county in the state is more bountifully supplied with clays of good quality, suitable for structural and ornamental purposes, than Boone. Clay shales and bituminous shales of the coal measures are abundantly exposed especially along the Des Moines river and its tributaries south and west of Boonesboro. To the southward they are cut by the "Ledge" sandstone, but they reappear farther down the river. The coal measures are overlain by a thick deposit of glacial debris, which is composed largely of calcareous clays. The upper drift, however, has been altered and the superficial covering, to a depth of from two to five feet, is now a siliceous, brown to grayish, somewhat alluvial-like soil.

Along the Des Moines the usual bottom land prevails. Near the stream the strictly alluvial character is noticed, but towards the slopes much of the slightly changed lime-bearing drift clay mixed with loamy material occurs a few feet beneath the alluvial surface.

At the present time the numerous clay-working factories in Boone county utilize the alluvium, the drift soil and the coal measure shales. The first of these has been adopted by several of the brick makers at and in the vicinity of Moingona. The drift soil is being extensively used at the yards west and southwest of Boone, and the shale clays at points east of the river in the same region. Only common structural brick are made of the unconsolidated clays, but the indurated beds are successfully manufactured into different grades of building brick, fire brick, tile and pottery.

BOONE CLAY WORKS.

The Boone clay works are located in the extreme southwest corner of Des Moines township, about two and one-half miles from the county seat. This factory was started during the latter part of the summer of 1889 by J. B. McHouse, present proprietor. A No. 2 kiln was used the first three years; at the end of this time the works were enlarged and a No. 1 put in. A dry pan made by the Des Moines Manufacturing Co. is used in pulverizing the raw material.

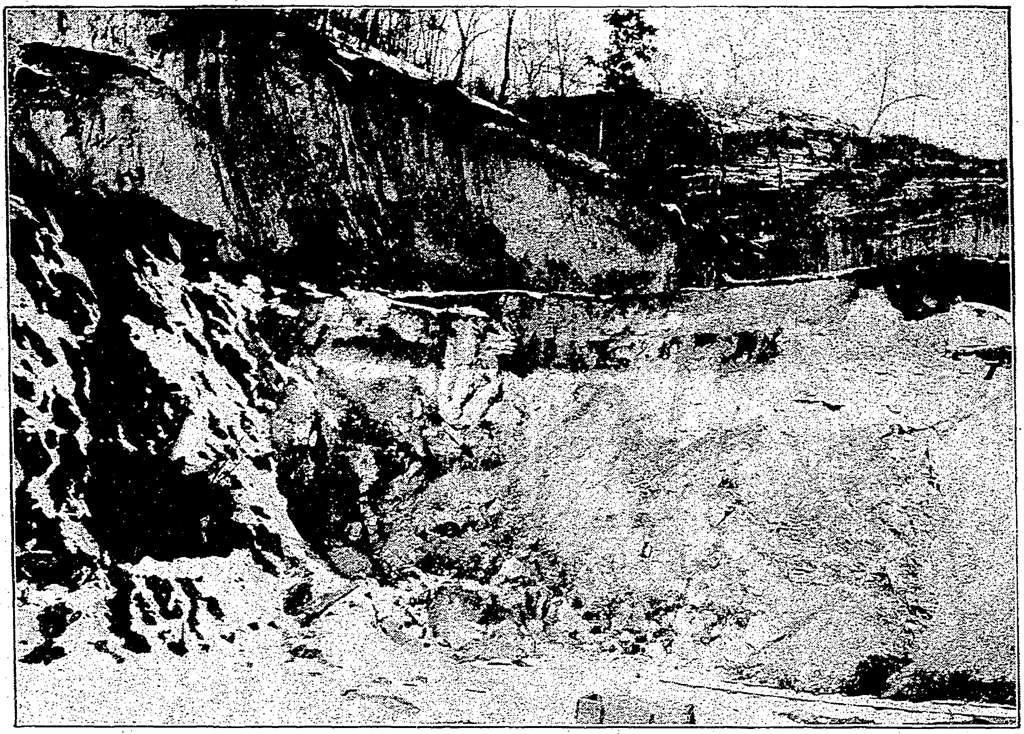


FIG. 30. Clay pit of Boone Clay Works.

The coal measure shales are developed here, and wrought into drain tile, sidewalk blocks, structural and fire brick. The following section is descriptive of the bank exposed.

		FEET.
9.	Drift	15+
8.	Potters clay	1½
7.	Clay shale, steel-colored	2
6.	Clay shale, gritty, ash-colored, iron-stained in the upper part	4

		Feet.
5.	Clay shale, colored red, blue and gray	12
4.	Shale, deep red, ochreous band	$\frac{2}{3}$
3.	Clay shale, similar to 2	2
2.	Fire clay	$1\frac{1}{2}$
1.	Shale, impure (exposed)	3

The above relations are shown in Fig. 30, taken from a photograph. The drift clay, which abounds in nodules of lime and hard pebbles, must be removed. Of the under clays, No. 3 is the principal clay used. It is of excellent quality and contains sufficient iron to give a good color to the finished products. The bottom clay is used in making fire brick. These command a fair price, and recently the output has been greatly increased. The entire bed is above the water level of the small branch which flows near by and is entirely available after the stripping is removed. Work at this point is carried on in a very expeditious manner. No loss is sustained through the ware checking as it becomes freed of its moisture. Drain tile is the principal product.

BOONE PAVING COMPANY.

The works of this company are located on the summit of the bluffs along the Des Moines river, near the extremity of the Shepardtown switch of the Chicago & Northwestern railway. Work was begun here several years ago, but through inadvertence rather than any other cause, the effort was not a success. During 1891 and 1892 the plant was idle. Since then the paving company has introduced new machinery, and at the present time is engaged in the manufacture of pavers of acceptable quality. The clay used belongs to the coal measures and is taken from a few feet above the river. It is raised on an incline to the works. The stripping necessitated is great. Over the clays desired there lies, perhaps, fifty feet of glacial debris, consisting mainly of sand and sandy clay abounding in lime concretions. It is impossible to mine the clay without removing the drift, since there is no adequate roof. However, the position of the bank renders stripping possible with a minimum expenditure of labor. At the base of the drift the section is:

		FEET.
5.	Clay shale, gray, rather pure; bituminous	$2\frac{1}{2}$
4.	Clay shales, gray, rather pure; bituminous parting at the base	1
3.	Clay shales, upper part white, pure; lower part somewhat variegated	3
2.	Limestone, impure fossiliferous	$\frac{2}{3}$
1.	Clay shales, color light gray	5

All of the above beds, excepting No. 2, can be utilized in making various products, but at present are used exclusively in the manufacture of paving brick. The clay is first treated by a Des Moines dry pan, then it is transferred to a Frey-Sheckler machine. The product is burned in a Eudaly kiln, holding 125,000, or in one or two ordinary down draft kilns, with a capacity of 26,000 each. The brick have been used in paving some of the principal streets of the city of Boone.

THE N. W. GRIFFEE POTTERY WORKS.

This plant is located in West Boone. Pottery making was begun here nearly thirty years ago, and during the last quarter ter of a century the factory has been under the present management. The raw material is obtained from the east bank of Diamond Hollow, about one-third of a mile eastward from the Des Moines river. The bed worked is but two feet thick. The upper two or three inches are of a dark gray color, and of good quality; under this is a buff, siliceous clay, sandier in the lower portion. A mixture of the two grades affords the best results. Over the clay lies a limestone ledge, which serves as a roof, the clay being mined by drifting into the side of the hill. Under the clay a sandstone appears. One ordinary down draft rectangular potters' kiln is used for burning. The product consists of the ordinary vessels in various sizes and shapes, the extreme capacities being one quart to twenty gallons. In addition to the plain ware, fancy ornamental pieces and toys are made. A ready market is found for the finished product at various points along the

Chicago & Northwestern railway and branches, between Marshalltown and Council Bluffs.

Other pottery works have existed in this locality, but at present the plant just described is the only one in operation.

THE JACOB YEGGE BRICKYARD.

This yard is located on the level upland, about one mile southwest of Boonesboro. The material used is known as "white oak" clay. On the surface it appears to be a light colored soil, which becomes brownish below. It can be used to a depth of perhaps two feet. The deposit is followed by a yellow, jointed, somewhat gravelly clay, which contains numerous particles and concretions of lime. The brick, the only product made, are moulded by hand, dried on the yard and burned in cased kilns, the largest kiln holding 442,000 brick. Four days are required for weathering and about five to burn the brick properly.

In the vicinity of Boonesboro, F. Bowman, Dean & Bowman, S. Smiley, J. Benson and L. Stephens operate brickyards. At all of these yards the raw material is of the same character as that utilized at the Yegge works. The methods employed in preparing, drying and burning the product are essentially the same. Moreover, the bricks themselves are almost identical with those of the Yegge yard. It seems, therefore, unnecessary to give separate descriptions of each plant. The F. Wilcox yard, between Moingona and Ogden, may be classed in the same category. T. Franklin started a small brickyard on the east side of the river and may also make some pottery. The clay used is the same as at Griffee's.

THE SLATER YARD

Mr. Slater was the pioneer brickmaker at Moingona. He opened a plant in the southwestern part of town as early as 1866. Work has been prosecuted ever since, but, until six or seven years ago, only sand-rolled brick were made. Machinery was then introduced and used for several years, but at present the greater proportion of the product is made by hand. The "white oak" clay for the hand-made brick is similar to that at Boonesboro, and is taken from the hilltop just south of the works. A few buff-colored bricks have been made from an almost white shale of good quality, which is exposed in a ravine near by. The dry-press brick were manufactured from a red shale. This shale outcrops near shaft No. 6 of the Moingona Coal company, and varies from three to six feet in thickness. This clay burns to a bright cherry-red color.

THE EVERETT YARD.

This comparatively new plant is located just southwest of the Chicago & Northwestern depot at Moingona. The raw material is taken from what might properly be called the "second bottom" deposit. The stratum utilized varies from one to five feet in thickness and is of a yellow to brown color. In texture it is somewhat sandy, yet rather strong, and grades upward into the surface soil, all of which is being utilized with good results.

There are three other manufacturers of clay products in this vicinity; two are near the station, the Erickson, and the McCloud & Carpenter, and a third is about a mile and a half southeast of town on the east side of the Des Moines. The last named factory is owned by S. Boles, who uses a clay essentially the same as that at the Everett bank. Both of those near the station use a loamy material. The Erickson clay belongs to a more recent deposit and is by no means strong. Attempts have been made to use the yellow under clay from the second bottom which lies below that used at the McCloud & Carpenter yard. All such attempts have proved futile on account of the excess of lime. The methods employed at these yards are similar. The brick, which are known as sand-rolled, are dried in the yard and burned in cased kilns. The color of the product is almost invariably good.

Small brick yards have been opened at several points along the river north of Moingona, but in material used, methods pursued and the final product are essentially the same as in those just described.

G. ECKERT YARD.

In 1893 this small plant was established at Madrid and has been operated continuously since. It is located about three-fourths of a mile southwestward from the town. The material used is a rather sandy drift soil about two feet in thickness. The brick are hand-moulded and burned in temporary cased kilns. L. L. Wheeler also operates a small yard in this vicinity.

SOILS.

As has been said the drift completely mantles the county and hence the soil is a heterogeneous mixture of sand, clay and vegetable humus, and bears no relation to the country rock. Although the surface materials have an extraneous origin and are of a composite nature, yet several well marked types may be distinguished. The principal streams are flanked on either side by alluvium, varying from a few inches to several feet in depth. The soil contains a considerable percentage of sand and is a quick, warm soil often highly productive. The crests of the bluffs adjoining the Des Moines valley and an area extending some distance inland are capped with a gray, ash-colored soil (white oak soil). The timber limit is almost coincident with the distribution of this type. The upland region which comprises seven-eighths of the area of the county is covered with a thick layer of grayish-brown to black, sandy loam.

In many cases, especially in the western half of the county, the soil is so heavily charged with humus it attains a jet black color and is extremely close-textured. On account of its great retentive power as regards water, it is often imperfectly drained and is not considered arable. Nearly one-fourth of the superficial area of the county remains untilled because of imperfect ventilation and drainage. To show that such soil does not lack the proper chemical constituents, but that its apparent worthlessness is due to physical conditions, the following analyses are appended.*

	Phosphoric acid P_2O_5		Potash.		Nitrogen.	
	Soluble in H Cl.	Soluble in Citric acid.	Soluble in H Cl.	Soluble in Citric acid	Total.	Soluble in Citric acid
1. Upland, well drained	0.20	0.0118	0.27	0.0039	0.179	0.0032
2. Upland, poorly drained	0.15	0.00235	0.33	0.0060	0.301	0.0150

The analyses require but little comment; the relative value of the two soils represented by the samples considered, measured in terms of available plant food is plainly evident, yet sample 2, was taken from supposedly the poorest land in the region.

Whitney has shown that the productiveness of a soil depends even in a greater degree upon its texture and physical constitution than upon its chemical composition. The apparent need of a considerable area of the county is the introduction of tile drains. By such means thousands of acres might easily be rendered tractable, and would soon become the most productive land in the region. Tile could readily be produced in the immediate vicinity, for no county possesses a greater amount of clay suitable for the purpose.

ROAD MATERIALS.

Sand and gravel knolls are not uncommon over the county, and these taken in conjunction with the stream sands and gravels afford an abundance of road material. The above sources also furnish an adequate supply of sand suitable for building purposes.

ARTESIAN WATERS.

The deep well in the city of Boone demonstrates the improbability of being able to obtain a flow from the great

*The above analyses were taken from a paper entitled The Chemical Analyses of Soils, by Prof. G. E Patrick, Iowa Acad. Sci., vol. II, p. 65. Des Moines, 1895. The samples were taken in Pocahontas county where the relations are similar to those in Boone.

sandstone formations of the lower Paleozoic. Of the drift wells, there are two well marked artesian basins represented in the county; the Beaver creek basin and the area drained by Squaw creek. All of the wells in these two areas afford but weak flows, yet the amount of water is sufficient for local consumption. The water is usually highly tinctured with salts of iron, but not in sufficient quantities to seriously interfere with its use for domestic purposes, and it seems to have no deleterious effects on stock. These wells range from 50 to 150 feet in depth. In other portions of the county good water is generally obtained at a depth of from 20 to 150 feet.

MINERALS.

Pyrite.—The coal measure shales afford an abundance of pyrite crystals, some of which reach a high degree of perfection. They usually occur as parallel growths and often form masses of considerable size composed of sub-individuals. The pyritohedron is the prevailing type.

Gypsum.—Good crystals of selenite are often encountered in the lower members of the drift. They usually occur in seams one or two inches in width, composed largely of "swallow tailed" twins. Gypsum is also not uncommon in the coal measures, filling interstices in shale, and it often appears as thin, white, semi-translucent partings in the coal itself.

Calcite.—This mineral in the crystalline form is rarely found in this locality. It enters largely into the formation of partitions in the septarian nodules and often occurs in small amounts in certain sandstones and shales. One of the most interesting forms assumed by calcium carbonate is that popularly known as cone-in-cone. Beautiful examples of this structure are found in the argillaceous shales along the Des Moines river near Madrid. This occurrence was noted by Owen* during his ascent of the Des Moines river in 1849. He describes it as "a band of translucent calcareous spar, having the prismatic structure of aragonite, and the fibrous prisms

*Geol. of Wis., Ia. and Minn., p. 123.

collected, however, into perfect conical bundles, with the apex of the cone turned either directly downward, or sometimes upwards, the external surface of the cones crimped, possessing in fact, at the same time, the most perfect *tutenmergel* structure, as if produced by some combined process of stalactitic infiltration and simultaneous crystallization." The cone-in-cone seam occurs some twenty feet above low water and varies from one and a half to three inches in thickness. It is practically parallel to the enclosing strata and gradually thins out and disappears laterally. A chemical examination by Prof.

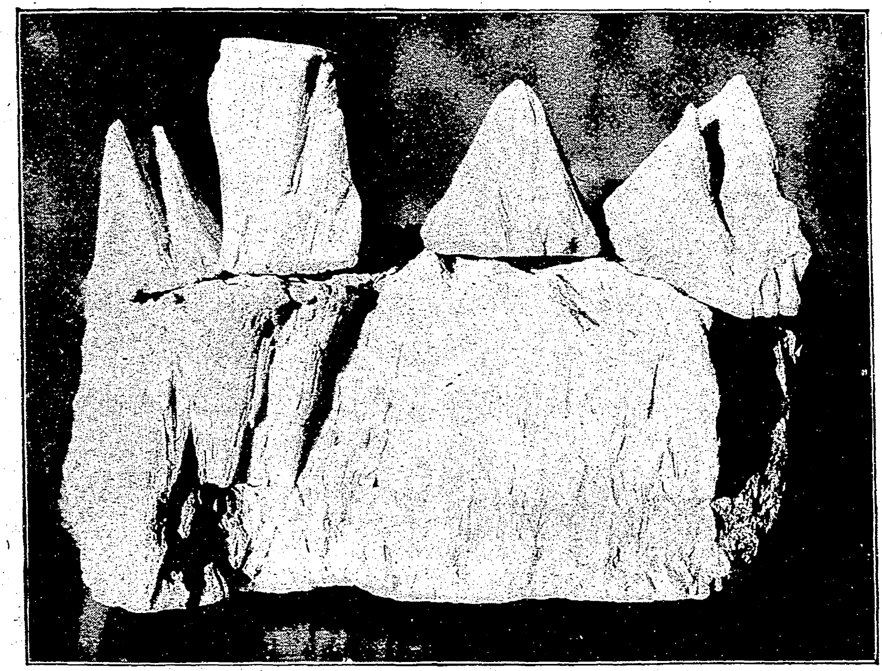


FIG. 31. Undisturbed cones in the lower portion with several detached cones above.

G. E. Patrick proves the substance to be essentially calcium carbonate ($C_a\ CO_3$ —83. 12 per cent.) contrary to the opinion of Dr. Owen who believed it to be the sulphate.

ACKNOWLEDGMENTS.

In the preparation of the present report the writer has received much valuable information from the officials of the various mining companies and clay industries. The officers of the W. D. Johnson Coal & Mining Co., the Boone Clay

works and the Boone Paving Brick Co., especially, have been courteous in co-operating with the representative of the survey. Mr. E. E. Chandler and Mr. E. D. Roberts of the city of Boone, have rendered generous assistance in placing at the disposal of the survey, the records of numerous shafts and wells in the vicinity. To them and to many others who have facilitated the work in many ways, the writer's best thanks are due.

CHARACTER AND DISTRIBUTION OF FOREST TREES AND SHRUBS IN BOONE COUNTY.

BY PROF. L. H. PAMMEL.

Central Iowa is not covered extensively with forest growth, and Boone county forms no exception to the rule. Its timbered area is, however, greater than that along the Skunk river in Story county, but fourteen miles distant. The timbered portion of Boone county covers an area varying from three to six miles in width. It is confined to the Des Moines river and its tributaries.

Two features are especially noteworthy: first, the timbered area of the alluvial and sandy flood plain of the Des Moines river and its larger tributaries; second, the timber occupying the hilly country, which consists of numerous valleys, elevated ridges and hills. There is usually a sharp demarkation of the species of the alluvial flood plain and the hilly country. The first area is occupied almost exclusively by the white elm (*Ulmus americana*) and the common cork elm (*U. racemosa*), soft maple (*Acer dasycarpum*), box elder (*A. negundo*), cottonwood (*Populus monilifera*), black walnut (*Juglans nigra*), willow (*Salix sps.*), and green ash (*Fraxinus viridis*, *F. sambucifolia*).

Among the hills the dominant trees are red oak (*Quercus rubra*), bur oak (*Q. macrocarpa*), white oak (*Q. alba*), chestnut oak (*Q. muhlenbergii*), green ash and white elm less commonly than along the river, butternut (*Juglans cinerea*), shell-bark hickory (*Carya alba*) and bitternut (*C. amara*).

On steep hillsides facing the river, ironwood (*Carpinus caroliniana*) and hop hornbeam (*Ostrya virginica*) occur. Slippery elm (*Ulmus fulva*) is abundant. In thickets, *Prunus americana*, *P. virginiana*, *Pyrus coronaria*, *Cratægus mollis*, *C. punctata*, *Cornus alternifolia* and *Viburnum pubescens* are also common to the bluffs.

Without doubt the soil bears an important relation to the kind of tree or shrub produced, and, to a certain extent, the soil and geological formation is an index to plant life. Most collectors in North America have given this subject very little attention.

The appended list of shrubs and trees found in Boone county, is in part represented by specimens in the Agricultural college herbarium. The remaining plants on the the list are inserted from observations by the writer, Dr. S. W. Beyer, or Messrs. Sirrine and Carver. In arrangement and synonomy Gray's Manual, sixth edition, has generally been followed.

ANGIOSPERMS DICOTYLEDONÆ.

TILIACEÆ.

Tilia americana L.

Hills and second bottoms; abundant.

RUTACEÆ.

Xanthoxylum americanum Mill.

Abundant in hilly woods.

CELASTRACEÆ.

Celastrus scandens L.

Upland woods, frequently climbing over small trees and shrubs; highly ornamental.

Euonymus atropurpureus Jacq.

Common in woods and on second bottom.

RHAMNACEÆ.

Rhamnus lanceolata Pursh.

Local, in upland woods. (Carver.)

Ceanothus americanus L.

Dry woodlands and along railroads on the prairies; abundant.

C. ovatus Desf.

Probably occurs on very dry drift soils; occurs in Story county.

VITACEÆ.

Vitis riparia Michx.

Abundant in upland woods and bottoms, climbing over shrubs and large trees.

Ampelopsis quinquefolia Michx.

Abundant in woods, first and second bottoms and uplands.

SAPINDACEÆ.

Aesculus glabra Willd.

On second bottoms and hillsides; not uncommon.

Acer dasycarpum Ehrh.

Low grounds and alluvial bottoms; abundant.

A. nigrum Torr. and Gray.

Hills; abundant.

Negundo aceroides Moench.

Low, rich grounds; abundant.

Staphylea trifolia L.

Upland woods and high banks.

ANACARDIACEÆ.

Rhus glabra L.

Abundant along the border of the woods and dry, sterile grounds.

R. toxicodendron L.

Low grounds and dry soil; abundant.

LEGUMINOSÆ.

Amorpha canescens Nutt.
Dry, sterile hills; abundant.

A. fruticosa L.
Common on low grounds and along streams.

Robinia pseudacacia L.
Introduced in places.

Gymnocladus canadensis Lam.
Common along streams.

Gleditschia triacanthos L.
Common along streams and on low grounds.

ROSACEÆ.

Prunus americana Marshall.
Forming thickets; abundant.

P. pennsylvanica L.
Valleys and rich woods; infrequent.

P. virginiana L.
Upland woods and steep banks; common.

P. serotina Ehrb.
Infrequent in upland woods.

Rubus occidentalis L.
Dry hillsides and upland woods; common.

R. villosus Ait.
Upland prairies; abundant.

Rosa arkansana. Porter.
Borders of woods and open prairies; abundant.

Pyrus coronaria L.
Common in the bottoms of all the smaller streams, forming large thickets.

Crataegus mollis Torr. and Gray.
Woods; frequent.

C. tomentosa L.
Frequent in upland woods.

C. punctata Jacq.
Thickets, borders of woods and second bottom.

Amelenchier canadensis Torr. and Gray.
Upland woods; frequent.

SAXIFRAGACEÆ.

Ribes cynosbati L.
In woods; not uncommon.

*R. gracile** Michx.
Low grounds in woods and open places; abundant.

R. floridum L'Her.
Low grounds, second bottoms and moist places in upland woods; frequent.

CORNACEÆ.

Cornus paniculata L'Her.
In upland woods; frequent.

C. alternifolia L.
Rocky woods; abundant near the "Ledges."

CAPRIFOLIACEÆ.

Sambucus canadensis L.
Bottoms; abundant.

Viburnum pubescens Pursh.
Rocky woods and declivities; abundant near the "Ledges."

V. lentago L.
Not uncommon in woods.

Symphoricarpus occidentalis Hook.
Rocky woods; common.

Lonicera glauca Hill.
Common in upland, moist woods.

RUBIACEÆ.

Cephalanthus occidentalis L.
Bottoms and sloughs; abundant.

OLEACEÆ.

Fraxinus viridis Michx.
Alluvial bottoms and upland woods; abundant.

F. sambucifolia Lam.
First and second bottoms; common.

URTICACEÆ.

Ulmus fulva Michx.

Abundant in upland woods.

U. americana L.

Valleys of upland woods and low bottoms; abundant.

U. racemosa Thomas.

This beautiful tree was only observed on the second bottom, near the "Ledges."

Celtis occidentalis L.

Low alluvial bottoms; Des Moines river.

Morus rubra L.

Local; Des Moines river bottom; not common.

PLATANACEÆ.

Platanus occidentalis L.

Bottoms along Des Moines river; not uncommon.

JUGLANDACEÆ.

Juglans cinerea L.

Second bottom and upland woods; abundant.

J. nigra L.

Common; rich soil; second bottom and alluvial bottoms of the larger streams.

Carya alba Nutt.

Upland woods; common.

C. amara Nutt.

Common; upland woods; especially in valleys and second bottoms.

CUPULIFERÆ.

Corylus americana Walt.

Upland woods; abundant.

Ostrya virginica Willd.

Abundant on exposed hills; "Ledges" and Moingona.

Carpinus caroliniana Walt.

Upland woods; rare. (Carver.)

Quercus alba L.

Hills and ridges; common.

Q. macrocarpa Michx.
Hills and ridges; common.

Q. muhlenbergii Engelm.
In valleys; fine, large trees; common.

Q. rubra L.
In valleys, second bottoms and on ridges; abundant.

Other species of Quercus undoubtedly occur in the county, as they have been observed near Des Moines and Webster City. At the latter point *Quercus texana* Buckley has been collected. It is not improbable that this species and *Q. coccinea* Wang occur in Boone county.

SALICACEÆ.

Salix nigra Marsh.
River banks and alluvial bottoms; abundant.

S. longifolia Muhl.
Sandy banks of the Des Moines river; abundant.

S. humilis Marsh.
Hills, prairies; frequent.

S. cordata Muhl.
Probably occurs in swampy ground. Reported from Story county by Hitchcock. (Catalogue Anthophyta and Pteridophyta of Ames, Iowa.)

Populus tremuloides Michx.
Upland woods; frequent.

P. grandidentata Michx.
Record has not been made of the occurrence of this species in the county, but I believe it occurs.

P. monilifera Ait.
Abundant on alluvial and second bottoms; also near coal mines and on talus slopes.

MONOCOTYLEDONÆ.

LILIACEÆ.

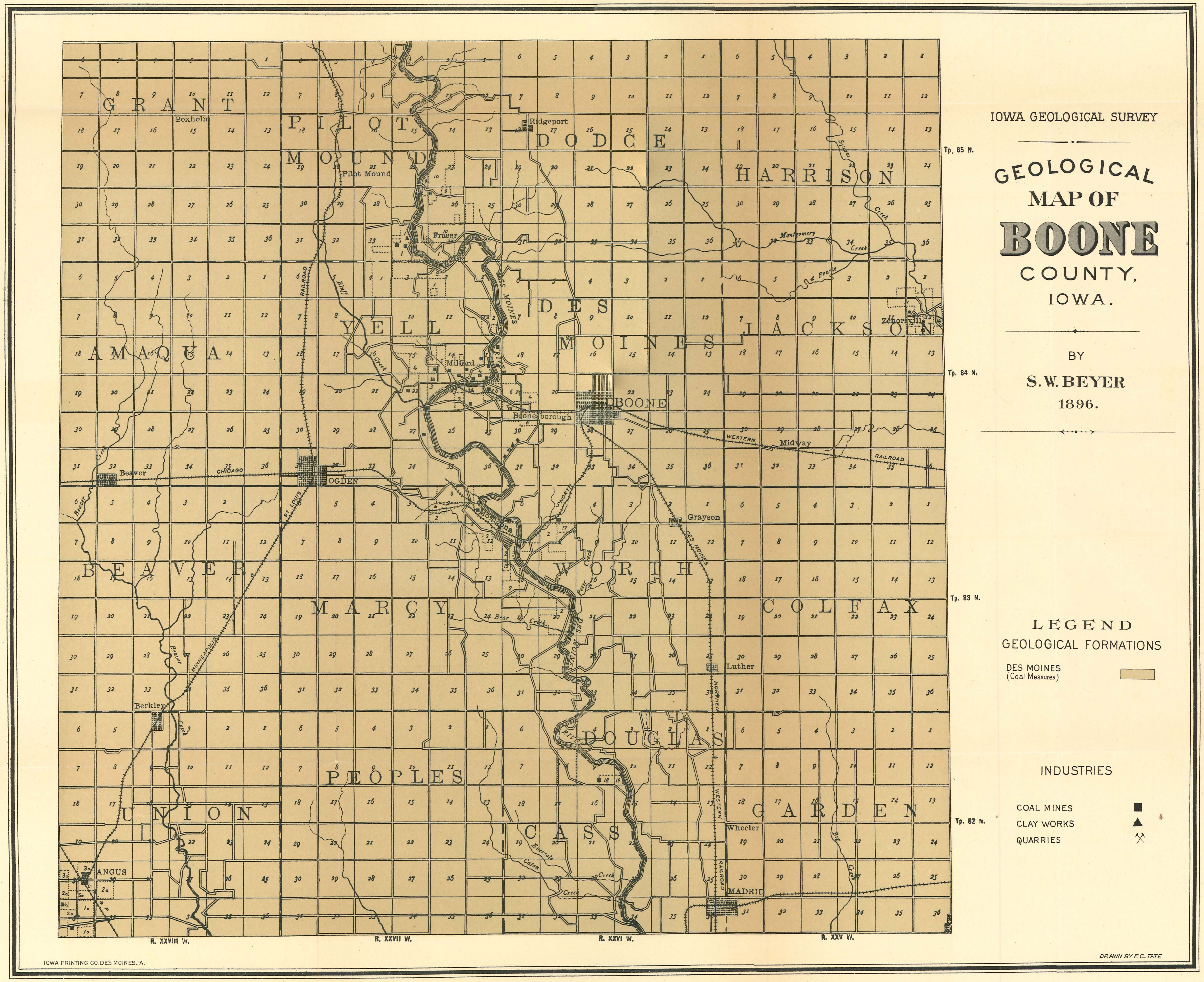
Smilax hispida Muhl.
In rich, upland woods; infrequent.

GYMNOSPERMÆ.

CONIFERÆ.

Juniperus virginiana L.

High bluffs; local; occasionally a tree on the most exposed salients. Perhaps it was once more common than now. The only Conifer native to the county.



IOWA GEOLOGICAL SURVEY
GEOLOGICAL MAP OF BOONE COUNTY, IOWA.
BY S. W. BEYER 1896.
LEGEND
GEOLOGICAL FORMATIONS
DES MOINES (Coal Measures)
INDUSTRIES
COAL MINES
CLAY WORKS
QUARRIES
Tp. 85 N.
Tp. 84 N.
Tp. 83 N.
Tp. 82 N.
R. XXVIII W.
R. XXVII W.
R. XXVI W.
R. XXV W.
GRANT
PILOT MOUND
DODGE
HARRISON
AMAQUA
YELL
DES MOINES
JACKSON
BEAVER
MARCY
WORTH
COLFAX
UNION
PEOPLES
DOUGLAS
CASS
GARDEN
Boxholm
Ridgeport
Pilot Mound
Fraser
Milford
Boonesborough
BOONE
Midway
Zenorsville
Beaver
OGDEN
Grayson
Luther
Berkley
Wheeler
ANGUS
MADRID
IOWA PRINTING CO. DES MOINES, IA.
DRAWN BY F. C. TATE

GEOLOGY OF WOODBURY COUNTY.

BY

H. FOSTER BAIN.

GEOLOGY OF WOODBURY COUNTY.

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INTRODUCTION.

LOCATION AND AREA.

Woodbury county lies on the western border, well toward the northern corner of the state. It is within sixty-five miles of the north state line; Lyon, Sioux and Plymouth counties intervening. The latter county lies directly north of Woodbury, while Ida borders it on the east, and Monona county on the south. On the west the Missouri river separates it from Nebraska, and the Big Sioux from South Dakota. The county lies at the head of the great bend in the Missouri river, where the stream changes its easterly direction and starts south on its journey to Kansas City. It includes a belt of country twenty-four miles wide stretching back from the river about thirty-six miles. Owing to the irregularities in the river boundary at the west, and the influence of correction lines in the northeast, it contains numerous fractional pieces of land, the total area being 860 square miles or considerably more than a half-million acres.

PREVIOUS GEOLOGICAL WORK.

The factor of location which so early made the chief city of the county a prominent trading post, its position at the turning point of the great river, has been equally potent in causing the early geological study of the region. The swinging of the river here to the extreme eastern limit of its valley has made numerous excellent exposures. These, in connection with the comparative ease with which they were visited, caused the earlier geological work in the region to start from this point. From the time when the Lewis and Clarke expedition ascended the river and collected fossils from these strata down to the present day every geologist who has worked on the region has studied the exposures near Sioux City. In the future as in the past, if one would most easily and surely learn of the stratigraphy, not only of northwestern Iowa, but of the whole upper Missouri region, he should begin his work with a study of these classic exposures.

A review of the observations of different workers in this region will be given in connection with notes on the different formations. It is perhaps sufficient to notice here that, of the official surveys of the state, the first or Hall survey, did not enter the region. During the second survey, both Doctor White and Mr. St John, studied the deposits of Woodbury county, though the short time allowed to the work did not permit much more than a reconnoissance. At the inauguration of the present survey the importance of the study of the exposures of this county as a key to the geology of the northwestern portion of the state was clearly recognized. During the first field season Doctor Calvin visited the county and his observations were recorded in the first volume of the present series of reports. This work so happily begun has since been carried on by other members of the survey.

PHYSIOGRAPHY.

TOPOGRAPHY.

The present surface relief of Woodbury county has been produced by the action of erosive forces. To get a clear conception of it one must first picture to himself an all but level, or very gently undulating plain, having a slight surface inclination to the south and west, and lying at a general elevation of about 1,400 feet. It should be conceived as composed of a material capable of catching and holding every line and curve carved upon it by the delicate tracery of a vigorous drainage system. Upon such a plain the rivers have worked, and in it they have carved their record of the past.

If a line be drawn from Sioux City to the south boundary of the county, about four miles west of Smithland, the land west of the line may be considered a second plain even more monotonously level than the one described, and lying some 300 feet below it. This second plain forms the bottom land of the Missouri and is, at its widest point in Woodbury county, some seventeen miles from bluff to river bank. On the Nebraska side there is a corresponding bottom land, beyond which may be seen the dark green of the Blackbird Hills and their northern continuation. Through this broad plain the Missouri wanders with many a crook and turn, marked on a summer day by clouds of dust gathered by the wind from its many lowlying islands and sand bars, with here and there a bright gleam of sunlight reflected from the swiftly moving waters.

This bottom land of the Missouri forms a marked topographic feature in the county, comprising, as it does, over 200

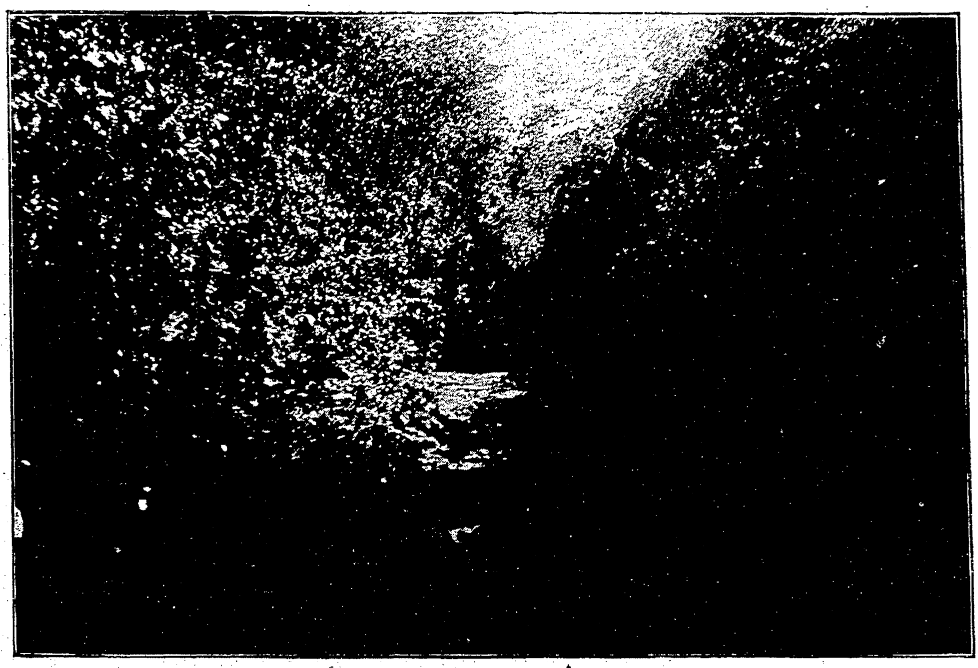


FIG. 32. Heavily wooded ravine in the loess region.

square miles, or nearly one-fourth of the entire area. The bluffs jut out upon it in a long, narrow spit at Sargents' Bluff, and the interior rivers of the county have cut their channels down nearly to its level and are now engaged, with their many minor tributaries, in reducing the whole area to this level. The work is new to them, and while the loess mantle cuts easily, it does not break down rapidly. The result is that the land along the streams presents an intricate and rugged series of erosional topographic forms. Deep, sharp-angled, steep-sided ravines lead back to abrupt earthern headwater bluffs over which, in rainy seasons, small streams dash merrily and fall foaming on the gravel below. Above such a fall may be seen the low swale of the upland, fully grassed over, and with slopes so gentle that, while serving for a catchment basin, they do not give current enough for the waters to cut away the sod. Below the thirty or forty foot bluff is a deep, narrow defile, fully wooded and usually dark, with sides almost too sharp for climbing, and with a gravel-strewn bed of a wet-weather stream at the bottom. Occasionally narrow terraces form a fit shelf for a wagon road, but usually they have themselves slipped out of place.

In the region between Smithland and Hornick, comprising the point of land between the Little Sioux and the Missouri

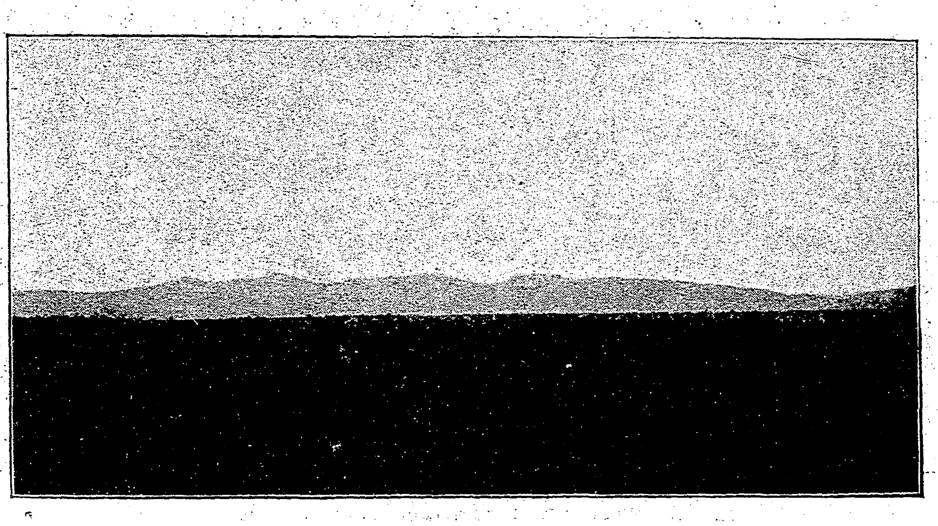


FIG. 33. Missouri escarpment; where the upland meets the lowland.

bottom lands, the tributary streams have cut into the hills and converted them into a series of intricately connected ridges barely wide enough at times to form a pathway, and with the sharp loess contours so sloping on either side that, as one walks along the crest, he unconsciously begins to balance himself as on the comb of a house roof. More frequently, however, these paths are wide enough to serve for wagon roads, and a drive along these old, now unused trails affords an ever changing succession of views at once striking and picturesque.

At the edge of the great bluff, where the upland drops abruptly down and becomes the lowland, the side streams have at many points cut off isolated, or nearly isolated hills, such as Prospect Hill in Sioux City. These hills of circumdenudation stand out abruptly with their beautiful flowing lines and gracefully carved peaks, resembling in the soft, dim afterglow of a summer evening, nothing so much as the towers and turrets of ancient castles. The beauty of the topographic forms seen in the county is a result of the great thickness and peculiar character of the surface material, which is the well known loess. This deposit exhibits here, to a superb degree, its characteristic of receiving and retaining those soft lines and curves which mark an unstable topography. The gently flowing concave slopes found here would never occur, or would soon be lost, in any other save a loess-covered or a rainless region.

There are three well marked types of topography within the limits of the county, the upland plain, the Missouri flood

FIG. 34. Loess hill east of Hornick.

plain, and the intervening stream-cut areas. The first is normally the characteristic prairie or drift plain type of long, low, rolling swells, flattening out into occasional broad areas of absolute level, and never exhibiting sharp profiles. It is covered, where uncultivated, by the tough wild grass of the prairies, and is unforested except where trees have been planted. The second is an even more monotonous level plain in which the smaller streams lose themselves and convert large areas into swamp land. The larger rivers cut across the plain in ditch-like channels. Above its level are raised a few sand dunes which form points in the landscape, as do also the quiet lakelets or sleepy lagoons formed of half-filled, and slowly silting up reaches of the river's abandoned channel. It is a broad, monotonous plain, fenced off into huge cattle ranches of thousands of acres in extent, where the ranch-house forms a conspicuous feature of the view, and is of sufficient importance to become a special station on the railway.

Where the upland plain meets the lowland, and in the vicinity of all the streams which flow across the region, the beautiful and intricate topography already described has been developed.

TABLE OF ALTITUDES.

The following altitudes are taken from the profile of the various railways, the notes of the Missouri river commission, and of the city engineer; they are in the main as given by Gannett. The elevations in Sioux City are referred to a uniform datum line which is approximately 998 feet above sea level. This amount has been added to the figures obtained from the engineer's office.

STATION.	Altitude.	AUTHORITY.
Anthon	1119	Ill. Cent. Ry.
Correctionville	1108	C. & N-W. Ry.
	1129	Ill. Cent. Ry.
Cushing	1279	C. & N-W. Ry.
Danbury	1311	C. & N-W. Ry.
Hornick	1073	C., M. & St. P. Ry.
James	1145	Ill. Cent. Ry.
Luton	1086	C., M. & St. P. Ry.
Morning Side	1241	C., M. & St. P. Ry.
Pierson	1272	C. & N-W. Ry.
Rodney	1091	C., M. & St. P. Ry.

STATION.	Altitude.	AUTHORITY.
Moville	1155	C. & N-W. Ry.
Oto	1094	Ill. Cent. Ry.
Salix	1092	S. Cy. & P. Ry.
Sargent's Bluff	1103	S. Cy. & P. Ry.
Sioux City—		
City reservoir	1342	City engineer.
Engine house, First street	1098	City engineer.
Douglas street, near Twenty-fourth	1314	City engineer.
Twenty-eighth street, near Virginia	1292	City engineer.
Jennings street, near Thirty-sixth	1317	City engineer.
Mondamin hotel, east door	1104	City engineer.
Northwest corner High school grounds	1228	City engineer.
Prospect Hill, top	1281	City engineer.
Prospect Hill, top of sandstone	1097	City engineer.
Jones street and Seventh	1195	City engineer.
Jones street and Tenth	1205	City engineer.
Jones street and Eleventh	1217	City engineer.
Head of Bacon Hollow	1398	Barometer.
Depot	1104	C., M. & St. P. Ry.
Low water	1076	Riv. Com.
High water	1099	Riv. Com.
Perry creek	1094	S. Cy. & P. Ry.
Floyd creek	1080	S. Cy. & P. Ry.
Sloan	1084	S. Cy. & P. Ry.
Smithland	1076	Ill. Cent. Ry.

DRAINAGE.

Woodbury county is well watered and drained by numerous streams belonging to the Missouri river system. The Missouri river itself forms the greater portion of the western boundary of the county. In this region it flows in a broad valley from one and one-half to seventeen miles wide, cut down through the rock to a depth frequently eighty to one hundred feet below the present water level.

The sandstone at the foot of Prospect Hill rises twenty-one feet above the low water mark of January 29, 1871. The solid rock is encountered 43.90 feet below low water, at a distance of 30 feet from the edge of the river on an extension of Kansas street. At 280 feet from the river's edge the rock lies at 34.70 feet below the water. At the Chicago, St. Paul, Minneapolis & Omaha railway bridge the depth to rock is slightly greater. The stream has a wide flood plain lying about 300 feet below the general level of the prairie. The banks are made up of loose unconsolidated materials, the river in this portion of its course being entirely free from rocky bars. The approximate average width from Sioux City to the mouth of the Platte is at high water 820 feet, and at low water 650 feet.*

Its current at low water stage is two to three miles per hour, and in time of flood it reaches as much as ten miles. There are two regular floods, the first being in April and lasting but a week or ten days; it is quite violent and seems to come from the upper river. The June rise is generally higher and of longer duration, being influenced by local rains and general saturation of the soil. The bottom land near Sioux City is at times covered in part by the waters of the Missouri and its tributary streams. The loose nature of the banks and the rapidity of the current causes the stream to carry a heavy load of sediment.

It has been shown by Major Suter that the channel of the Missouri is in reality a series of inter-locking pools. The width of the river allows the formation in it of a series of bars, on either side of which is deep water. These pools are so arranged that the head of one is about opposite the middle of the pool on the other side of the bar. The water thus finds its way from pool to pool, cutting across the bars in narrow, shifting channels. The bars act, to a certain extent, as dams, and even in stages of high water their effect on the rapidity of the current is plainly apparent. They also force the current against the bank where eddies are generated and erosion becomes active. In those reaches of the river where the stream is too narrow to allow the formation of bars, its course is but little changed since the earliest surveys (1817); elsewhere the changes have been many.

The second largest stream in the county is the Big Sioux, which forms the western boundary of the county from the northwest corner to the mouth of the river near Sioux City.

*Suter: Improvement of the Missouri; House Ex. Doc., 46th Cong., 3rd Ses., No. 92, p. 9. Washington, 1881.

It is a stream of considerable size and has a fall in a direct line of about 1.4 feet to the mile, or probably not more than six inches to the mile following the actual course of the stream. Below Westfield, in Plymouth county, the stream has properly no valley of its own, but flows close along the eastern border of the larger Missouri valley. In Woodbury county it is bordered by sharp, high bluffs, of which Cedar Bluff is, perhaps, the best known, made up of the indurated Cretaceous rocks, in the lower portion, covered principally with loess. It is along this river that the greater portion of the best Cretaceous exposures in Iowa occur.

Below the mouth of the Big Sioux river there are but two streams which flow directly into the Missouri within the limits of the county. These are Perry creek and Floyd river. They reach the Missouri river within the limits of Sioux City, and have very largely influenced the character of the surface upon which the city is built. Perry creek rises in the southwestern portion of Plymouth county and flows in the general direction of the slope a distance of seventeen miles in a direct line, with a total fall of nearly 180 feet. The average fall, following the stream, is probably not far from five feet to the mile. The current is rapid, the valley is narrow, and the bluffs are composed of loess and drift.

The Floyd river rises in O'Brien county and, flowing across Sioux and Plymouth into Woodbury, enters the county about ten miles east of the Big Sioux. From this point it flows southwest to the Missouri, having within the limits of the county a total fall of twenty-three feet, or about 3.2 feet to the mile. It is larger than Perry creek and throughout most of its course flows through a beautiful alluvial valley one to two miles wide, bounded by low, rounded, drift covered hills. Near Sioux City, extending, indeed, beyond the Plymouth-Woodbury line, there are exposures of Cretaceous.

Big and Little Whiskey, Elliott and Camp creeks are smaller streams flowing nearly south, and losing themselves upon the Missouri bottom in a slough now drained into the west fork of the Little Sioux. This latter stream flows across the county in a narrow, steep-sided valley lying from 100 to 180 feet below the general level of the plain. It cuts through the bluffs and comes out upon the Missouri bottom land near Holly Springs. Mud creek, and eventually Whiskey creek, drain into it from the west, while from the east it receives Wolf creek, itself an important stream with numerous tributaries.

The Little Sioux river is one of the larger and more important rivers of northwestern Iowa, having its source in Minnesota and falling over 500 feet to its mouth in Monona county. The greater portion of this descent is made before the stream enters Woodbury county. A little less than a mile below Correctionville, it is only nine feet above the Missouri river at Sioux City directly west. In a direct line the fall of the river in the county is about two feet to the mile, but by the stream it is probably more nearly three-fourths of a foot per mile. The valley is from one to two miles wide and is bounded by steep bluffs 300 to 400 feet high. In the lower portions of the river's course the bluffs show the presence of loess only; farther up the stream sandy gravel and drift, topped by a thin veneer of silt-like loess, is seen. The stream has evidently cut its channel down to grade and is now engaged in widening its valley.

The river, with its smaller tributaries, drains in this county an area of about 216 square miles. Within the county it receives from the west Pierson and Rock creeks, and from the east Bacon, Wright, Parmelly and Miller creeks. Eventually it receives also the waters of the West Fork and its tributaries, as well as of Maple river. Maple river is, within this county, independent of the Little Sioux. It cuts across the extreme southeastern corner of the district for a distance of about seven miles, draining nearly seventy square miles of the county. It receives, within the county, Reynolds and Koker creeks.

STRATIGRAPHY.

General Relations of Strata.

The rocks of Woodbury county belong to two distinct and widely separated periods between which is an important time break. The underlying indurated beds are of Cretaceous age. Above these, and concealing them except at a very few points, is a heavy covering of Pleistocene deposits consisting for the greater part of loess. Between the loess and the uppermost Cretaceous beds are the gravels and boulder clays of the drift, as well as certain obscure sands and clays whose exact relations are not very clearly defined.

The following table represents synoptically the different formations present.

Classification of Formations.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.		Alluvium.
		Glacial.		Loess.
			Kansan.	Drift.
	?			Riverside sands.
Mesozoic.	Cretaceous.	Upper.	Colorado.	Niobrara chalk. Benton shales.
			Dakota.	

GENERAL GEOLOGICAL SECTION.

The greater part of the exposures of these beds may be seen in the immediate vicinity of Sioux City. A complete section may be found in passing from Sargent's Bluff to Cedar Bluff. Such a section would show the following beds.

		FEET.
16.	Loess of usual character, variable in thickness	50
15.	Clay, plastic, brown; weathering yellow along joints, usually free from grit, pebbles rarely found	6
14.	Gravel, drift pebbles; not always present, varying greatly in thickness	10
13.	Sand, fine, white, even-grained; with occasional small, granitic pebbles; no distinctively northern gravel	12
12.	Limestone, thinly bedded, containing numerous shells of *Inoceramus labiatus* and with interbedded chalk layers	50
11.	Shale, buff, sandy, with layers of sandstone one to two inches thick and with ferruginous concretions	18
10.	Shales, drab to dark blue, fine-grained, argillaceous	22
9.	Sandstone, fine, white, soft	4
8.	Shale, drab, fissile	12
7.	Lignite, impure, two to three inches	¼
6.	Sandstone, coarse, yellow, quartzitic	7
5.	Shale, clayey, dark blue to drab	12
4.	Sandstone, fine-grained, homogeneous, white	25
3.	Lignite, more or less earthy, usually dark purple	1½
2.	Shale, variegated, brilliant orange to olive green, with beds of fine sand and ferruginous concretions containing plant remains	18
1.	Shale, sandy, reddish, becoming drab to orange below, and containing plant remains	25

Of the above section, numbers 1 to 4 inclusive are exposed at Sargent's Bluff. Numbers 4, 5 and 6 make up the Prospect Hill section. Numbers 6 to 11 inclusive may be seen at Riverside. Numbers 10 to 12 are particularly well seen at Cedar Bluff; lower beds also occur there. Numbers 13 to 15 may be seen in the gravel pits at North Riverside.

Numbers 1 to 9 inclusive may be referred to the Dakota. Numbers 10 and 11 make up the Benton, and number 12 represents the Niobrara. Number 13 is of uncertain age; 14 to 15 represents the drift beds, and 16 is later.

PRE-CRETACEOUS STRATA.

Strata older than the Cretaceous are not exposed within this county, and hence their presence and character can only be known from borings and from studies of neighboring outcrops. North of Woodbury county, in the region surrounding Sioux Falls, there are numerous exposures of the Sioux quartzite, a formation probably of pre-Paleozoic age. Toward the east, the limestones and associated beds of the Carboniferous and earlier Paleozoic systems appear. South of Woodbury is found the latest phase of the Carboniferous as developed in Iowa. The beds of this system are exposed as far up the river as De Soto, and there pass below the Cretaceous.

The oldest strata exposed at the surface in northwestern Iowa and adjoining region is the Sioux quartzite. This has been referred to the Algonkian system, and is considered as pre-Paleozoic in age. There is little reason for believing that before the latest Cretaceous it was ever entirely below sea level, and it may not have been altogether covered even then. It has formed, from earliest times, a peninsula or an island, which has been gradually sinking. The pre-Paleozic surface of this island has been shown by Todd* to have been exceedingly irregular. Certain gray granites referred to the pre-Paleozoic were encountered in the Sioux City well at a depth of 1,515 feet, or 355 feet below sea level, while at Le Mars similar beds occur 150 feet above sea level. At Pawnee City, Neb., gray schists were encountered at 620 feet above the sea level. At 785 feet below sea level the Omaha boring had apparently failed to pass through the Carboniferous. The quartz-porphyry at Hull, which probably belongs to the same series, lies at 878 feet above sea level, while at Sioux Falls the quartzite itself has an elevation of about 1,400 feet.

Apparently this old surface sank beneath the water at the same time that the isle of Wisconsin was rising, so that, whereas, in the case of the latter, the central core is surrounded by a series of belts of later formations of which the oldest is nearest the center, the reverse is true of the Sioux island. It seems that each succeeding formation overlapped

*Am. Geologist, vol. XV, p. 64, Minneapolis, 1895.

the earlier one, and it was only in Niobrara times that the region as far north as Carson, S. D., was under water.

The following is the record of the strata passed through in sinking the deep well at Sioux City. It is in part based upon notes furnished by Mr. D. A. Magee, and in part upon an examination of the drillings as preserved by him. The elevation of the mouth of the well is, according to Todd, 1,160 feet.

NUMBER AND NAME.	Thickness	Depth.
14. Loess	60	60
13. Drift	25	85
12. Shale	54	139
11. Sand and Sandstone	191	334
10. White sandstone	100	434
9. Gray sandstone	110	540
8. Sand and gray limestone alternating	115	655
7. Limestone, gray and white	150	805
6. Limestone and shales	445	1250
5. Sand, red above	25	1275
4. Sand and marl	45	1320
3. Limestone	190	1510
2. Hard brown rock	15	1525
1. Micaceous schist	589	2011

It seems impossible definitely to correlate each of the members of the section. Numbers 13 and 14 can, of course, be placed in the Pleistocene. It seems most probable that the base of number 9 marks the lower limit of the Cretaceous. Number 1 and probably number 2 belong to the pre-Paleozoic. Just what portion of the Paleozoic is represented by beds 3 to 8 cannot be certainly stated.

The well diggings at Sioux City and Le Mars show, between this underlying pre-Paleozoic complex and the Cretaceous beds, the presence of a series of limestones which have been usually referred to the Carboniferous. Such a series is usually found in wells drilled throughout the region. Whether these beds represent the Mississippian or some later portion of the Carboniferous cannot be definitely stated. It is even probable that they, in part, represent still earlier beds of the Paleozoic.

That there must have been at some time during the Carboniferous a shore line surrounding the Sioux island is obvious; that such a shore line would afford favorable conditions for the formation of coal is probable; but as yet this old shore line has not been found, and it is not at all certain that it ever will be. Between the close of the Paleozoic and the opening of the Mesozoic this entire region suffered very heavy erosion, and by far the greater portion of the Carboniferous beds under this region seem to have been swept away.

STANDARD SECTIONS.

Among the various natural exposures in the county a few have been selected which together represent all the beds

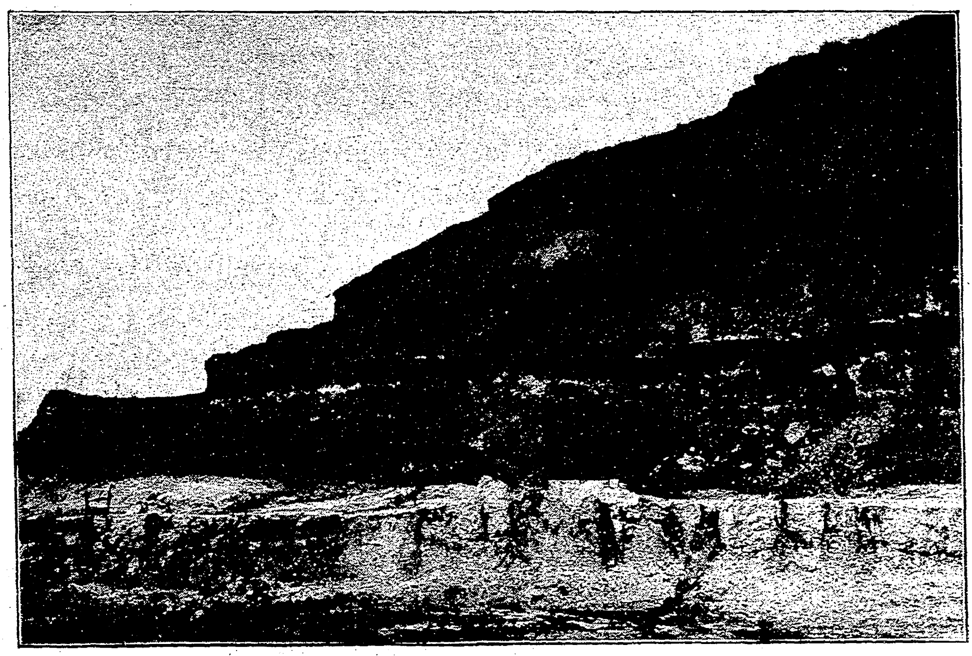


FIG. 35. Dakota formation, showing clays, lignite and sandstone, capped by loess; Sargent's Bluff, Woodbury county.

exposed at the surface, and which may be combined to make the general section already given. The lowest strata exposed within the limits of the county may be be seen in the well known outcrop at Sargent's Bluff, seven miles south of Sioux City.

SARGENT'S BLUFF SECTION.

		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

Number 4 of this section forms the lowest member of the Prospect Hill section and occurs just below the surface at North Riverside. A section at the latter point, including the strata exposed in the pit of the Sioux City Paving Brick company and those found in borings at the pottery immediately above, is as follows.

		FEET.
15.	Shale, sandy	14
14.	Shale, drab, fissile	12
13.	Sandstone, impure, calcareous	1
12.	Shale, drab, fissile	16
11.	Sandstone, fine, white, soft	4
10.	Shale, drab, fissile	12
9	Lignite, impure, 2 to 3 inches	¼
8.	Sandstone, coarse, yellow, quartzitic	7
7.	Clay, white, plastic	19
6.	Sandstone, soft, shaly	14
5.	Clay, clear, drab	2
4.	Shale, argillaceous, very hard	4
3.	Fire clay	2
2.	Sandstone, hard, ferruginous	3
1.	Clay, fine, clean	16

Numbers 8 to 15 of the above section may be seen in the clay pit at the brick plant mentioned. Number 7 is exposed in a tunnel near by and was passed through at the pottery. The strata below this bed were found in the explorations at the latter place. Of the section, numbers 12 to 15, are referred to Benton; the lower beds, with all of the Sargent's Bluffs section, may be referred to the Dakota.

North of Riverside, the strata rise a little, and at Cedar Bluff, the best and most noteworthy exposure in the county, the corresponding beds appear a few feet higher above the river. The section here, as measured by corrected barometric readings, is as follows.

CEDAR BLUFF SECTION.

		FEET.
9.	Loess	30
8.	Limestone, thinly bedded, exposed in slope above; actual exposure, 20 feet, total limit	50
7.	Shale, buff, sandy, with layers of sandstone one to two inches thick, and ferruginous concretions	18
6.	Shale, drab to dark blue, fine-grained, argillaceous	22
5.	Sand and lignite mixed	1½
4.	Sandstone, white, calcareous, loosely consolidated	10
3.	Shale argillaceous, sandy in part, drab to blue	15
2.	Sandstone, white to orange, coarse-grained, with ferruginous concretions	10
1.	Shale, variable, largely arenaceous; imperfectly exposed	30

Number 7 of this section is number 15 of the Riverside section, and number 2 is apparently number 7 of that section, and may be examined at a number of exposures between the two points. While number 4 of the Cedar Bluff section and number 11 at Riverside occupy the same horizon, it does not seem that they are directly connected. At Cedar Bluff the Dakota includes numbers 1 to 5; the Benton is shown in 6 and 7, and the Niobrara in 8.

Above the Cretaceous, and below the loess and associated glacial deposits, is a sand bed, well shown in the pits northeast of the Brugier bridge at Riverside.

SAND PIT SECTION.

		FEET.
4.	Loess, usual character, variable thickness	30
3.	Clay, plastic, brown; weathering yellow along joints, usually free from grit; pebbles rarely found	6
2.	Gravel, erratic drift pebbles	½
1.	Sand, fine, white, even-grained, with occasional small granitic pebbles, no distinctly northern gravel	12

In the greater number of exposures throughout the county these beds are absent, the loess resting directly upon the Cretaceous, or with only an occasional thin layer of gravelly drift intervening.

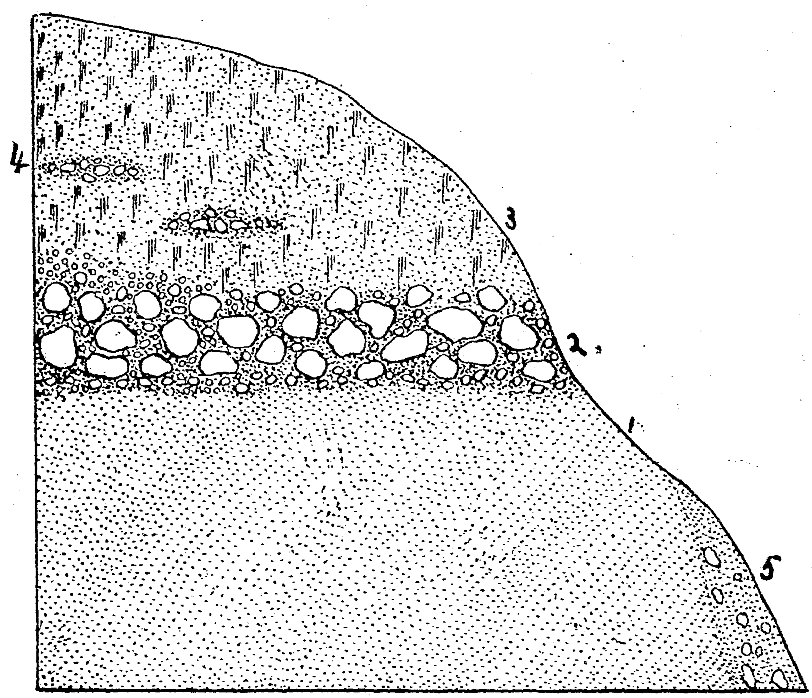


FIG. 36. Sand pit at Riverside opposite street railway station.

The character of these exposures and the relation of the drift to the loess are well shown in a small gravel pit opposite the Riverside Park street railway station.

5. Talus of loess.
4. Small lenses 4–14 inches in diameter, of coarse gravel and boulders in the loess.
3. Loess of usual character, exposed 15 feet.
2. Layer of large boulder erratics, varying from 2 inches to 1 foot in diameter, with sand in the interstices.
1. Sand cross-bedded, coarse-grained; grains $\frac{1}{12}$ to $\frac{1}{8}$ of an inch in diameter; really a very fine gravel, containing frequent pebbles $\frac{1}{2}$ to 1 inch in diameter, and occasional large, flat-sided, granitic boulders 8 inches or more in diameter, exposed 10 feet.

TYPICAL EXPOSURES.

The best natural sections exposed within the county are found along the Missouri and Big Sioux rivers. Of these, the Sargent's Bluff, North Riverside and Cedar Bluff sections have already been given.

At the foot of Prospect Hill, within the limits of Sioux City, and lying between Floyd river and Perry creek, is an exposure from which many of the early collections of the region came. As now exposed, it shows the following strata, all of which may be referred to the Dakota.

PROSPECT HILL SECTION.

		FEET.
3.	Sandstone, dark yellow, coarse-grained, with ferruginous concretions	10
2.	Shale, clayey, dark blue to drab	12
1.	Sandstone, fine-grained, homogeneous, white	25

Beyond this point the loess covers all the indurated rocks until North Riverside is reached. Here a good section may be obtained by following the electric railway down the hill. The beds seen are as follows.

		FEET.
10.	Loess	25
9.	Shale, drab, argillaceous; upper six inches colored by iron oxide	2
8.	Lignite, impure, brown, earthy	$\frac{2}{3}$
7.	Sandstone, fine, white, calcareous	6
6.	Sandstone, very ferruginous	$\frac{1}{2}$
5.	Shale, light colored, sandy	8
4.	Lignite, impure, earthy	1
3.	Sandstone, coarse-grained, yellow, with large, hard, quartzitic concretions	10
2.	Shale, drab	6
1.	Unexposed to water	20

A short distance north of this point is the Riverside section already given, and with which it may be readily correlated. Beyond the pottery the various beds are occasionally exposed, though no complete sections appear short of Cedar Bluff. The chalk beds appear in the hills northeast of the Brugier bridge (Tp. 89 N., R. XLVIII W., Sec. 14, Se. qr., Ne. $\frac{1}{4}$), but are not well shown for some distance farther up the river. The prominent sandstone band of the Cedar Bluff section (number 2) makes its apparance some distance below the bluff. It is shown at Reese's "granite" quarry (Tp. 89 N., R. XLVIII W., Sec. 11), where a portion has assumed the hard quartzitic facies already mentioned.

Away from the Missouri and the Big Sioux only a very few exposures are known. On the Floyd river, within the limits of Sioux City, the following section is seen (Tp. 89 N., R. XLVII W., Sec. 15, Ne. qr.).

		FEET.
9.	Loess	15
8.	Clay, yellow, with small lime nodules and erratics	2
7.	Sandstone, soft, fine-grained, white	6
6.	Clay parting	½
5.	Sandstone as above	4
4.	Clay	½
3.	Sandstone as above	8
2.	Clay, blue, shaly, mixed with sand	2
1.	Sandstone, white to orange; heavily cross-bedded	20

On the east side of the same stream, extending up to and slightly beyond Leeds, the chalk beds are occasionally exposed. Near Climbing Hill P. O., on the west fork of Little Sioux (Tp. 87 N., R. XLV W., Sec. 16), there is an obscure exposure of Niobrara. At one point in the bluffs, fronting the Missouri bottom land (Tp. 87 N., R. XLV W., Sec. 36), a number of Inoceramus shells have been found. While no strata are as yet positively known to occur *in situ* at this point, it seems not improbable, from the abundance of the shells, that ultimately such may be found.

With the exception of the exposures mentioned, and a few on Perry creek, there are no known exposures of the indurated rocks within the county, and stream cuttings in other portions of the county show only the loess and associated drift deposits.

Geological Formations.

CRETACEOUS.

The rocks near Sioux City were among the first Cretaceous rocks to be studied in America, and the problems of the structure and divisions of the great interior Cretaceous formations were first attacked in this immediate region. It was here that Meek and Hayden's Upper Missouri Section, which has so long been the standard with which others are compared, was developed. Some of the facts first observed here were so totally at variance with all previous observations that it may well be believed that they were not accepted without a deal of controversy. The evidence, pro and con, received from a host of distinguished workers such careful consideration as has rarely been accorded to geological problems. Certain of these controversies were in their day quite famous, and were so intimately connected with the early growth of American geology that it may not be unprofitable to review them briefly.

In 1804-1805, Messrs. Lewis and Clarke ascended the Missouri river. In the course of their journey they noted the sandstone at Blackbird Hills* and the exposures near Ponca, calling the latter "Mineral Bluffs." Subsequently Nuttal and Long, the latter in 1820, in their journeys up the Missouri collected fossils from this region. At the time of these expeditions the Cretaceous as such had not yet been recognized in America. In 1833 Morton,† in speaking of the fossils collected by these expeditions, refers to them as "Marl fossils," though he had in 1828‡ published Vanuxem's recognition of the Cretaceous. In 1834, Morton assembled his various papers on the Cretaceous fossils and published his Synopsis of Organic Remains of the Cretaceous Group of the United States.§ In 1838, the Prince Neuweid‖ published notes on an

*Coues: History of the Lewis and Clarke Expedition, Vol. 1, pp. 72-86. New York, 1893.

†Am. Jour. Sci., (1), XXIII, 289. 1833.

‡Jour. Acad. Nat. Sci., Philadelphia, VI, 59-71. 1828.

§Philadelphia, 1834.

‖Reise durch Nordamerika, Coblentz, 1838.

expedition to the upper Missouri region made in 1832. On this expedition he collected a number of Cretaceous types.

In 1839, Nicollet visited this region, publishing his full report* in 1841, and a shorter paper† about the same time. The exposures visited by Lewis and Clarke, and by them called Mineral bluffs, he named Dixon's bluff. He noted as he thought four formations as follows.

D. Plastic clay deposit, divided by a stratum of carbonate of lime nodules, 200 feet.

C. Ferruginous clay of yellowish color, with septaria and selenite.

B. Calcareous marl, 30 to 40 feet.

A. Argillaceous limestone, containing *Inoceramus barabini* in great numbers and very much compressed, giving the rock a slaty appearance.

Numbers A and B of this section seem to represent the Niobrara as now known, while C and D are probably representative of the Pierre. The Benton seems to have been overlooked as well as the Dakota. The fossils collected by Nicollet were described by Morton,‡ while the chalk was studied by Bailey.§

In 1849 Evans, one of Owen's assistants, traveled through the region and collected fossils which were described in 1852.‖ In 1853 Meek and Hayden visited the Upper Missouri region on a collecting expedition for James Hall. In 1856 Hall and Meek¶ published as a result of this expedition the first section showing all five of the members present in their correct position. In the same year Meek and Hayden** published jointly their first paper on the region. In this the five members were recognized and referred to by numbers. This became the Upper Missouri section and underwent slight

*Sen. Doc., 26 Cong., 2nd Sess., Vol. V, pt. ii, No. 237 Washington, 1841.

†Am. Jour. Sci., (1), XLV, 153-156. 1843.

‡Proc. Acad. Nat. Sci., Philadelphia, I, 106-110. 1841.

‡Jour. Acad. Nat. Sci., Philadelphia, VIII, 207-227. 1842.

§Proc. Acad. Nat. Sci., Philadelphia, I, 75. 1841.

§Am. Jour. Sci, (1), XLI, 400-401. 1841.

‖Owen: Geol. Sur. Wisconsin, Iowa and Minnesota, pp. 195-196. 1852.

¶Mem. Am. Acad. Arts and Sci., V., N. S., 379-411. 1856.

**Proc. Acad. Nat. Sci., Philadelphia, VIII, 63. 1856.

changes from time to time. It was not until 1861* however, that they give names to the various members. The section then assumed practically its final form; Meek, in 1876† contenting himself with simply reproducing it.

DAKOTA.

The lowest rocks exposed within the limits of the county belong to the Dakota formation. Their character is well shown in the sections already described; they are predominantly sandstones and shales, the latter being frequently

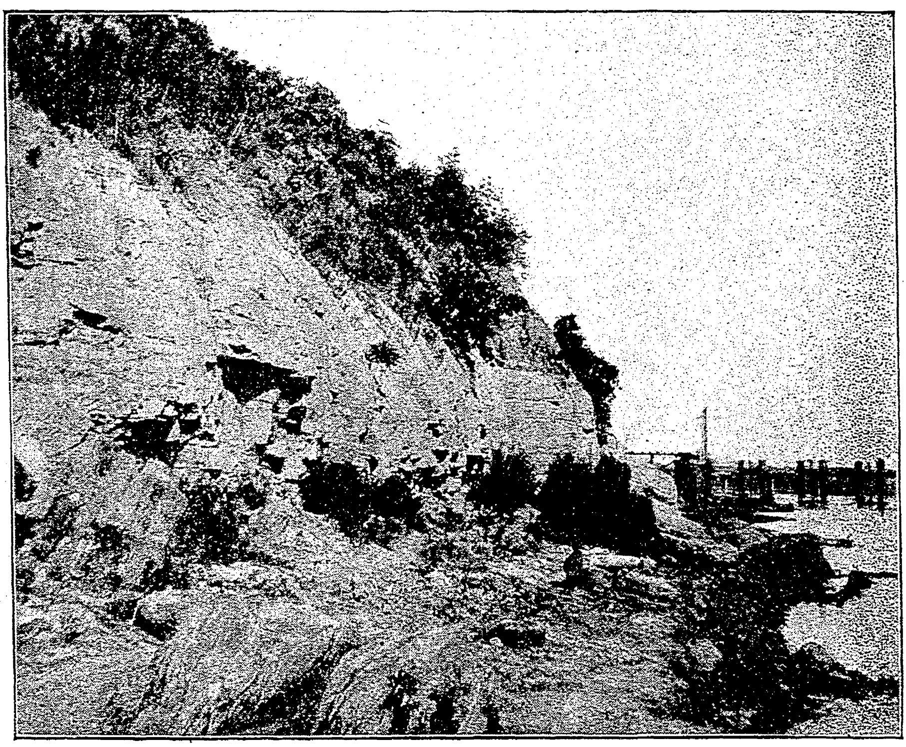


FIG. 37. Dakota sandstone at the foot of Prospect Hill, Sioux City. It was mainly from this exposure that the early collections of fossils were made.

arenaceous in character. The heavier sandstone beds seen on the Nebraska side farther down the river do not appear in the county. They are replaced by thinner sandstones and a greater proportion of argillaceous material. The sandstones occurring consist of two general types. The first is a light

*Proc. Acad. Nat. Sci., Philadelphia, XII, 415-447. 1861.

†U. S. Geol. Surv. Terr., (Hayden) IX, 24-25. Washington, 1876.

colored, buff to white, fine-grained, loosely-consolidated stone in which the cementing material seems frequently to be calcareous. It is stone of this kind which is found at the top of the Sargent's Bluff section, at the base of the Prospect Hill section, and which forms the upper of the two prominent sandstones at Cedar bluff. It frequently contains small pieces of charcoal, and in it are numerous leaves and plant impressions.

The second type of sandstone is seen forming the upper part of the Prospect Hill exposure, number eight of the Riverside section, and the lower of the two sandstones at Cedar bluff. It is coarse-grained, yellow to red in color, and has for cementing material iron, calcite and silica. The first is more usually predominant, and gives the stone a normal reddish tinge. At certain points these harder quartzitic masses, varying in size from a few inches up to several feet in diameter, resemble concretions. Their formation seems due to a secondary infiltration of calcite; the result of the process is a hard, quartzitic rock in which the original sand grains are surrounded by the secondary mineral. There has been no metamorphic change so as to obscure the clastic structure, which is as sharp as ever. Hayden and the earlier explorers called attention to these masses as a source of building stone, but the limited quantity of the material has prevented its large use.

The clays found in the Dakota are abundant and of great variety and adaptability; they are very rarely fossiliferous except where markedly arenaceous. At Sargent's Bluff the shale (No. 2) contains numerous ferruginous concretions arranged occasionally into well marked bands of red sandstone. In these are numerous plant remains. A collection from these layers recently determined by Mr. Paul Bartsch and Professor Macbride gave the following species.

Populus kansaseana Lesq.

Populus hyperorea Heer.

Salix proteæfolia, var. *longifolia* Lesq.

Myrica longa Heer.
Ficus magnollæfolia Lesq.
Ficus inæqualis Lesq.
Daphnophyllum dakotense Lesq.
Cinnamonium ellipsoideum Sap. and Mar.
Cinnamonium sezannense Watelet. ?
Diospyras primæna Heer.
Diospyras pseudoanceps Lesq.
Diospyras rotundifolia Lesq.
Inya cretaceæ Lesq.
Rhamus tenax Lesq.
Rhamus inæquilateralis Lesq.
Liriodendron giganteum Lesq. ?

In a preliminary report* a general section of the Dakota has been given. Since that work was carried on a rich Colorado fauna has been discovered in the clay pits at Riverside, and farther studies have made necessary several minor changes in this section. As now understood the Dakota comprises the beds assigned to it in the general section already given.

One of the most interesting discussions which occurred in the development of the geology of North America was that relating to the age of the Dakota. As has been seen the earlier workers, including Morton, Nicollet and Evans, had but slight knowledge of the Dakota, but correctly referred to the Cretaceous the higher beds which they did study. Hall and Meek† in their section, referred number 1 to the Cretaceous without question. Marcou,‡ from studies in the southwest, was led to infer an earlier age, and regarded the rocks at Ponca as New Red. Meek and Hayden§ in their first section say of number 1, that "it is not positively known to be Cretaceous," and again the same year‖ they remark that

*Iowa Geol. Surv., III, 109. 1895.
†Mem. Am. Acad. Arts and Sci., V, N. S., 405. 1856.
§Geol. Map N. Am., Ann. de Mines, (2), VII. 1855
‡Proc. Acad. Nat. Sci, Philadelphia, VIII, 63. 1856.
‖Proc. Acad. Nat. Sci., VIII, 267. 1856.

"number 1 may be Jurassic, or, perhaps, in part earlier." Hall* in 1857 divided the Cretaceous into three divisions, to the lower of which, number 1 of the Nebraska division is assigned.

Marcou,† in 1858, continued to refer the beds to the New Red. In the same year Meek and Hayden‡ unqualifiedly placed these rocks, as seen between Council Bluffs and Sioux City, in the "Lower Cretaceous." So far but few fossils had been found in them except plant remains. Sketches of several of the latter were sent by these authors to Professor Oswald Heer, but as his answer was delayed, the collection was referred to Newberry who pronounced the plants Cretaceous. Much to every one's surprise, Heer pronounced the forms Miocene. Marcou§ then, having previously assigned the rocks to the Jurassic,‖ maintained that Meek and Hayden had confused as one group the rocks from the Jurassic to the Miocene. Meek and Hayden¶ replied by showing that at many points the disputed beds were covered by strata containing well known Cretaceous forms. Newberry** recorded similar sections and further argued from the plant remains for the Cretaceous age of the beds in question.†† To the latter evidence Heer‡‡ replied, and while admitting the force of the other evidence, maintained that the flora was predominately Miocene in character. In 1863 Messrs. Jules Marcou and J. Capellini made an excursion to Sioux City for the purpose of studying the rocks in controversy.

The following year Marcou§§ announced his belief in the Cretaceous age of the Dakota, as the rocks were by that time

*U. S. and Mex. Bound. Surv., I, 134. 1857.

†Geology of North America, 143. 1858.

‡Proc. Acad. Nat., Sci., Philadelphia, X, 145-146. 1858.

§Letter on some points of the Geology of Texas, New Mexico, Kansas and Nebraska; addressed to F. B. Meek and F. V. Hayden.

‖Notes pour server a une description geologiqui des Montages Rocheuses, p. 20.

¶Proc. Acad. Nat. Sci., Philadelphia, X, 256-264. 1858.

¶Am. Jour. Sci., (2), XXVII, 219-227. 1859.

**Am. Jour. Sci., (2), XXVIII, 298-299. 1859.

††Am. Jour. Sci., (2), XXIX, 208-218. 1860.

‡‡Am. Jour. Sci., (2), XXXI, 435-440, 1861.

§§Bul. geol. Soc. de France, (2), XXI, 132-147. 1864.

called. In a later paper* he gives further details. In 1865 Meek† reviewed the controversy, and in 1867 Hayden‡ after reading the joint paper written by Capellini and Heer§ also discussed the subject.

Since that time the Cretaceous age of the Dakota has not been seriously questioned, though Lesquereaux‖ at one time suggested that the presence of a Miocene flora under a Cretaceous fauna might be due to some such curious condition as allows the survival of certain Mesozoic types of animal life in the deeper seas at present. In 1884 Gardner¶ maintained that the flora of the basal American Cretaceous is Eocene in character, and seemed disposed to the belief that this is an instance of persistence of Cretaceous types into Eocene time rather than of the earlier introduction of forms which later characterized the Eocene.

As has been said, the Dakota is predominately made up of sandstones and sandy shales. The sandstones frequently show heavy cross-bedding and are closely related to the overlying shales of the Benton. So close is this relation in fact, that Meek and Hayden** at one time, cautiously suggested that the Dakota might ultimately be found to be only a subdivision of the Benton, and White†† in his studies of the Iowa exposures was led to group all the strata below the Inoceramus beds in one division under the name of Woodbury shales and sandstones. Calvin‡‡ has interpreted the deposits as indicating continuous subsidence.

These views all accord in making the Dakota a brackish water or estuary deposit formed under influences connected with marine conditions. The presence, however, in the sandstones of numerous plant remains has caused the Dakota to

*Bul. geol. Soc. de France, (2), XXIV, 56. 1866.

†Am. Jour. Sci., (2), XXXIX, 157-174. 1865.

‡Am. Jour. Sci., (2), XLIII, 171-179. 1867.

§Mem. Soc. Helvetique des Sci. nat, XII, 1-24. 1867.

‖U. S. Geol. Surv. Terr. (Hayden), Ann. Rep. 1870, 377-385. 1871.

¶Brit. As. Adv. Sci., 54th. Meet., 1884, 739-741. 1885.

**Proc. Acad. Nat. Sci. Philadelphia, XII, 415-447. 1861.

††Geol. of Iowa, I, 289. 1870.

‡‡Geol. Iowa, I, 147-161. 1893.

be considered by many as non-marine or fresh-water. Marcou* advanced this idea, naming as a fresh-water form found in it *Cyrena Nova-Mexicana.* Capellini† held the same opinion saying: "The Cretaceous strata in the environs of Sioux City * * * may be divided into two distinct parts, one rich in leaves, a fresh-water formation * * *." White‡ says of the formation in general: "This formation is of non-marine origin * * *. In some districts the presence of Unio * * * shows that fresh water conditions prevailed. In other districts * * * forms indicate * * * brackish water, and in the southern and southeastern portion * * * fossils * * * show * * * the waters gradually changed from a fresh to a marine character."

On the other hand, the marine character of the deposits has not been without advocates. Thus Meek,§ in dissenting from Marcou, states his belief that *Cyrena Nova-Mexicana* of the former is *Cyrena arenaria* M. and H., which has been found with Axinea (Pectunculus), *Mactra siouxensis* and Pharella. Of these, Mactra and Pectunculus are well known marine forms, and Cyrena and Pharella indicate brackish water. From this, Meek was inclined to believe that the Dakota beds were indicative of estuary conditions. Hayden,‖ after quoting Capellini's opinion, says: "I would simply say I have always regarded it as marine, and I am sure this has been the opinion of my friend Mr. Meek. At any rate, we have found mingled with the leaves, at Sioux City, quite well preserved casts of *Pharella* (?) *Dakotensis*, *Axinea Siouxensis* and *Cyprina arenacea* shells peculiar to marine deposits." Hicks¶ has reported the discovery at Fairbury, Neb., of a very rich marine fauna in the Dakota. These forms have been examined by White**, who finds that they are non-marine. Todd††

* Bul. geol. Soc. de France, XXI, 132-147. 1864.
† Mem. Soc. Helvitique des Sci. Nat., XXII, 1-24. 1867.
‡ Bul. U. S. Geol. Surv., No. 82, 171. 1891.
§ Am. Jour. Sci., (2), XXXIX, 172.
‖ Am. Jour. Sci, (2), XLIII, 178.
¶ Proc. Am. As. Adv. Sci., XXXIV, 219.
** Proc. U. S. Nat. Mus., Vol. XVII, pp. 131-138. Washington, 1895.
†† South Dakota Geol. Sur., Bul. I, pp. 82-84. Sioux Falls, 1894.

has recently reviewed the subject and seems to think a marine or brackish water origin more probable.

It would seem probable that the fresh-water character of the beds has perhaps been too strongly insisted upon. Certainly it is true, as remarked by Todd, that it is easier to account for fresh-water forms in marine deposits than to account for marine forms in fresh-water beds. The presence of marine forms mingled with the leaves at Sioux City, as noted by Hayden, and the undoubted close relations between the Dakota and Colorado as seen here, would seem fair warrant for the belief that Meek's suggestion of estuary conditions is, here at least, a good one. The predominance of sandstone, its cross-bedded character, the presence of lignites, the occasional finding of marine forms, and the gradual transition upward into true marine beds, are all analogous to the conditions found in the lower coal measures of the state, where they have been repeatedly interpreted as indicative of marine shore conditions.

COLORADO.

Above the Dakota is a series of beds which are, on the whole, divisible into two parts. Of these the lower, which has been known as the Benton, or Fort Benton, is in Iowa a bed of argillaceous shale of a prevailingly drab color, and with a maximum thickness of about forty feet. It is not usually sharply separated from the underlying more sandy beds of the Dakota or the overlying calcareous beds of the Niobrara. Lithologically it is, as a rule, more closely connected with the Dakota, but paleontologically its affinities are with the Niobrara. The lower portion is seen in number 9, of the section at the Riverside Electric railway station, and it is better shown in numbers 12-15 of the North Riverside section at the Sioux Paving Brick works. Here it contains a thin, sandy layer, and occasionally calcareous nodules are found in a more or less regular band. In the Cedar Bluff section the Benton has its greatest thickness and is shown in two facies, a lower, more argillaceous, and an upper, more arenaceous, division. The upper layers of the latter division show the presence of *Inoceramus labiatus* Schloth., and the beginning of the chalk. There is, however, a considerable slope before the well marked chalk beds are clearly exposed.

The upper portion of the Colorado, the Niobrara, is shown at Cedar Bluff and on the tops of the hills northeast of the Brugier bridge. South of this point it is not exposed on the Iowa side of the Missouri, unless the locality in West Fork township already mentioned be excepted. On the Nebraska side of the river the beds are found near Homer, and Meek and Hayden* mention finding them thirty miles below the mouth of the Big Sioux. Lonsdale has recently found these beds exposed as far south and east as Auburn in Sac county. The Niobrara beds are predominantly calcareous, being made up of thin, shelly limestones with interbedded chalk. The limestone is well characterized by numerous fossils† among which in Iowa *Inoceramus labiatus* and *Ostera congesta* are easily most prominent. The limestone is usually crowded full of these shells. In addition to these forms, Mr. J. C. C. Hoskins‡ has found sharks' teeth on Perry creek (Tp. 90 N., R. XLVII W., Sec. 17), and St. John§ mentions fish remains as occurring at Cedar Bluff. The bones of marine saurians have also been found. Calvin‖ who has recently studied the chalk of the Niobrara, mentions a number of species of foraminifera as occurring near Sioux City.

In the pit of the Sioux Paving Brick Co., at Riverside, a number of characteristic Colorado forms have been collected from the beds referred above to the Benton. Among them may be mentioned *Inoceramus labiatus* Schloth., *Callista* (*Aphrodina?*) *tenuis* M. & H. and *Prionocyclas* sp. und.

In Meek and Hayden's Upper Missouri section five members were recognized.

*Proc. Acad. Nat. Sci., Philadelphia, X, 256-264. 1858

†See Staunton for a review of the Colorado fauna: Bul. U. S. Geol. Surv., No. 106. 1893.

‡See foot note: Proc. Am. As. Adv. Sci., XXXI, 1872, 191. 1873.

§Geol. of Iowa, II, 198, 1870.

‖Iowa Geol. Sur , III, 213-236. 1895.

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

These divisions were differentiated largely on lithological and stratigraphical grounds, and as early as 1856 these authors remark of numbers 4 and 5 that they are "inclined to regard (them) as only well marked subordinate members of the same natural group*." So Meek,† in his final report, notes the fact that paleontologically there are only three divisions. The term Colorado was proposed by King‡ to include the beds previously known as Benton, Niobrara, and Pierre. It was later restricted by White§ so as to include only the Niobrara and Benton and is in that sense used here. White,‖ in his earlier studies of the Iowa Cretaceous used the terms Woodbury shales and sandstones and Inoceramus beds. Calvin¶ correlated these beds with the divisions as recognized by Meek and Hayden, and there seems now no need for the farther use of White's terms. The upper beds, known as the Montana formation, do not appear within the limits of Woodbury, though found in Sioux county farther north.

PLEISTOCENE.

The history of this region since the close of Cretaceous time falls readily into three periods, the preglacial, glacial, and postglacial. The first of these extends throughout Tertiary and into Pleistocene times, but inasmuch as the deposits made since the Cretaceous probably belong to the Pleistocene the whole may be considered here.

PREGLACIAL DEPOSITS.

During Cretaceous times the sea invaded Iowa successively farther and farther, the encroaching waters coming from the

*Proc. Acad. Nat. Sci., Philadelphia, VIII, 266. 1856.
†U. S. Geol. Surv. Ter., (Hayden) IX, pp. xxi-xxvii. 1876.
‡U. S. Geol. Surv. 40th. Par., I, 298. 1878.
§U S. Geol. Surv. Ter., (Hayden), Ann. Rep. of 1876, 22. 1878.
‖Geology of Iowa, I, 289. 1870.
¶Am. Geol., XI. 300, 1893; and Proc. Iowa Acad. Sci., I, iii, 7, 1893.

west. At first there was the period of estuary and shore deposits marked by the Dakota. Following this came a time when the clays of the infra-littoral zone, which are seen in the Benton shales, were being laid down. This period which in Iowa does not seem to have been a long one, was terminated by the rapid incursion of the deep sea represented in the off shore deposits of the Niobrara. These waters swept far eastward, but apparently did not remain long. When the sea retreated there was a period during which Iowa remained perhaps but little elevated above the sea. At the same time the later Cretaceous beds farther west were being laid down. At the close of the Cretaceous came the remarkable uplifts and earth movements which elevated the Rocky mountains, tilted the plains, and gave birth to the major features of the drainage of the Mississippi valley. These movements affected profoundly the area under consideration. It was elevated from its previous low-lying position to a point considerably above sea level, and not unlikely a good many feet above its present elevation.

Sometime in the long period between the orographic movements just mentioned and the advent of the ice, the Missouri river cut its present greater valley, which is as has been said, a great, rock-bound trough, from three to seventeen miles wide, with drift and loess-veneered walls on either side. The Missouri, in part at least, cut down to a depth of from seventy to one hundred feet below its present low water level, and the same statement may be made respecting the minor streams. The erosion of the Missouri cut successively through the Niobrara and Benton beds, and deep down into the Dakota. As the major stream worked its way down step by step to lower levels, it carried with it the tributary streams until the whole drainage system was working on a plain considerably below the present. Here corrasion became inconsiderable and lateral degredation set in. The efforts of the streams were directed to broadening their valleys. This stage seems to have been a long one, and it was in that period that the wanderings of the river current, together with the usual tendency of river bluffs to retreat from the stream, led to the development of the now wide, but then perhaps wider, flood plain of the Missouri.

At some time in the period between the retreat of the Cretaceous sea and the advent of glacial conditons, at least a portion of Woodbury county was covered by a shallow lake. The deposits made at that time were noticed in giving the sand pit section. They consist of fine to coarse white sand containing occasional small pebbles, in the main granitic, with chips of wood and a few fossils. The pebbles found are of small size, water worn, and of such type that they might readily come from either the west or the north. There are, so far as a careful search reveals, no distinctively northern rocks present, and certainly no rocks showing ice action. The general character of the sand is much like that of the Neocene or Pliocene beds found a few miles west in Nebraska and South Dakota.

Similar beds occur at several other points in Iowa as well as in Nebraska and South Dakota. Todd*, who first described them, considered the beds to mark the eastern limit of Lake Cheyenne, described by King, and to be evidence of the persistence of that body of water up to glacial times. He mentioned finding Megalonyx remains in similar beds in Mills county. In 1890† he added certain notes on the distribution of the sand, mentioning it as occurring opposite Canton, S. D., and announcing its probable presence beneath the drift at Le Mars.

In the beds at Sioux City Mr. J. C. C. Hoskins found certain fossil teeth which, upon being referred to Professor E. D. Cope, were pronounced to be "three left superior molars of the horse, *Equus major* Dek., of Pleistocene age. It is entirely restricted to that horizon." These teeth, and the bones of the Megalonyx, already referred to, are the only fossils ever found in these beds. They may, however, be from

*Proc. Am. As. Adv. Sci., XXXVII, 202-203. 1889.

†Proc. Iowa Acad. Sci., Vol. I, pt. ii, 14-15. 1892.

different horizons, since the Mills county beds and the sands found at Riverside are not, so far as known, connected.

There is then, in the presence of these beds, evidence of a slight and probably short subsidence over this region occurring in earliest Pleistocene, or possibly beginning in later Neocene times. The evidence exhibited near Sioux City seems to favor the belief that this subsidence took place before the Missouri river channel was cut. The objection to this view is the great breadth of the valley both at Sioux City and at some points higher up the river. It seems not improbable, however, that the present width of the valley is a resultant of the soft character of the rocks of the region, rather than the expression of long time erosion. This seems all the more probable when one considers the greater carrying power of the river in glacial times.

If this be the correct interpretation, we would have then, in this region, a period of deposition followed by a period of stream cutting immediately preceding glacial conditions. The period of deposition, coming as it did in earliest Pleistocene or later Neocene, would be in a general way contemporaneous with the Lafayette deposition of the southern and eastern United States. The following of the deposition by a period of uplift, as evidenced by stream erosion, is also well in accord with the history of the earth movement as seen in other states. In this connection it is of interest to note that the stream cutting preceding the ice invasion is not peculiar to Woodbury county, but has left its traces in many other counties in the state. The records of numerous deep borings have shown the presence of preglacial channels similar in character to those which are now followed by the streams of Woodbury county, at many points.* These are not confined to Iowa, but have been found in many other states, and Mr. McGee† has pointed out that they may be traced from point to point until the region never covered by drift is reached. Here a similar set of trenches are found which may, in part

*Iowa Acad. Sci., II, 23-26. Des Moines, 1895.

†Communicated.

at least, be definitely referred to the post-Lafayette emergence. There would seem to be no good reason for separating these channels and, until a better correlation can be made, it would seem in place to consider the preglacial river channels of Woodbury and other counties in Iowa as the expression of the earth movement which terminated the Lafayette.

GLACIAL DEPOSITS.

Drift.—Woodbury county lies outside the Altamont moraine and within the area covered by the Kansan ice sheet. The deposits found within the county and referred to this period are not conspicuous, owing in part to the presence of the

FIG. 38. Ledge forming waterfall, Woodwarth's glen.

very thick loess and in part to the terraces along the river. Heavy beds of boulder clay, such as are commonly exposed in the southern and eastern part of the state, are occasionally reported from wells, but rarely exposed at the surface. The drift which is seen is thin and patchy, and frequently presents more or less strong indications of water action. The section previously given of a gravel pit at Riverside is a good example, though usually the gravel and sand are mixed together so that neither can be used without screening.

In Woodwarth's glen, just outside the county (Tp. 86 N., R. XLIV W., Sec. 17, Sw. qr.), an opportunity is afforded to get a section into the heart of the loess promontory lying between the Little Sioux and the Missouri. This glen is a narrow defile cut by a small stream, and running back well into the interstream area. It is steep-sided and heavily wooded, and throughout most of its extent nothing is seen except loess and a narrow terrace of modern wash dirt. Farther up the ravine, the drift beds which underlie the loess may be seen. At one point is a small cascade where the water falls some eight or ten feet. The section shown here is fairly typical, and is as follows.

		FEET.
6.	Loess of usual character above, sandy below	15
5.	Coarse gravel	1
4.	Boulder clay	1½
3.	Coarse, loose sand	5
2.	Sand, consolidated to a fragile sandstone	2
1.	Coarse sand	6

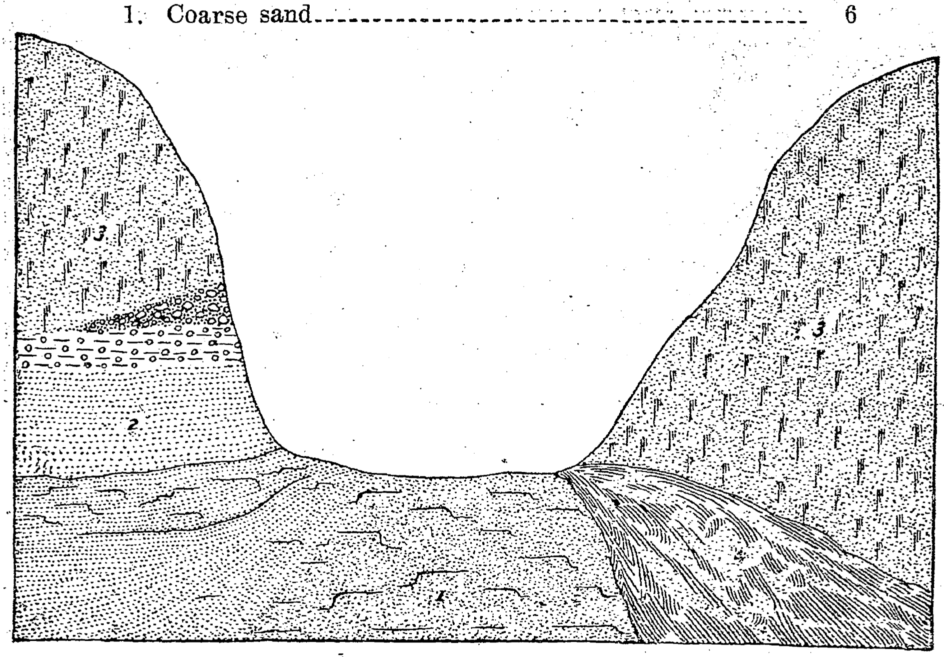


FIG. 39. Drift at waterfall in Woodwarth's glen. The numbers in the figure refer to the numbers of the section as follows: 1, No. 1; 2, No. 3; 3, No. 6; No. 4, represents a talus.

The sand forming the base of the section is coarsely bedded and loosely consolidated. The different members of the section do not maintain themselves over any great area, though the presence of the coarse sand is indicated at several points farther down the ravine, and a large number of boulders are found in the bed of the stream. At one point, a blue boulder clay is seen to be present, though its thickness could not be determined. The fall at the cascade is due to the induration of the upper portion of the sand layer, as shown in the figure. This induration is due to the cementing of the fine gravel and sand by a calcareous bond, apparently derived from the lime nodules, which are, as usual, abundant in the loess. That the water is heavily charged with calcium carbonate is shown by the calcareous coating on sticks and leaves lying near the foot of the fall. The rivulet is a wet-weather stream only, and derives its supply of water from drainage of the loess upland.

Near Anthon there is a second example of the secondary formation of lime conglomerate. In a small ravine (Tp. 87 N., R. XLIII W., Sec. 16, Nw. qr., Se. ¼) there is a well defined ledge of what is at first glance a limestone. A closer examination shows it to be made up of pebbles and coarse sand, cemented together by a calcareous cement. The consolidated stratum lies at the base of the loess capping the gravelly drift which is characteristic of the region, and the ledge of conglomerate is about eighteen inches thick.

On the west fork of Little Sioux, below Moville, little but loess is seen. At one or two points coarse, sandy gravels are exposed. Between the east and west forks of the same river similar beds are occasionally seen, and along the east fork gravel terraces are found. At most of the exposures near Sioux City the loess rests directly upon the Cretaceous rocks. Where drift deposits occur, they are very similar to the beds already described.

Along the loess escarpment, stretching southeast from Sargent's Bluff, there are occasional exposures of gravelly drift cropping out from beneath the loess. East of Hornick these beds have been opened up at one or two points for the purpose of obtaining gravel and sand.

An interesting phase of the drift is the brown to lead-colored clay which is seen resting above the Riverside sands already described. This is not in any sense a typical drift clay, and yet beneath it, and occasionally in it, are found boulders and northern gravel. It is very plastic, and may prove to be valuable in the manufacture of certain grades of clay goods.

Loess.—The most striking and picturesque feature of the topography of this region is the loess landscape. All along the Missouri, and a considerable distance up the minor streams, the loess is prominent. The earlier writers on this region referred to it as the "Bluff deposit," since it formed so prominent a feature in the river bluffs. At Sioux City it is 100 to

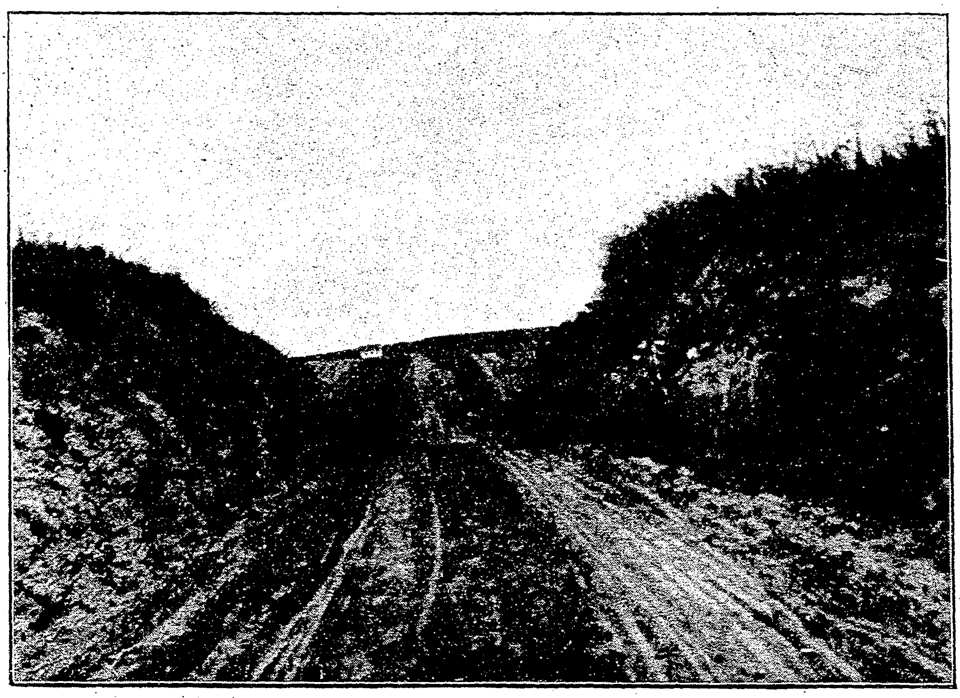


Fig. 40. Country wagon road in the loess region.

150 feet thick and is well exposed in the numerous street and railway cuttings as well as in natural sections. It is the typical, fine silt-like deposit of a light buff to ash-gray color, becoming slightly merged with the sand and drift below where the latter is present. It contains the usual loess-kindchen and is, in places, fossiliferous.

Concerning the origin of the loess some interesting evidence has recently come to light.* Near Riverside station there is an exposure, illustrated in figure 41 which shows an interbedding of till and loess. As exposed in 1894 the section here is as follows.

	FEET.
5. Loess of the usual character, thickening back on the hills to 100 feet or more, and in which Todd in 1889 collected *Helix hirsuta*, Lymnea and Cyclas	30
4. Clay, brownish to yellow, with numerous northern boulders irregularly disseminated in it; dividing toward the south and feathering out toward the north	2 to 12
3. Loess, ashen, silt-like, containing Succinia and other living forms	2 to 6
2. Gravel, very coarse, with northern boulders	10
1. Talus of loess	12

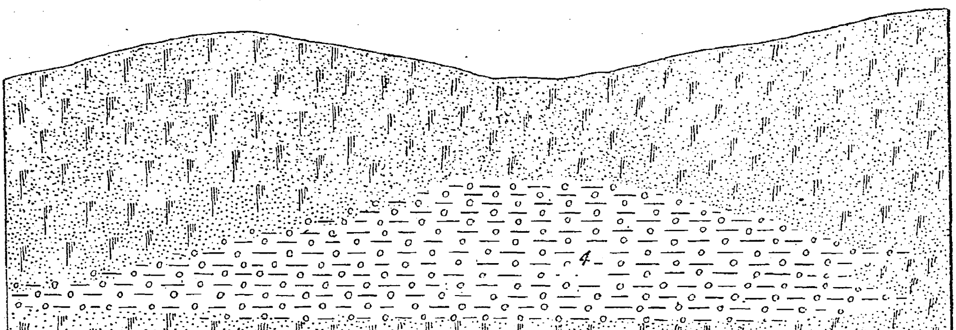


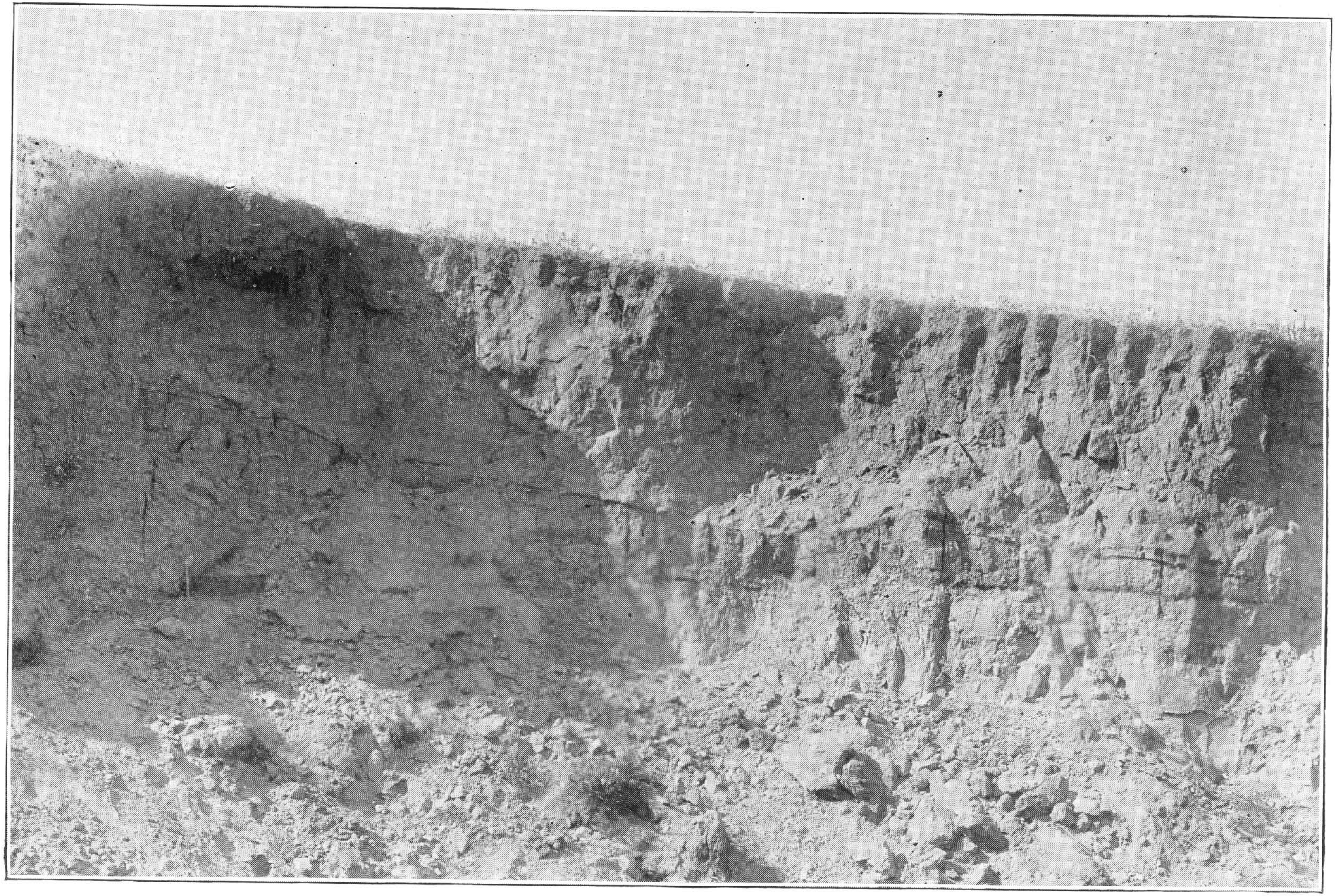
FIG 41. Drift interbedded with loess. Riverside, Sioux City.

For this exposure the explanation has been offered of a slipping of till and loess from higher levels down into a lower terrace of loess. There is, however, in one of the sandpits already mentioned, northeast of the Brugier bridge, a similar exposure which it does not seem can be explained in this way. This exposure, which is illustrated in plate v, is about 150 feet above the river, and the till is above any similar deposit

*See Proc. Iowa Acad. Sci., II, 20-23. 1895.

known to occur in the vicinity. The exposure shows a bed of typical till consisting of a matrix of dark brown clay, in which are numerous boulders of Sioux quartzite (one of these is pointed out by the hammer) and other northern rocks, with loess of the usual character, both above and below. The bed is of variable thickness, being at the center more than six feet and tapering from that to a feather edge. From the outline shown, the bed seems to be lens-shaped, with a considerable areal extent in proportion to its thickness. The loess is exposed to a considerable thickness, both above and below the till, and is in every way similar to the loess found in the neighboring cuttings.

The presence of the till in the loess indicates the contemporaneous origin of the two deposits, and it seems clear that in this case the explanation offered for the Riverside exposure can not suffice, even if in that it be deemed sufficient. The till here was probably dropped from a floating iceberg, while the loess itself was being deposited as a fine silt in the quiet waters of the expanded Missouri. The position of the various moraines renders it very probable that this took place at about the time the ice occupied the Altamont moraine. At that time the channel of the Missouri, it is believed, had already been cut. The valley was, in fact, even wider than at present. When the ice stood over the region northeast of Woodbury, this county was under water. The water was deep enough to float small icebergs over the tops of the pre-existing bluffs, and in the quiet depth of this body of water the loess was laid down as finer silts are now laid down over a flood plain. The tendency would be to disguise the roughness of any pre-existing topography, and hence the loess would be banked up against any old shore. It is known that the loess as a distinctive bed extends up the Maple to Danbury, and up the Little Sioux about to Oto. Beyond these points and over the upland it is not so typical and forms the covering which is the characteristic top dressing over the prairies of the northwestern counties.



TILL INTERBEDDED WITH LOESS. SAND PITS, NORTH RIVERSIDE, SIOUX CITY.

Terraces.—Since the deposition of the loess two important series of beds have been laid down. These are the river terraces and the alluvial deposits. Strictly they form but one series, since the modern flood plain of the river is merely the most recent terrace. Since, however, the earlier terraces were probably more or less directly connected with the later ice sheet, they may be considered as probably belonging to glacial history. The present flood plain must be considered as entirely postglacial.

Todd in his work on the Missouri river has found that several terraces may be traced. One of these, which may be called the loess terrace, is well shown south of Sioux City and at other points in the county. From various stations on the elevated railway, if one will look south toward Thompson's Bluff and the hills back of it and farther from the river, the terrace form may be readily seen. Thompson's Bluff runs out as a spit from the river bluffs which rise back of it. From a distance the upper surface of the lower bluff forms a distinct line in the landscape and is readily seen to be considerably lower than the hills farther east. Traces of this terrace may be observed at various points along the Missouri near Riverside. Todd has suggested that this terrace is a later silt deposition laid down at a time when the Missouri, while much higher and larger than at present, did not reach the height of the waters which laid down the older and more prominent loess.

Well-marked terraces are also seen along the minor streams in the county. Near Rodney on the Little Sioux there are three, as follows.

3. Older loess terrace, 210 feet above the river.
2. Newer loess terrace, 70 feet above the river.
1. Modern flood plain, 15 feet above the river.

Near Anthon the following occur:

3. Drift with thin top dressing of loess, about 150 feet above the river
2. Gravel terrace, well-marked, 1 to 1½ miles wide, 30 feet above the river.
1. Modern flood plain, 14 feet above the river.

These various terraces have not yet been correlated, and no certain inferences as to their relations and age may yet be drawn.

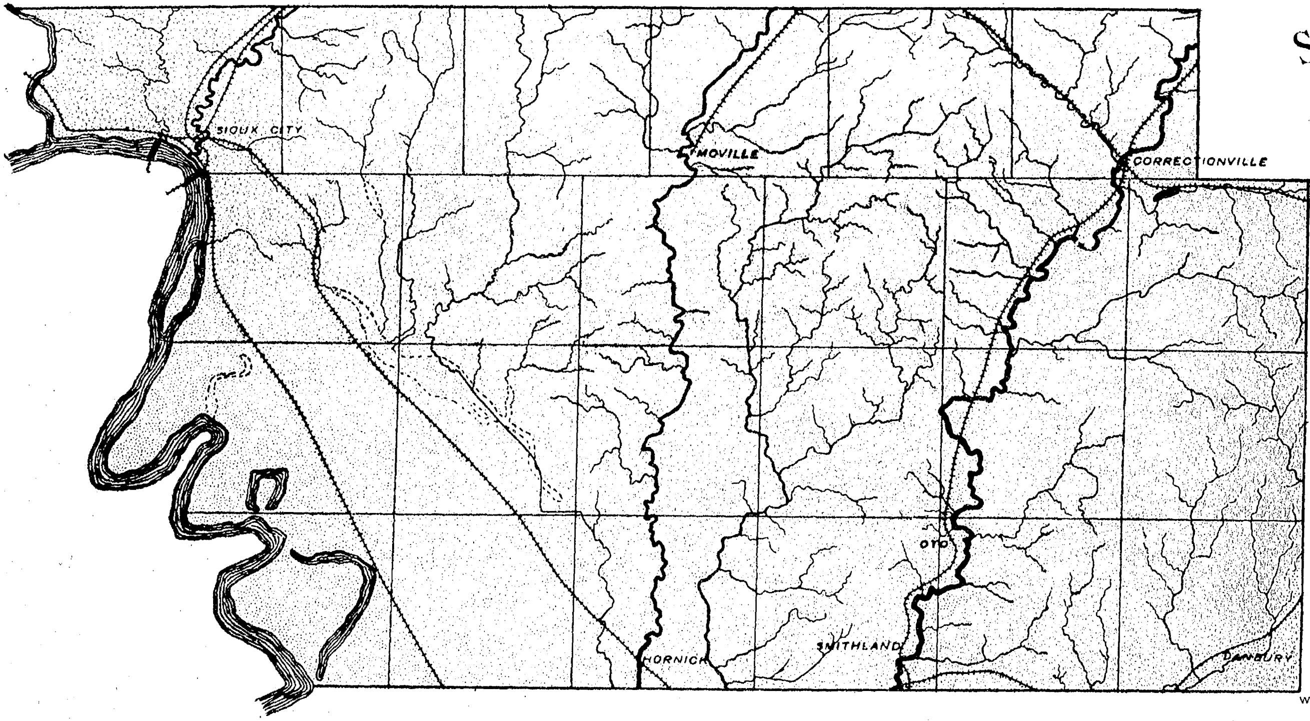
The structure of the terraces has not been investigated. It seems probable that they are genetically connected with the glacial deposits and were made at the time the Altamont moraine was formed. In the region there are terraces of deposition, a very good example being shown in Woodwarth's glen. Whether all the terraces had a similar origin, or whether they are, in part, terraces of erosion, can not be stated.

POSTGLACIAL DEPOSITS.

Alluvium.—On the accompanying sketch map the alluvium and other superficial deposits are laid down. The map is approximate only, but the delimitation of the major areas of alluvium is believed to be accurate. The character of the alluvium in nowise differs from that which is usually found in river bottom land. The great width of the Missouri flood plain, however, and its uniform surface make its artificial drainage a very difficult problem. Along the foot of the bluffs the usual back water swamp has developed in accordance with the well known law that flood plains rise toward the stream. In this swamp the small streams from the hills formerly lost themselves, but now the whole is drained into the Little Sioux by an artificial ditch.

Geological Structure.

General Structure.—The rocks of Woodbury county show but slight disturbances, and with the exception of the break between the Cretaceous and Pleistocene, they present a continuous sequence. The Dakota, Benton, and Niobrara follow each other in regular order, though it seems probable that within the county the Benton wedges out toward the south and east and the Niobrara overlaps, resting directly on the Dakota. The rocks seem to have been but little disturbed since deposition. A general section up the Sioux river and a



MAP OF THE SUPERFICIAL DEPOSITS OF WOODBURY COUNTY

BY

H. FOSTER BAIN

1896.

ALLUVIUM

LOESS

DRIFT
WITH TOP DRESSING OF LOESS

Iowa Printing Co. Des Moines.

corresponding reconnoissance up the Missouri show that there is a slight dip to the north and west, but so far as this immediate region is concerned the dip might well be believed to be the original seaward inclination of the ocean floor. No folds or faults in the strata appear, and the occasional anticlines and synclines are of very inconsiderable extent.

Cross-sections. — A section along the Missouri and Big Sioux river from Sargent's Bluff to Cedar Bluff is shown in the accompanying figure. Good exposures for extending the section south does not occur, though the presence of heavy sandstone beds belonging to the Dakota, and of chalk beds of the Niobrara, is readily determined. In figure 42 the numbers refer to localities as follows: (1) Sargent's Bluff; (2) Floyd river; (3) Prospect Hill; (4) Riverside; (5) Cedar Bluff. The letters refer to the beds corresponding to those of the general section already given. The Dakota includes *a–g*, the Benton *h–i*, while *j* and *k* represent the Niobrara and loess.

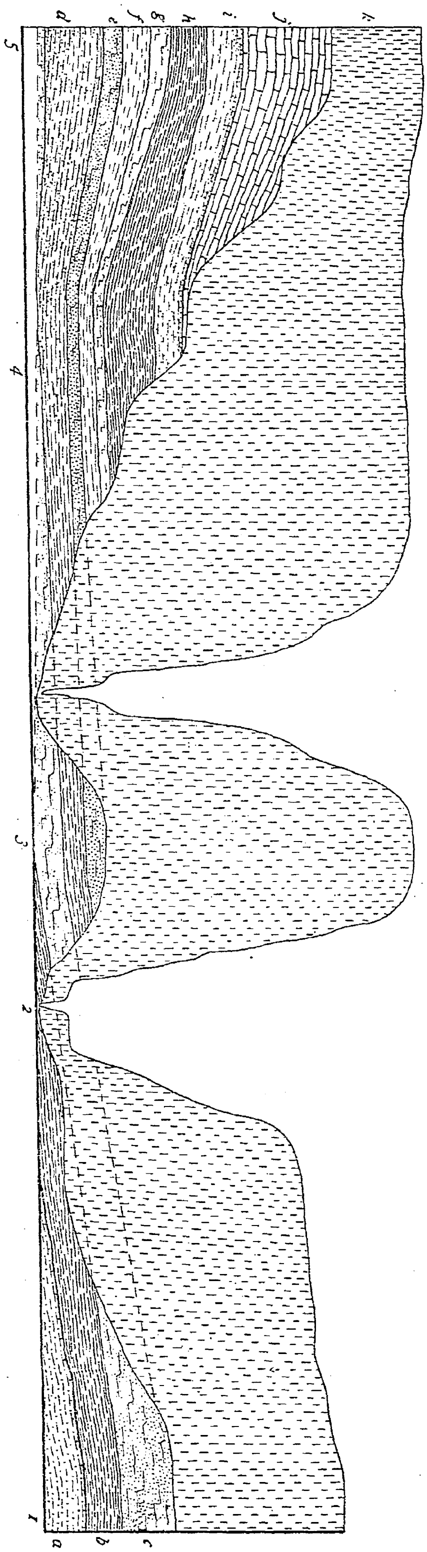


Fig. 42. Geological section from Sargent's Bluff to Cedar Bluff.

ECONOMIC PRODUCTS.

CLAYS.

CHARACTER AND DISTRIBUTION.

The geological formations exposed within this county are all clay producers or are capable of becoming such. The bedded rocks belong to the Cretaceous, and their general character may be inferred from the descriptions already given. Above the Cretaceous is the thin bed of sand which seems to be earlier than the drift. Over the drift there is, in the southwestern part of the county, a very heavy covering of loess in its typical form. Towards the northeast the loess covering becomes thinner.

A generalized section of the rocks of the county has already been given. Clay suitable for manufacturing purposes is obtained from numbers 1, 2, 5, 8, 10 and 15. Other layers might also be readily used.

The lowest clay beds worked in the county belong to numbers 1 and 2 and are exposed at Sargent's Bluff. These clay beds belong to the Dakota formation and are of excellent quality. The same formation includes the clay bed exposed at the foot of Prospect Hill and the clays penetrated in the prospecting at the North Riverside pottery. Both Dakota and Benton clays are taken from the pit of the Sioux Paving Brick company, the Benton clays being found above the soft white sandstone, here rather a sandy shale, which occurs some sixteen feet above the base of the pit. The clay below the base of the pit, exposed in a tunnel near the factory, is evidently to be correlated with that seen at the foot of Prospect Hill, and is above the Sargent's Bluff clay beds.

The Benton, or lower division of the Colorado, is best exposed at Cedar Bluff. As seen here it is made up of two separate clay beds of nearly equal thickness. The lower bed is more argillaceous and represents the horizon now worked at Riverside. The upper bed is rarely so pure as the lower. It frequently merges at the top into the chalk and limestone of the Niobrara. There are thus four well marked clay horizons in the Cretaceous of the county, three being in the Dakota and one in the Benton. They afford a wide variety of material and are adapted to almost any kind of clay work. Drain tile, sewer pipe, stock, face, enamel and paving brick, terra cotta and pottery may all be manufactured, and most of them are now actually being made, from the Cretaceous clays of this region. It is, perhaps, significant that the great clay industries of New Jersey and Maryland are founded upon beds of the same age.

In addition to the abundance and great variety of Cretaceous clays present in Woodbury county, there are other valuable deposits. The thin bed of blue-gray clay which overlies the Cretaceous near Sioux City is quite plastic and free from impurities. Apparently it would be valuable, and might be readily used.

The drift in this county is thin and of irregular distribution. It seems hardly likely that it will ever rank as an important clay producer. Above it is the loess, which occurs in remarkable purity and in great thickness. With the exception of the lime concretions which are often found in it, it contains nothing deleterious. The percentage of iron present causes it to burn to a good red color, and the ease with which it is obtained and manipulated leads to its large use. It is a material capable of making most excellent ware, and is widely used.

Woodbury county is exceptional in the large amount of alluvial land which it contains. Fully one-fourth of the area of the county is covered by material of this character. Alluvial clay is so readily made up into common brick and drain tile, by the simplest and least expensive processes, that in other regions it is largely used. Here, however, the exceptional abundance of better clays make it hardly probable that the alluvium will ever meet with much favor.

CLAY INDUSTRIES.

The works of the Sioux Paving Brick company, of which Mr. W. B. Lower is manager, are located between Riverside and North Riverside at Sioux City. The plant was established some seven years ago and has since been extensively enlarged. A Penfield plunger was at first used, but a Chambers machine with a rotary cut-off has since been substituted. The Chambers machine has given excellent satisfaction. A Penfield steam re-press has also been used to some extent.

The brick are dried in part in steam heated sheds, and in part under ordinary roofed sheds. In burning, both a Hoffman ten-arch partition kiln, having a capacity of 400,000 brick, and a clamp kiln of 350,000 capacity are used. The material is taken from the Benton and Dakota horizons of the Cretaceous, and is dug from a pit near the kilns. A general view of the pit is shown in figure 43, and a detailed section of the strata is given below.

		FEET.	INCHES.
13.	Loess (on slope)	10	
12.	Shale, very arenaceous, with selenite in veins	14	
11.	Shale, light to drab gray, in part sandy; selenite in seams	15	
10.	Shale, with impure limestone in irregular boulder-like masses	3	
9.	Shale and sand, ferruginous, in alternating layers	4	
8.	Shale, gray, non-siliceous	10	
7.	Shale, grayish to drab, with four-inch rock ledges about the center	6	
6.	Sandstone, calcareous, in part shaly	4	
5.	Shale, gray fissile	2	6
4.	Shale, gray, very finely siliceous, with ferruginous masses near middle, also in upper part	5	6
3.	Shale, lignitic		8
2.	Sandstone, light-colored	7	
1.	Shale	1	

Number 12 is rather impure, containing in addition to the gypsum mentioned, a thin ledge of hard, calcareous sandrock, The shale of number 4 is of good quality though rather refractory. Number 8 contains the Benton fossils already mentioned.

Nearly all the material taken from the pit may be used. Ordinarily the strata from number 3 to number 12, inclusive, are after the gross rock impurities have been sorted out,

FIG. 43. Clay pit of the Sioux Paving Brick Co., North Riverside, Sioux City.

mixed with a nearly equal proportion of loess and soil material.

The brick shipped from this plant are of excellent quality and find ready sale throughout northwestern Iowa and neighboring portions of the adjacent states.

The plant of the Northwestern Sewer Pipe & Tile company is located a short distance south of the Sioux Paving Brick works. The material used is obtained from the Cretaceous, the clay being taken from beds 4 and 7 of the following section.

	FEET.
7. Shale, gray to white, siliceous	15
6. Lignite, impure	1

		FEET.
5.	Sandstone, marly, white	2½
4.	Shale, gray to white, with ferruginous colorings; also layers of siliceous boulders	12
3.	Shale, drab to white, arenaceous	2
2.	Sandstone, white to red	7
1.	Shale, gray, sandy, especially below; exposed	7

The clay is treated both by the dry-pan and the wet-pan process and is worked upon a Vaugh machine. The ware is dried in a large two story steam heated dry shed, and burned in Eudaly kilns, of which there are nine on the premises. The pipe are glazed with salt, and have a decided metallic ring as well as a handsome appearance. A considerable variety of sizes is turned out. Sewer pipe ranging in diameter from three inches to two feet are being shipped. The early attempts at the manufacture of sewer pipe at this plant were quite discouraging, but under new management better results have been obtained.

The Sioux City pottery is located north of the Sioux Paving Brick works; it was established some years since by Mr. J. K. Prugh, but has not been in operation recently. The clay used was taken from a bed corresponding to number 1 of the section at the Sioux Paving Brick works and seems well adapted for use in the manufacture of ordinary pottery. When the plant was in operation a considerable portion of the ware was crimped. This could probably be avoided by proper treatment.

The Sioux City Brick & Tile Co., operate a large plant at Springdale, a suburb of Sioux City. They have a large annual output of building brick and command an excellent trade. The material used is the loess, and is taken from the bluffs along the Floyd river. It is for the most part quite pure, though lime concretions are abundant in certain portions of the pit. The clay is moulded on a Kells & Son stiff-mud machine, and a small portion of the output is treated on a Drake re-press. In drying steam heat is used. A large Radford partition, and a Hoffman continuous kiln are used in burning.

The Peterson & Smith brick yard is in the valley of Prairie creek, at Hamilton and Twenty-fourth streets. The loess is used, being moulded on an H. Martin soft-mud machine, dried in the open air and burned in clamp kilns.

C. B. Woodley operates a brick yard at the foot of Orchard Hill, near the Illinois Central railroad. A Wallace machine was formerly used, but a Kells & Sons has been substituted. The loess is taken from a slope near the plant, and makes up into a smooth brick of excellent color.

The Sargent's Bluff pottery was founded in 1838, being located at first on the west side of the Missouri river. In 1862 it was transferred to its present site. Mr. E. Mattox now runs the plant, which consists of the ordinary pug mill, jolly and turning-wheel. A small down draft kiln is used in burning. The clay used is from a bed corresponding to No. 2 of the section at the Holman pit. The bed is seven feet thick and seems well adapted to the manufacture of ordinary pottery. It stands a high heat and takes a good glaze. The output of the yard is small.

The C. J. Holman & Bros. Brick and Tile works were founded in 1867. For the first two years hand-made brick alone were made. Later a Van Vallen horse power mud mill was used, but in 1880 a Cream City stiff-mud machine was substituted. This was in turn replaced in 1887 by a Penfield machine, and in 1890 a Chambers was set up. A number of different crushers, including the Wallace, Penfield, Potts and a Frey-Sheckler dry-pan. The latter is now used. The plant also includes a steam power Raymond re-press, ample shed room for drying, six down draft kilns with a total capacity of 400,000 brick, and one clamp kiln holding 225,000 brick.

The output is large and includes common, structural and fire brick, pavers, sidewalk blocks and bricks, and stock brick from the re-press.

The clay used is from the Dakota horizon, and is dug from the south side of the long spit of high land known as Sargent's Bluff.

The general section at this point has already been given. The details seen at this individual pit are as follows.

		FEET.
7.	Loess, typical on slope	40
6.	Sandstone, exposed	10
5.	Shale, lignitic to argillaceous	1¼
4.	Shale, argillaceous to sandy	5
3.	Shale, unctuous, dark to light gray in color	8
2.	Shale, "white," somewhat arenaceous	6
1.	Shale, buff to yellow and gray	16

With the exception of the sandstone and the lignite, the entire section is workable. The loess may be used for various grades of structural brick. Number 4 is used for quite a wide variety of purposes. Number 3 is well adapted to the manufacture of pottery, burning white with very little shrinkage. Number 2 is properly a fire clay, but combines readily with the less refractory clays and is largely used in the manufacture of common brick. Number 1 is especially good for dry-press building brick and pavers. It contains concretions of ferruginous sandstone, in which, as well as in the clay itself, the plant remains already noted occur.

The entire plant is conveniently arranged and it has ample railway facilities, being connected with the Sioux City & Pacific railway, which runs just west of the yard. The output of the plant is of excellent character and commands a ready market. So far but few paving brick have been manufactured, though a number of the streets of Sioux City have been paved with brick made at this plant.

The Sargent's Bluff & Sioux City Brick company operate a plant located near that of Holman Bros. Up to 1892, when the plant was destroyed by fire, the company was known as the Terra Cotta Tile and Brick company. Early in 1893 the plant was entirely rebuilt. It now includes a Boyd dry-press and dry-pan, a Drake crusher, a large storage dry-house with elevators, a Barnhart steam shovel, five Eudaly kilns having a combined capacity of 1,200,000 brick, and a Radford continuous, fourteen-compartment kiln having a capacity of 324,000 brick.

The clay used comes from the Dakota formation, and is taken from layers essentially similar to those exposed in the Holman pit. The principal output of the plant is front brick, and numerous beautiful soft tints, ranging from a deep red to cream white, are produced. Veneerings are being experimented with, with good prospects for success. The quality of the ware produced is excellent and the output large. While a considerable portion of the product goes to Sioux City, a large number of brick are shipped to various other markets.

CEMENT.

The manufacture of Portland cement is a business which in this country is rapidly expanding. The Western Portland Cement company of Yankton has shown that the chalks and clays of the upper Missouri region are especially well adapted to this use. At the Yankton plant the chalk of the Niobrara and the clay of the Pierre are used, and by the wet process are made into an excellent grade of cement. The material as it comes from the pits is ground and mixed together in proportions determined by analysis. This "slurry" is dried under sheds and then broken up and burned. The burned material is reground by means of rolls and millstones and is then ready for the market.

Sometime since, experiments were carried on in Sioux City, in the course of which it was demonstrated that excellent cement could be made from material occurring at that place. The proportions used were five parts of one clay, two of another, and one of chalk.* These materials all occur in abundance along the Big Sioux, north of Sioux City, and there seems to be no good reason why the manufacture of cement at some point along the river, if carefully carried on, would not be successful. The value and importance of a good cement, in connection with the clays, which must always furnish the chief building material of the region, is apparent. The presence also of rock well adapted to concrete work

*Lonsdale: Proc. Iowa Acad, Sci., II, 173. Des Moines, 1895.

though not so readily available for dimension stone makes possible a wide use of cement independent of brick construction.

BUILDING STONES.

The rocks of the county do not afford any very great supply of stone suitable for building. Some portions of the Dakota sandstone may be available, especially the quartzitic facies, such as is seen at the Reese quarry; but the supply of such material is very inconsiderable. Certain parts of the Niobrara chalks and limestones have been quarried to a limited extent in this region. The chalk rock, while soft, stands on the whole better than could be expected, but its use can not be recommended. So far as relates to supplies of building material, the clays must always be the main dependence of the people of this region.

LIME.

The Niobrara chalks and limestone beds were in the early days burned for lime and afforded a fairly good article. The local product has been, however, long since driven from the market by the better grades of eastern lime, and it seems doubtful if the industry will ever be revived to any great extent.

SAND AND GRAVEL.

These materials may be found along the major streams. The pits north of Sioux City have already been described. Along the Little Sioux the middle terrace furnishes in places good material of both kinds. The two materials are, however, so intermingled that neither can be used without screening. The loess, while not of much value for ballast, is much used for roadmaking; being admirable for fills and roadbeds.

COAL AND LIGNITE.

There is no reason to believe that coal in paying quantities will ever be found within the limits of the county. If the coal measures ever extended over the region, they must have been very largely, if not entirely, removed during the long succeeding period of erosion. Such limited areas as may possibly remain, are securely buried below 300 to 500 feet of overlaying Cretaceous and drift. When one remembers that in the coal region of Iowa the beds themselves are so irregular that in some cases as many as ten or more diamond drill holes must be bored in a single section before the coal bed is outlined definitely enough to warrant planning the mine workings, it will readily be seen that the expense of prospecting would here always exceed the returns reasonably to be expected, even admitting the possible presence of outliers of coal; a point which is itself open to more than doubt.

The Cretaceous beds contain, as has been said, certain bands of lignite. These usually occur in the Dakota, though the bed so long intermittently worked at Ponca is found near the base of the Benton. Thin beds may be noted at several points along the Missouri and Big Sioux, but those seen in this county are of very inconsiderable thickness. These lignites are impure forms of coal. As shown here they usually consist of thin streaks or seams of coaly matter, from one-fourth to three inches in thickness, interbedded with loose carbonaceous clay. The latter is often plastic and may be moulded with the fingers. The thinner streaks of coaly matter burn readily, but the proportion of combustible matter to clay and dirt is very small, and they apparently can not be made available except by washing the dirt out. If a bed of sufficient thickness to justify the expense should ever be found, it is possible that, by grinding and washing, a material could be obtained which in the form of briquetts would find ready sale as a fuel. Such seams are not, however, known to occur. The Dakota, as exposed along the river, shows no coal beds approximating the requisite thickness, and there is no good reason to believe that the exposures here are other than typical.

WATER SUPPLY.

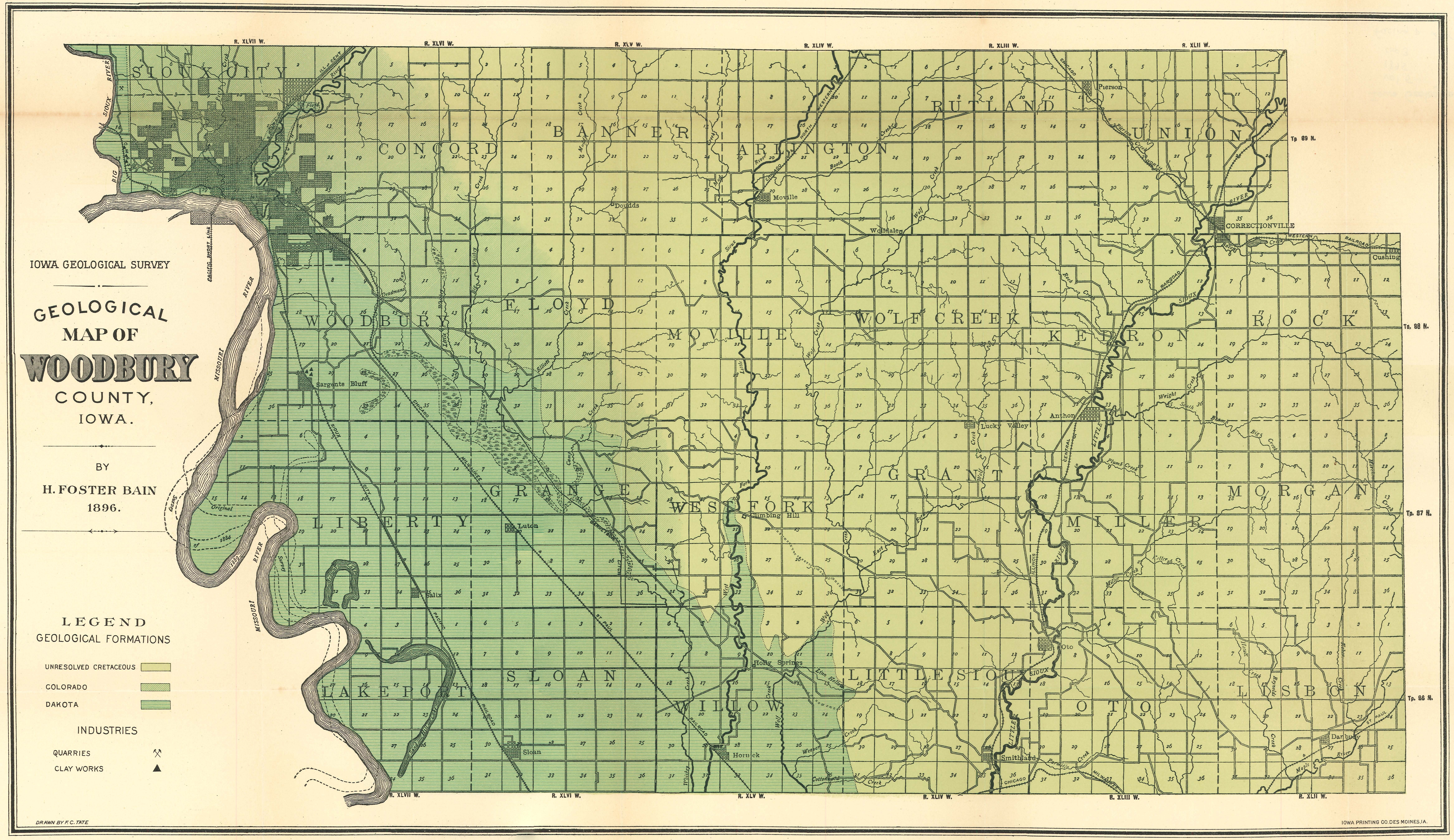
The many rivers and streams afford at all ordinary times abundant supplies of water. Wells of good character may almost always be obtained by sinking to the base of the loess. In Sioux City the wells derive their water from the drift. With the exception of those which are sunk in recently made land, they are not affected by the rise and fall of the river. The drift horizon is marked by a number of springs in various parts of the county. There is a second spring horizon at the base of the Niobrara. One of the best known springs which belongs to this horizon is the Lithia spring on the Talbot farm (Tp. 89 N., R. XLVIII W., Sec. 1).

Water was obtained in the deep well at Sioux City at three horizons. A water-bearing sand and limestone was encountered at 540 feet, and extended to 570 feet. From this horizon water rose to within twelve feet of the surface. At about 1,250 feet a second water-bearing sand rock was encountered. This extended to 1,270 feet, and a flow of three gallons per minute was obtained. At 1,480 feet a third flow was obtained.

The water from these horizons seems to come from the Paleozoic, and hence to be below the Cretaceous. The Dakota sandstone, which forms the great source of phreatic water throughout South Dakota, crops out along the Sioux and Missouri rivers. It is marked on the Nebraska side of the Missouri by a number of beautiful springs, and apparently loses its water supply, to a very large extent at least, before entering Iowa. There is very little reason for looking upon it as a probable source of water supply in this state.

SOILS.

The soils of Woodbury county are of great fertility and value. They are made up of alluvium and loess, and the absence of boulders makes cultivation easy. The porous nature of the loess covering of the upland simplifies the problem of drainage.


IOWA GEOLOGICAL SURVEY
GEOLOGICAL
MAP OF
WOODBURY
COUNTY,
IOWA.
BY
H. FOSTER BAIN
1896.
LEGEND
GEOLOGICAL FORMATIONS
UNRESOLVED CRETACEOUS
COLORADO
DAKOTA
INDUSTRIES
QUARRIES
CLAY WORKS
R. XLVII W.
R. XLVI W.
R. XLV W.
R. XLIV W.
R. XLIII W.
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Tp. 87 N.
Tp. 86 N.
SIOUX CITY
CONCORD
BANNER
ARLINGTON
RUTLAND
UNION
WOODBURY
FLOYD
MOVILLE
WOLF CREEK
KEDRON
ROCK
LIBERTY
GRANGE
WEST FORK
GRANT
MILLER
MORGAN
LAKEPORT
SLOAN
WILLOW
LITTLE SIOUX
OTO
LISBON
Pierson
Moville
Correctionville
Cushing
Sargents Bluff
Luton
Salix
Sloan
Climbing Hill
Lucky Valley
Anthon
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Wolcott
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MISSOURI RIVER
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LITTLE SIOUX
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ACKNOWLEDGMENTS.

Thanks are due to those gentlemen of Sioux City who have so courteously aided in every way possible myself and other members of the survey in our work in this region. Among the many may be especially mentioned Messrs. D. H. Talbot, John H. Charles, Judge G. C. Wakefield and Mr. J. C. C. Hoskins. The co-operation of the last named gentleman has been especially helpful, because of his long and intimate knowledge of the locality. His published notes* have been found to be both accurate and valuable, and have been freely incorporated in this report. To Prof. J. E. Todd, of Vermillion, South Dakota, special acknowledgments are also due for co-operation in the field and for many suggestions regarding the Pleistocene deposits. Of the members of the survey, the notes of Dr. Calvin on the Cretaceous, and of Mr. E. H. Lonsdale on the clay industries, have been freely used.

*Hist Woodbury and Plymouth counties, Chapter II, Topography and Geology, pp. 14-46 Chicago, 1890-1891,

GEOLOGY OF WARREN COUNTY.

BY

J. L. TILTON.

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LOCATION.

Warren county is in the south central part of Iowa. It is in the third tier of counties from the southern boundary and in the center of the state east and west.

PHYSIOGRAPHY.

The weathering of the rocks supplies in various ways material which is gradually washed into the streams. The latter, working under the force of gravity upon strata of different hardness and dip, eroding here, depositing there, effected by the slightest crustal movement, writes the geographic history of the region in the landscape.

When once a broad plain has become subject to erosion, the gradual wearing away of the rocks would, after a period, reduce the country to a surface dotted with low rounded hills. The series of changes which a landscape undergoes as it thus wears away until it is again raised for erosion to begin its work anew, constitutes a cycle. Generally the changes of one cycle erase from the landscape much that resulted from preceding cycles; but in the area under consideration the oscillations that have occurred since the land was finally raised above the sea, each successive elevation marking separate incomplete cycles, seem to have aided erosion along lines first marked out and hastened the development of the present physiography.

The interpretation of the physical geography of Warren county must not only answer questions presented by the topography of the county itself, but also explain the phenomena presented in the adjoining counties. It must be in harmony with the facts observed in the great area now drained by the Missouri river. It must stand in proper relation to any explanation of the conditions existing in northeastern Iowa. It must allow a suitable explanation of the upper course of the Mississippi river as contrasted with its course farther south. All these physiographic features are expressions of the movements that have occurred in the various parts of the Mississippi valley and the explanation of any one must be in harmony with a possible explanation of all.

DESCRIPTIVE PHYSIOGRAPHY.

General Drainage of the Region.—Along the eastern border of the state flows the Mississippi river, along the western the Missouri. These two great rivers are the master-streams of the entire west central region of the United States. A line passing through Clarke county, the southwestern part of Madison, through Adair, thence in a continued curve through Sac, Buena Vista and Dickinson counties, divides the state into two areas, the larger one to the east draining into the Mississippi river, the smaller area to the west draining into the Missouri. In the eastern area are large secondary rivers —in this case subsequent streams—some of them originating along this divide and gathering to their waters the numerous smaller streams that drain the adjacent territory. Two of these streams, the Des Moines and Skunk rivers, have selected their courses along the shales of the coal measures, draining an area between the heavy limestones of the Mississippian series to the northeast and similar limestones of the Missouri stage to the southwest.

Streams of Warren County.—Among the streams referred to are North river, Middle river, and South river, all of which take their rise along the crest of the divide in Clarke, Madison and Adair counties, and meet the Des Moines river near the northeastern corner of Warren county, together draining an area of approximately 1,440 square miles, including the whole of Warren county with the exception of the southeastern part where the drainage is into Whitebreast creek; another of the streams arising along the divide and flowing parallel to the three rivers mentioned to the Des Moines. It should be noticed that all the main streams of the county have a general direction to the northeast.

The areas drained by these rivers are as follows.

	Area drained outside the county.	Area drained within the county.	Total area drained.
South river	278	304	582
Middle river	352	114	466
North river	312	80	392
Whitebreast	329	69	398

General Character of the Streams as Illustrated by Middle River.—Middle river lies close to bluffs on the south along its entire course through the county, though departing here and there in sharp curves as it wanders across a flood plain excessively large.

In the long gentle slopes to the north of the river are but few well developed ravines. The few that exist are in Jefferson township. The bluffs along the south of the river are cut by numerous trenches, some running three to five miles into the uplands where they originate in numerous smaller ravines between the gently rounded knolls. One of these, Clanton creek, is of considerable importance, having a well developed valley of its own which in direction and size is analogous to that of Middle river. Only a portion of this stream, however, lies within the county. In the lower course of the river Butcher creek is developed parallel to the general course of the main stream, but reaches it only as that river is about to join the Des Moines. Butcher creek then, in the rank of its development, corresponds to Middle river rather than to a lateral ravine. With the exception of these two creeks, especially the latter, all the ravines extend laterally from the rivers.

This description of Middle river stands in a general way for both North and South rivers, excepting so far as relates to the particular lateral ravines that exist. From the uplands south of South river flow three large creeks, Coal creek, Otter creek and Squaw creek, while the river itself flows parallel to these creeks along the west side of White Oak township.

Escarpment Makers.—For the most part the strata consist of soft clay shale with interstratified calcareous sandstone.

The latter is quite thin, the beds being rarely more than about eighteen inches in thickness. The sandstone generally decomposes easily on exposure to the air because of oxidation of the contained iron, and the reaction between the sulphuric acid derived from the pyrites and the limestone.

Certain of the strata deserve especial attention. The heavy brownish sandstone that caps the bluffs along the Des Moines river in the northeastern part of the county, and extends some distance along the lower course of South river, gives a most interesting variation to the usual slopes where the river cuts into the hills. This rock is not resistant, and only forms very steep slopes where the river can wash away the rapidly accumulating talus.

At Spring Hill a sandstone which lies a few feet above the railroad track contains so much lime that the lower part of it well deserves to be called a limestone. This lower portion is especially resistant to atmospheric action and prevents the rapid wearing away of the hillsides. In the hills south of South river, especially in Otter township, is a layer of very desirable stone which occupies a position similar to that of the Spring Hill sandstone, and likewise aids much in protecting the underlying shales.

In the central and eastern part of White Oak, high sandstone bluffs again appear. While easily decomposed they form a conspicuous feature in the sections referred to, and seem to supply the material underlying the drift through the entire western part of White Oak. This sandstone is also to be found at various points of the county east and south of the bluffs here mentioned.

Across the central parts of Virginia, Squaw, and Liberty townships a heavy arenaceous limestone of about five feet in thickness outcrops. Here again the underlying soft strata are well protected. Where thus protected the strata stand out more prominently along the rivers and ravines, forming escarpments especially marked in comparison with those found elsewhere in the county.

Escarpments.—A topographic map of the county would show that lines of escarpment are to be found where these harder rocks exist, forming irregular fronts approximately at right angles to the general direction of the rivers and creeks, though the escarpment lines would be very faint. One escarpment is along the Des Moines river; a second extends northwestward through Otter township, then westward across the northern part of White Oak, finally northward through Jefferson and Linn townships, forming a very irregular front with outliers of high ground at and north of Indianola. The

FIG. 44. The skyline as seen just south of Indianola, looking southeast across the bottom lands of South river towards Otter township. The brow of the hill in the foreground cuts off the view of the more gentle slope on the north side of the valley, as contrasted with the more abrupt slope in the distance.

third line of escarpment extends southeast to northwest across Virginia township, though this same escarpment is continued at a somewhat lower level across Squaw township to north of Liberty Center. The general trend of the escarpments is westward through the southern half of the county, and in a curve northward through the western part of the county.

The Skyline.—Looking out upon the horizon from the top of any of the hills the highest surface is seen to extend in all directions in a quite even skyline rising gradually to the southwest, though this general rise of uplands within the county is scarcely perceptible to the eye. It is, however, perceptible along Middle river in the eastern part of Madison county, especially when looked upon from a distance to the north. Figure 44 is presented especially to illustrate the evenness of skyline, while figures 45 and 46 also bring out this feature.

Through the upland the larger streams flow along beds of even slope, only varied slightly here and there as they pass exposed broken edges of the harder layers of sandstone. In every direction the highlands are deeply cut by ravines that divide and subdivide till on close view nearly the whole country seems rounded and smoothed. Figure 45 brings out in a measure this branching of the ravines, and the rounding of land between them.

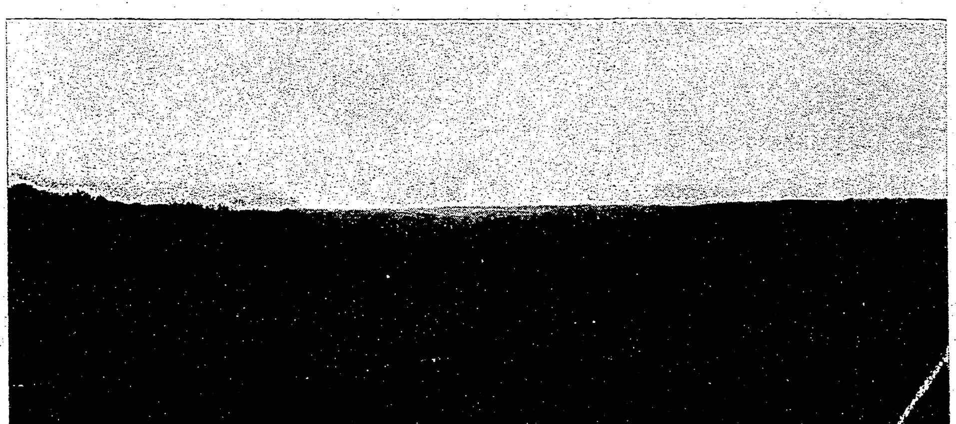


FIG. 45. View down one of the small ravines selected as a type to illustrate the branching and rounded sides of ravines. This ravine is on the southern outskirts of Indianola looking southwest.

Dip of Strata.—While there are escarpments progressively higher to the southwest ("retreating escarpments") and the strata of the county have an almost continuous, though slight, dip in the same direction, the rivers flow across these escarpments in a direction opposite the dip to join the Des Moines river.

EXPLANATION OF PHYSIOGRAPHY.

Since a correct interpretation of the physical geography of this county must stand in accord with all that surrounds it, it is to be regretted that the details of the physiographic development of the large area to which the southwestern part of Iowa belongs, have not as yet been thoroughly worked out; but the following conclusions reached by geologists here mentioned present the best information at present obtainable concerning the part of the country in which Warren county is situated.

First.—It is commonly recognized that throughout Cretaceous times a part of Iowa and a vast region to the west was the bottom of a large sea extending from what is now the Gulf of Mexico, northwestward possibly to the Arctic ocean.

Second.—As stated by Upham* there is evidence of a general uplift of the country at the close of the Cretaceous period.

Third.—Todd† infers from evidence he finds that southwestern Iowa was at a low elevation up to the beginning of the Glacial epoch.

Fourth.—In the article mentioned by Upham the next general uplift is referred to the beginning of the Tertiary period and the next, "Between the general Tertiary cycle of baselevelling and the glacial period."

Fifth.—Westgate, in tracing the "Geographic Development of the Eastern Part of the Mississippi Drainage System,"‡ presents the conclusion that up to the close of the Cretaceous period the upper part of the Mississippi river, which is older than its more southern extension, had an outlet toward the west; and that from the close of the Cretaceous period the Missisippi came to flow in its present valley east of Iowa. While the uplifts mentioned affected nearly all, if not all, of the United States, they were more marked in the western than in the eastern part of the country.

To the above conclusion may be added another: whatever changes§ in altitude may have occurred since what is now

*Tertiary and Early Quaternary Baselevelling in Minnesota, etc., Am. Geol., Vol. XIV page 235. Minneapolis. 1894.

†Proc. A. A. A. S., Cleveland meeting, Vol. XXXVII. 1888.

‡Am. Geol, XI, pp. 245-260. 1893.

§For the change in elevation during the Carboniferous period, see Iowa Geol. Surv., Vol. II, p. 114.

Warren county first emerged from the waters in which the strata were deposited, the changes did not affect in any marked degree the horizontal position of the strata in central and southwestern Iowa. It is probable that the direction of drainage over the whole of the central and southwestern part of Iowa was toward the southwest, till the close of the Cretaceous period.

The features of the county already described find their most probable explanation in the following outline of events. Throughout Cretaceous times the surface was that of a low plain draining to the west, with lateral streams developing along the outcrop of the soft shales. These lateral streams would be called subsequent steams. At the close of the Cretaceous period the elevation, especially marked westward, gradually changed the drainage over a considerable portion of the state to the southeast, the lines of drainage following the direction of the subsequent streams already developed along the strike of the soft strata. To this group of subsequent streams flowing to the Mississippi as the master-stream, belong, among others, the Des Moines and the lower course of Chariton river. From these subsequent streams, other streams worked their way back on either side, those on the south working their way as obsequent streams in the valleys that formerly drained southwest. To this group of obsequent streams belong North, Middle and South rivers of Warren county, also Butcher creek and Whitebreast creek. At the present time the divide between these streams and those still flowing southwest, extends through Clarke county, southwestern Madison and through Adair.

The course of Chariton river exemplifies particularly well the results of such a history. It has worked its way back along the strike of soft strata to the city of Chariton as if beheading one stream after another. Above Chariton the course is from the southwest. The beheaded stream still continuing toward the northeast is Cedar creek. In Warren county a similar tendency to develop valleys parallel to the strike of this same outcrop of soft strata is observed in all the streams. From the Whitebreast creek a ravine now extends along the strike of the soft strata with the head of the ravine even between Chariton river and Cedar creek. South river flows north along the west side of White Oak township and then turns east along the same series of soft strata, while another ravine just beyond a narrow divide continues the northward course to Middle river. During the Glacial epoch the land received its superficial deposit that clogged all the river valleys. Into this deposit the rivers have since cut their present trenches, though not to the depth of the preglacial valleys. The rivers and their larger tributaries are still in the preglacial valleys, but many of the smaller ravines have no relation to preglacial ravines.

FIG. 46. The broad valley of the Middle river, as seen looking south toward Summerset. In the foreground the hill slopes gently toward the bottom land Beyond Middle river, along the distant margin of tne lowlands, the hills rise comparatively abruptly.

Immensity of the Erosion.—The immensity of the erosion cannot fail to impress one who stands upon the hills overlooking Middle river at Summerset (see figure 46) and looks up and down the wide valley containing that stream, usually so insignificant.

South of Indianola the evidence of great erosion is no less marked as is shown by figure 47. These two illustrations serve as types of all the larger valleys in the county.

FIG. 47. The broad valley of South river, as seen looking northward toward Indianola. Here the river has left the steeper hills on the south of the valley and wandered over the flat lowlands of the valley itself. In the background the gradually rising hills can be seen below the distant skyline.

This erosion, immense though it is, is not yet completed. The landscape still presents much than can be eroded before the country is reduced to a peneplain. We have a landscape that is only approaching maturity of development.

TABLE OF ELEVATIONS.

As there is no topographical map of the county, the following records of altitudes are inserted as a basis for a study of the topography, a table for general reference, and a series of stations for use, should the preparation of a topographical map ever be undertaken.

The various levels obtained have been reduced to sea level at the Gulf of Mexico, Biloxi gauge, taking the record of the C., B. & Q. railroad station at Indianola as a central station assumed to be correct. By means of a barometer, the level of the C., R. I. & P. railroad station at Indianola was compared with the C., B. & Q. station at that place, thus eliminating the slight disagreement (five and a half feet) in the railroad survey records. The record of the D. M. & K. C. railroad levels were then connected with the C., R. I. & P. railroad records by means of the crossing west of Lothrop. From these known levels the altitudes of the stream beds at different points were determined, either by a barometer or by a tape line, and the slope of the streams ascertained.

	FEET.
(Tp. 77 N., R. XXII W.)	
Section 12, Sw. qr., Sw. ¼, river bed of South river beneath the railroad bridge	735.7
Ford railroad station	759.74
Section 34, river bed beneath the wagon road bridge	759.44
(Tp. 77 N., R. XXIII W.)	
Section 2, river bed beneath railroad bridge over North river	760.45
Carlisle railroad station	787.1
Section 12, river bed beneath wagon road bridge	812.21
Section 15, river bed beneath wagon road bridge, Middle river	750.35
Summerset junction	799.1
Summerset station	802.1
River bed of Middle river, close to Summerset	775.1
(Tp. 77 N., R. XXIV W.)	
Section 18, Norwalk railroad station	982.15
Section 21, Ne. qr., Se. ¼, bed of North river	780.44
Section 30, river bed beneath railroad bridge	806.15
(Tp. 77 N., R. XXV W.)	
Section 36, where railroad crosses the township line	878.15
(Tp. 76. N., R. XXII W.)	
Section 4, river bed beneath wagon road bridge	768.31
Section 19, river bed beneath railroad bridge	805.87
(Tp. 76 N., R. XXIII W.)	
Indianola, C., B. & Q. railroad station	968.6
Indianola, Rock Island station	964.1
Ackworth railroad station	856.99
Section 25, river bed beneath railroad bridge	775.1
(Tp. 76 N., R. XXIV W.)	
Section 4, river bed beneath wagon road bridge east of Spring Hill	798.47
Spring Hill railroad station	839.1
Section 8, railroad beneath wagon road bridge south of Spring Hill	806.26
(Tp. 76 N., R. XXV. W.)	
Prole railroad station	989.15

	FEET.
Lothrop railroad station	847.1
Junction of Winterset branch and the D. M. & K. C. railroad	837.4
Des Moines & Kansas City railroad bridge over Middle river	842.15
River bed beneath the Des Moines & Kansas City railroad bridge	816.15
Bevington railroad station	868.1
River bed at Bevington	852.1
Wick railroad station	597.15
(Tp. 75 N., R. XXII W.)	
Milo railroad station	971.53
Top of recorded well boring, Sec. 19, Sw. qr., Nw. ¼	937.53
(Tp. 75 N., R. XXIII W.)	
Section 6, river bed beneath bridge south of Indianola	801.1
(Tp. 75 N., R. XXIV W.)	
Section 6, river bed beneath wagon road bridge	838.72
Section 31, river bed, Sw. qr., Sw. ¼	869.9
(Tp. 75 N., R. XXV W.)	
Railroad at crossing of road, one-half mile west of Saint Mary's	1,062.15
Section 19, railroad at county line	1,069.15
(Tp. 74 N., R. XXII W.)	
Section 13, creek bed of county line	787.74
Lacona railroad station	822.2
Section 35, creek bed at county line	806.43
Section 35, railroad at county line	854.48
(Tp. 74 N., R. XXV W.)	
Section 16, railroad bridge over South river	914.15
Section 16, river bed beneath railroad bridge	896.15
Section 19, railroad at county line	937.15
Section 19, river bed at county line	921.65
Section 21, railroad at road crossing on north section line	1,051.15
New Virginia, old railroad station	1,088.15
New Virginia, new railroad station	1,041.15
Section 33, railroad at county line	968.15

LEVELS OF POINTS OUTSIDE OF THE COUNTY CONSULTED IN DRAWING THE RIVER SECTIONS.

River bed near the mouth of North river, beneath the C., B. & Q. railroad bridge	752.24
Bed of Whitebreast creek, beneath C., B & Q. railroad bridge, about three miles west of Knoxville	723.7

	FEET.
Bed of Whitebreast creek, beneath C., B. & Q. railroad bridge, a mile south of Warren county line, on the Indianola branch	809.1
Bed of Whitebreast creek, beneath C., B. & Q. railroad bridge, a mile east of Cleveland, Lucas county	851.1
Low water mark, Raccoon river (datum level for the D. M. & K. C. railroad, survey reckoned from Indianola by means of levels on C., R. I. & P. railroad, Winterset branch, and the junction with the D. M. & K. C. railroad)	797.15

SLOPE OF RIVER BEDS.

NORTH RIVER.

Total fall of the river, from the D. M. & K. C. railroad bridge, in the western part of Greenfield township, to the C., R. I. & P. railroad near Carlisle	45.7
Fall per mile in a straight line (eleven and one-fourth miles)	4.06

MIDDLE RIVER.

Total fall from Bevington to Summerset	77.
Fall per mile, in a straight line (fourteen miles)	5.5

SOUTH RIVER.

Total fall in South river, from county line, Virginia township, to the C., B. & Q. railroad bridge, sec. 12, Richland township	185.95
Average fall per mile, in a straight line diagonally across the county (thirty-one and one-third miles)	5.93

WHITEBREAST CREEK.

Total fall within the county	18.69
Average fall per mile in a straight line (three and one-half miles long)	5.34

GEOLOGICAL FORMATIONS.

PLEISTOCENE.

The surface deposits of the county belong to two epochs. The alluvium represents the recent epoch, and the glacial deposit, consisting of loess and drift, the glacial epoch.

ALLUVIUM.

Upon the low ground along the streams a considerable amount of silt has been deposited. Over the higher portions of the low ground this deposit is very thin, scarcely more than enough to mix with the loess and obscure the character of the latter. In the lower parts of the river valleys there are numerous swampy places, the partially filled lagoons left after the rivers have formed new trenches in the vicinity. These low grounds have received sediment washed from the adjoining higher ground or brought in by occasional overflow of the river. The material is frequently rendered black by abundance of vegetable material. All of these deposits may be classed as alluvium.

LOESS.

On the hilltops and in the valleys, even to the very banks of the river trenches, there is a fine, light, yellowish-brown deposit, largely made up of clay and fine sub-angular quartz.* The upper portions are black because of vegetable mould, the carbonaceous remains from decay of various plants. The fine material of the loess seems to have been washed from material brought by neighboring ice masses.

The exposure of loess at the Indianola Brick & Tile Co. plant, just northeast of Indianola may be taken as a typical exposure. At the surface two and a half feet are rendered black by vegetable mould. Beneath this mould there are two distinct deposits, the upper one, five feet thick, containing fossils characteristic of the loess (*Succinia obliqua* and *Mesodon multilineata* as identified by Professor B. Shimek). Beneath this loess, at a distance of about seven feet from the surface, is another clay deposit that for the present is here called the lower loess deposit. This lower deposit appears darker than the upper loess as seen in place. It does not contain fossils. The line of separation between these two deposits has a peculiar wavy appearance, suggesting a possible downward limit to present oxidation, or a disturbed surface on which the upper loess has been deposited. There is no dark line between the two to indicate a previous land surface, such as is sometimes found in deposits of loess.

*For analyses consult the tables given under clay deposits, in the latter part of this report.

The two deposits differ in composition in one important particular—the silica of the upper deposit is nearly all free, while that of the lower deposit is combined. This contrast is very marked when the two deposits are examined under a microscope. Samples collected from different levels above the line of separation between the two deposits present a uniform appearance, each sample containing an abundance of fine sub-angular quartz fragments. Below the line separating the two deposits the quartz fragments are far less numerous, the field of the microscope being largely occupied by dull, clayey material.

The differences in the composition of the two deposits suggest a possible difference in the sources of the material. The upper material may have been derived from a more loose sandy deposit, while the lower may have been derived from the disintegration of granite. Such a difference suggests further that the lower deposit may have been derived from the Kansan drift formation, which underlies the loess throughout the county. If it be true that the lower deposit is derived from the Kansan drift, the disturbed line between the two deposits represents an unconformity from which all evidence of vegetation, if such evidence existed, has been removed under the conditions which immediately preceded the deposition of the upper loess.

DRIFT.

In the eastern part of Greenfield township a sandy deposit extends southward to the divide between North and Middle rivers southeast of Spring Hill and a little to the north and west of Indianola. In Richland township the central sections are capped by a sandy material as if the deposit were a continuation to the south of a drift ridge east of Des Moines considered to be an esker. Between the two localities mentioned lie the gravel beds at Avon just north of the Warren county line. How much the early character of these deposits may be due to the soft sandstone and sandy shale just beneath the glacial deposits it is not possible to state.

The drift under the loess consists of a boulder clay or till containing pebbles of various sizes and shapes. These pebbles are of various kinds, granites, porphyry, quartz, agate, red quartzite and sandstone. The smoothed surfaces of some of these boulders are marked by peculiar scratches and gouges. A typical boulder may now be seen just northwest of Mrs. Watson's residence in the northwestern part of Indianola (Sec. 24, Sw. qr., Nw. ¼). This rock is a dense red quartzite with a rounded somewhat rectangular shape. It contains numerous pebbles revealing distinct planes of stratification dipping at present southwest, while on the eastern face the hard stone is scratched and gouged along lines at present almost perpendicular. The whole surface, scratches and all, is polished thoroughly. It is notable that this rock does not resemble the native Carboniferous sandstones; its planes of stratification do not correspond to the planes of stratification of the neighboring strata, and the glacial scratches are at right angles to the slope of the nearest ravine.

While this boulder, selected as a type, resembles Sioux quartzite, most of the boulders appear to be of granite. They are not very numerous on the surface of the ground, but, where the loess deposit is cut through, the boulders from the drift accumulate in the ravines.

The boulders mentioned are characteristic of the Kansan glacial formation that extends over the southern and western part of Iowa.

CARBONIFEROUS.

GENERAL DESCRIPTION.

In the preceding description of the physiography of the county the strata were referred to as an old shore deposit. The strata are in general clayey, or sandy shale, with here an arenaceous limestone and there a sandstone. The sandstones are generally ferruginous, sometimes dense and concretionary, sometimes soft, sometimes cross-bedded. The whole formation belongs to the great system of coal-bearing strata which extends from Iowa southwestward into Indian territory and Texas.

Relation of Strata to the Formation Below.—Immediately beneath the Carboniferous shales exposed in this county, lies the Saint Louis limestone. The borings put down at several points indicate that the surface of this Saint Louis formation on which the coal measures were deposited is uneven, like an old landscape with hills and valleys.

Conditions of Deposition.—During the deposition of the coal measures the conditions were at times favorable to the formation of swamps, and the vegetable material accumulated from the lepidodendrons, sigillarids and ferns that crowded the low swampy places. At times the region received fine clay sediments brought down by streams. At times conditions favorable to limestone formations spread a calcareous deposit over all. Again, the deposits, raised till exposed to erosive action were worn away here and there, only to again receive a deposit laid unconformably on the surface.*

Relation of Strata to the Formation Above.—As the seas advanced the heavy limestones of Madison and other counties west were laid down marking a condition of deep water more constant than had existed during the deposit of the shales. These limestones are, however, classified with the coal measures; for, while these were forming, Pennsylvania was receiving her stores of future wealth in the vegetable deposit† which later became coal. The difference between the conditions in which clays and sandy shales were deposited and those in which the heavy limestones were formed is so marked that it has been deemed advisable to classify these formations as separate subdivisions of the coal measures.

Classification of Strata.

GROUP.	SYSTEM.	SERIES.	STAGE.
Paleozoic.	Carboniferous.	Pennsylvanian.	Missouri. Des Moines.
		Mississippian.	Saint Louis Augusta. Kinderhook.

*For a record of these oscillations, see Iowa Geological Survey, Vol. I, p. 119.

†Dana's Manual, 4th ed., pp. 648 and 656.

The strata exposed in Warren county belong to the Des Moines stage of the Pennsylvanian series of coal measures. While the limestone of the Missouri stage, seen in Madison county almost touch the western border of Jackson township, they nowhere extend eastward across the county line.* Consequently all our strata belong to the same subdivision.

In the cross-sections along Middle and South rivers it will be seen that the limestone of the Missouri stage does not gradually change into shale as would be true if the present "lower coal measures" (Des Moines stage) were the shore equivalents of the present exposures of the Missouri limestone. While it is undoubtedly true the present exposures of the Missouri limestone did have a shore equivalent of shale when the limestone was deposited, that old shore equivalent has been eroded. The shales of the present Des Moines formation are now continued underneath the limestone of the Missouri stage. The sections outcropping along South and Middle rivers† are of special importance in their bearing because they are in a direction at right angles to the old shore line.

The variety of fossils that occur abundantly in the county is not very great. *Productus muricatus* is by far the most common, the small shells, half an inch long, forming the entire mass of the rocks in some places. In the heavier sandstones *Spirifer cameratus*, and *Productus costatus*, two of the larger shells about two inches long, frequently occur. In the thin layers of limestone to be found especially in the western half of the county occur crinoid stems, together with *Chonetes mesoloba*, *Athyris subtilita* and sometimes *Lophophyllum proliferum*.‡

*In the older geological reports of the state the thick bed of clay and sandy shale beneath the limestone was included with the limestone in the "Upper Coal Measures," and as thus defined; the Upper Coal Measures extend into Warren county; but the conditions under which this bed of clay and sandy shale was laid down were similar to those under which the strata beneath were deposited. The base of the heavy limestone marks the beginning of a deeper water formation in contrast with the shallow water deposits of the shales beneath. Hence it has been thought that the line of separation between the Des Moines and Missouri stages should be drawn at the base of the heavy limestone.

†For a continuation of the Middle river cross-section (Plate viii) to the Missouri stage limestone of Madison county, see "Geological section along Middle river in central Iowa," J. L. Tilton, Iowa Geol. Surv., Vol. III, p 137.

‡On the coal measure fauna the following references are convenient:
U. S. Geological surveys west of the 100 meridian, Vol. IV, Paleontogy.
Missouri Geological Survey, Vols. IV and V. 1894.
Geol of Illinois, Vol. V.
Hayden's Final Report on the Geol. Surv. of Nebraska. Washington, 1872.

DETAILED SECTIONS ACROSS THE COUNTY.

The sections here given were obtained along the different ravines, carefully measured by a barometer or tape line and referred to the river beds as base lines. The slope of the river bed was in each case determined from railroad surveys.

It is to be regretted that there are not more records of borings accessible. There have been but four drill holes made, the records of which are now obtainable and of value in a study of our strata. The first was put down by the town of Milo (Tp. 75 N., R. XXII W., Sec. 19, Sw. qr., Nw. ¼). The record of the boring was published in the mine inspector's report, 1882-83, p. 67. The second boring is in Tp. 76 N., R. XXIV W., Sec. 9, Nw. qr., Se. ¼, southeast of Spring Hill. It was made by Earle Brothers who kindly furnished the figures and description from their records. The third is in Union township, Tp. 76 N., R. XXII W., Sec. 5, Sw. qr., Sw. ¼. The fourth boring is in Tp. 76 N., R. XXII W., Sec. 5, Sw. qr. Sw ¼. The latter were made by Mr. A. G. West, who furnished the record at the request of Mr. W. N. Bartholomew, for whom the work was done. In the absence of more borings the different outcrops must be connected, and the results considered as representing the general relation of strata in the neighborhood. In each plate of sections along the ravines, the location of outcrops is marked.

SOUTH RIVER CROSS-SECTION.

The best series of outcrops is that along South river. The slope of the river was determined as follows.

The records of the Chicago, Burlington & Quincy railroad survey show the altitude of the river bed beneath the railroad bridge at the mouth of the river and south of Ackworth; also the altitude of Indianola and Osceola. By means of a barometer the difference in level between the Indianola station and the bed of the river directly south was measured. From the survey of the Des Moines & Kansas City railroad the difference in level between the station at Osceola and the point where the railroad crosses the west county line close to South river was ascertained, as well as the difference in level between the latter place and the bridge across South river, in section 16 of Virginia township. Since a river cuts through hard strata and fills with sediments the stretches from one hard stratum to the next till the entire slope of the river bed presents a slightly concave line, a knowledge of the altitude of the five points mentioned is sufficient to determine the slope of the entire river bed across the county.

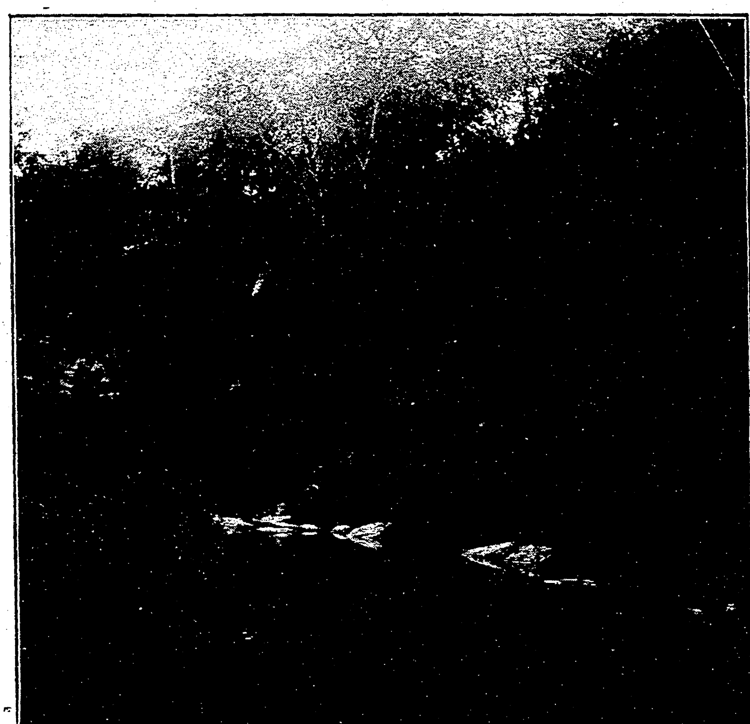


FIG. 48. The Ford sandstone as seen in the north central part of section 24 near exposure 1. Here the dip is visible on the southwestern side of the low anticline found in the northeastern part of the county.

Among the outcrops that occur there are thirteen of especial value, because of their size, their freedom from settling, and their position along the line. These outcrops and their locations are as follows.

SECTION I.

Exposure near the mouth of South river in Richland township (Tp. 77 N., R. XXII W., Sec. 24, Sw. qr., Ne. ¼). This section is just northeast of the crest of a gentle anticline. The dip is here 10° to 15° to the northeast.

		FEET.	INCHES.
4.	Drift	12	
3.	Shale, clay and sand, thinner banded above, heavier below	32	
2.	Sandstone, red, heavy, cross-bedded, with much globular iron pyrite	14	2
1.	River		

SECTION II.

Richland township near the mouth of Coal creek (Tp. 77 N., R. XXII W., Sec. 25., Sw. qr., Se. ¼), offers the following exposures.

		FEET.
4.	Drift	
3.	Shale, bluish gray, finely laminated with sandstone in thin layers to bed of Coal creek	40
2.	Not exposed	9
1.	River	

SECTION III.

The following outcrop is seen in Richland township (Tp. 77 N., R. XXII W., Sec. 35, Nw. qr., Se. ¼).

		FEET.
5.	Not exposed	93
4.	Shale, black, exposed	2
3.	Coal	2
2.	Shale, gray, sandy	32
1.	River	

SECTION IV.

Union township (Tp. 76 N., R. XXII W., Sec. 3, Se. qr., Nw. ¼).

		FEET.	INCHES.
12.	Drift	15	
11.	Shale, clay, black	2	
10.	Coal	1	
9.	Shale, clay, gray	4	
8.	Limestone, gray, arenaceous, fossiliferous	2	
7.	Shale, clay, gray	8	
6.	Coal	3	7
5.	Shale, bluish gray	10	
4.	Shale, gray, sandy	24	
3.	Coal	1	1
2.	Shale, clay	2	6
1.	River		

SECTION V.

The following section shows beds which also appear in Union township (Tp. 76 N., R. XXII W., Sec. 9, Ne. qr., Nw. ¼).

		Feet.	Inches.
8.	Drift	2	
7.	Limestone, blue, dense		2
6.	Shale, gray below and above, black through the center	19	
5.	Coal		6
4.	Shale, gray, fossiliferous below	11	
3.	Limestone, gray arenaceous shaly above; fossiliferous	2	6
2.	Shale, gray above, black below	14	
1.	River		

SECTION VI.

In Palmyra township (Tp. 76 N., R. XXII W., Sec. 5, Sw. qr.) is a boring to the depth of three hundred and sixty-seven feet and six inches, the top of which is one hundred and twenty feet above the bed of South river. The record of this boring as kept by Mr. A. G. West for Mr. W. N. Bartholomew is as follows.

		Feet.	Inches.
35.	Soil	4	
34.	Clay, yellow with gravel below	20	
33.	Sandstone, yellowish	11	
32.	Shale, blue	3	
31.	Limestone, fossiliferous	4	
30.	Shale, black	4	
29.	Coal	1	8
28.	Fire clay	8	
27.	Sandstone	4	
26.	Shale, gray	12	
25.	Shale clay, black	2	
24.	Coal	1	4
23.	Fire clay	3	
22.	Shale, clayey	16	
21.	Shale, clayey, red running to brown, bed of South river	26	
20.	Shale, brown, sandy below	19	
19.	Slate, bituminous	2	
18.	Shale, clayey	14	
17.	Shale, clayey, black	6	

		FEET.	INCHES.
16.	Coal	3	8
15.	Fire clay	4	
14.	Shale, gray with hard bands	10	
13.	Shale, soft-blue, with bands of gravel	27	
12	Shale, sandy	11	
11.	Sandstone, compact	6	
10.	Shale, light, with ironstone bands	17	
9.	Shale, clayey, red, blue and brown	26	
8.	Sandstone, fine-grained	4	
7.	Shale, clayey, light above, dark below, very hard bituminous	23	
6	Coal	1	10
5.	Fire clay	2	
4.	Shale, clayey, black	16	
3.	Shale, light, with hard bands	7	
2.	Shale, gray, very hard and sandy	12	
1.	Saint Louis limestone	38	
	Total	367	6

A second boring was made a short distance south, the top being is 132 feet below the top of the boring just given. The record of the second is as follows.

		FEET.
23.	Black soil, wash and drift	37
22.	Sand and gravel	8
26.	Shale, clayey, light	6
20.	Shale, clayey, red	15
19.	Shale, clayey, black	3
18.	Shale with coal	2
17.	Shale, clayey, light	4
16.	Shale, clayey, gray	13
15.	Sandstone, light	6
14.	Shale, clayey, gray	10
13.	Shale, clayey, black, soft	1
12.	Shale, clayey, white, soft	6
11.	Shale, sandy, blue	8
10.	Sandstone, fine, white	30
9.	Shale, dark, sandy, with hard bands	11
8.	Shale, clay, dark	6
7.	Sandstone, fine-grained, with hard bands	6
6.	Shale, white	5
5.	Shale, sandy, gray, hard	15
4.	Sandstone, light-colored	4
3.	Shale, sandy, gray	3

		FEET.
2.	Shale, sandy, light-colored, with hard bands	32
1.	Saint Louis limestone	2
	Total	233

SECTION VII.

The measurements next given are from Union township (Tp. 76 N., R. XXII W., Sec. 17, Sw. qr., Nw. ¼).

		FEET.	INCHES.
13.	Drift	10	
12.	Shale, clayey, gray	2	
11.	Shale, clayey, black	1	2
10.	Coal	1	
9.	Shale, clayey	2	
8.	Limestone, gray, dense, arenaceous	1	
7.	Shale, clayey, gray, nodular	32	2
6.	Limestone, blue, arenaceous fossiliferous	1	2
5.	Shale, clayey, gray	7	
4.	Limestone, blue, dense		6
3.	Shale, clayey, blue, finely laminated	5	
2	Not exposed	5	
1.	River		

SECTION VIII.

East of Ackworth (Tp. 76 N., R. XXII W., Sec. 30). This section is made up from exposures on both sides of the hill just east of the river.

		FEET.	INCHES.
15.	Loess		
14.	Shale, gray, clayey, sandy	2	
13.	Sandstone	3	
12.	Shale, clay		6
11.	Not exposed	12	
10.	Shale, gray, sandy	18	
9.	Not well exposed, but undoubtedly shale, gray, sandy	12	
8.	Shale, clayey	3	
7.	Sandstone, gray		8
6.	Shale, clay, black	1	2
5.	Coal	1	6
4.	Shale, clay, black, not fully exposed	11	
3.	Sandstone, gray, dense, fossiliferous	1	3
2.	Shale, clay, gray to black		9
1.	Coal		

SECTION IX.

South of Ackworth (Tp. 76 N., R. XXIII W., Sec. 36, Sw. qr., Se. ¼), is a series of outcrops that occur along the ravine extending from section 36 to section 35.

		FEET.	INCHES.
16.	Loess		
15.	Limestone, dense, very fossiliferous	1	
14.	Shale, clayey, black	4	
13.	Coal		9
12.	Fire clay above, clay shale below	8	6
11.	Sandstone, shaly, irregular	1	6
10.	Shale, clayey	1	
9.	Sandstone, gray, thick-bedded, soft	1	4
8.	Shale, gray, sandy, thin irregular bands	6	8
7.	Sandstone, reddish		8
6.	Shale, clayey, gray above, dark below	6	8
5.	Coal		2¼
4.	Fire clay		6
3.	Shale, dark		4
2.	Not exposed	2	
1.	River		

SECTION X.

North of Hammondsburg (Tp. 75 N., R. XXIII W., Sec. 2), the outcrops from which this section is made are scattered for a considerable distance along a ravine.

		FEET.	INCHES.
14.	Loess	"	
13.	Upper part sandstone, gray, heavily-bedded, graduating below to gray shale, then to gray, sandy shale	39	
12.	Coal	1	4
11.	Shale, clayey, grayish	13	6
10.	Limestone, very fossiliferous	1	
9.	Shale, clayey, blue above, black below	5	6
8.	Sandstone, gray, concretionary, somewhat calcareous		6
7.	Shale, clay, black	1	
6.	Coal, dipping south		7
5.	Shale, clay, gray	5	
4.	Sandstone, reddish, soft		9
3.	Shale, gray, sandy, thin-bedded, exposed	20	
2.	Not exposed	22	
1.	River		

SECTION XI.

South of Indianola (Tp. 75 N., R. XXIII W., Secs. 1 and 12), the exposures here given are found along the sides of a ravine.

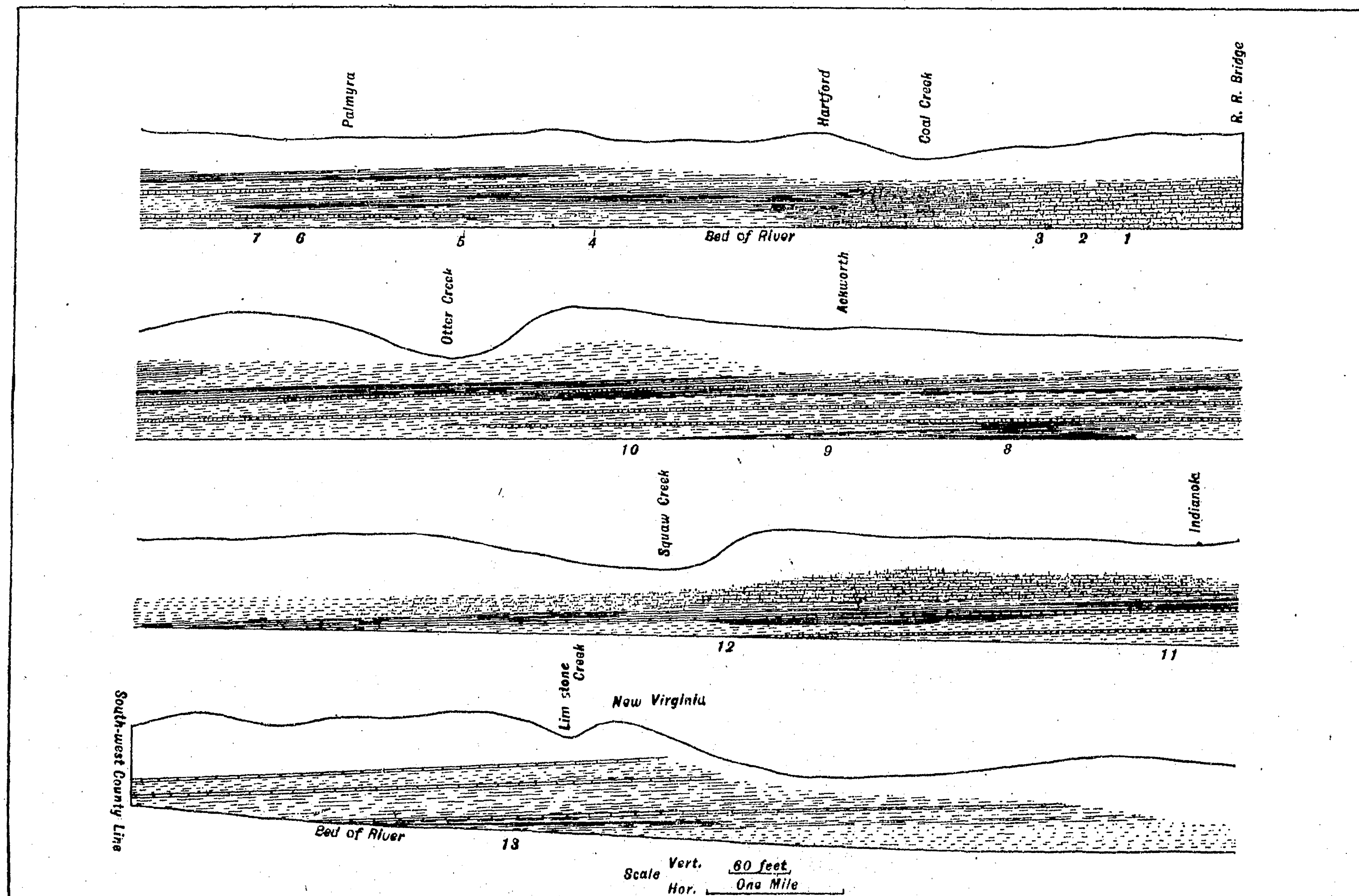
		FEET.	INCHES.
10.	Sandstone, gray, thin-bedded above, shale gray, sandy below	35	6
9.	Coal		7
8.	Fire clay		6
7.	Not exposed	6	6
6.	Limestone, shaly, arenaceous	1	6
5.	Shale, sandy, gray, lower part clay, gray, with reddish bands	21	
4.	Sandstone, gray	1	6
3.	Shale, sandy, gray	7	6
2.	Shale, clayey, dark	2	
1.	Not exposed	8	

SECTION XII.

The following exposure is near the "Quarries" on Squaw creek (Tp. 75 N., R. XXIV W., Sec. 22). A part may be found at the quarry itself, a part up a ravine a little to the north.

FIG. 49. The sandstone cliff at the old quarries in White Oak township (section 22).

		FEET.	INCHES.
9.	Sandstone, very massive, soft, grayish brown	14	
8.	Shale, gray, sandy above, clayey below; lower part not well exposed	11	
7.	Limestone, gray, very fossiliferous	1	1
6.	Shale, sandy, gray	1	
5.	Shale, clay, dark (exposed)	7	
4.	Limestone, concretionary		6
3.	Shale, clayey, black	1	2
2.	Coal	1	
1.	Not exposed	16	6



GEOLOGICAL CROSS-SECTION ALONG SOUTH RIVER IN WARREN COUNTY.

SECTION XIII.

This section is obtained from a combination of several series of outcrops on Limestone creek. The most important one is in section 17 (Tp. 74 N., R. XXV W.).

		FEET.	INCHES.
12.	Not exposed	54	
11.	Limestone, heavy above, shaly below	3	
10.	Shale, sandy, gray	30	
9.	Limestone	2	
8.	Shale, sandy, gray	10	
7.	Not exposed	15	
6.	Limestone, arenaceous	1	
5.	Shale, clayey	1	6
4.	Coal		4
3.	Shale, sandy, gray	15	
2.	Shale, black, carboniferous	1	
1.	River		

The outcrops above described, arranged each in its relative position, and the lines continued from one to the next, yield the general section seen illustrated in plate vii. In this diagram two slight gaps of a few feet occur, but from the field evidence the underlying strata at these points may be inferred without doubt. From the outcrops on Squaw creek, White Oak township, section 22, to those near Limestone creek, in Virginia township, there are no important outcrops, but the few that do occur, and the abundance of red sand to be found beneath the soil through much of the distance, give evidence of sandstone strata continued through most of this region.

WHITEBREAST CREEK CROSS-SECTION.

The section along Whitebreast creek in this county is quite short. One of the central outcrops will serve for the entire

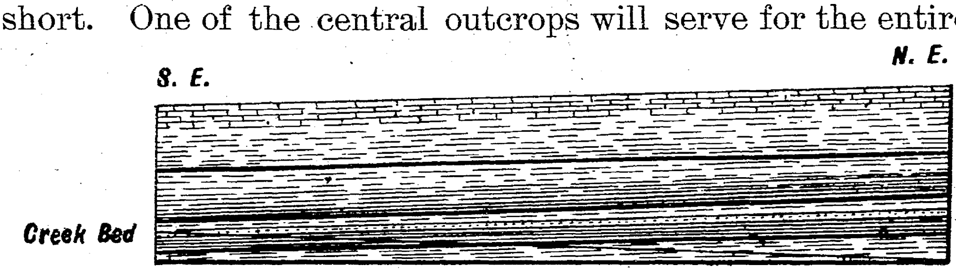


FIG. 50. Whitebreast Creek cross-section.

section. In fact, it is the only good outcrop to be found, though other small ones assist in correlation.

SECTION I.

Composite section for Tp. 74 N., R. XXII W., Sec. 26, Sw. qr.

		FEET.	INCHES.
15.	Sandstone, heavy, gray shale above, not well exposed below	62	
14.	Coal	1	5
13.	Shale, clayey, gray and blue, fire clay above	28	
12.	Shale, clayey, black	4	6
11.	Coal		9
10.	Clay, carbonaceous		4
9.	Clay, fire clay above, gray below	9	
8.	Sandstone, decomposed, calcareous		6
7.	Shale, sandy and clayey, gray		6
6.	Sandstone, very fossiliferous, gray		6
5.	Shale, gray, sandy	5	4
4.	Shale, clay, black	1	
3.	Coal, sulphur-bearing	1	8
2.	Fire clay	4	
1.	Creek		

MIDDLE RIVER CROSS-SECTION.

SECTION I.

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

		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

This 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 the principal seam of coal which appears just above the railroad track at the station, comes to an end as 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. Near this point 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.

SECTION II.

Just above the bridge between Carlisle and Palmyra the following section appears (Tp. 77 N., R. XXIII W., Sec. 15, Se. qr., Se. ¼).

		FEET.	INCHES.
12.	Shale, clayey	1	
11.	Coal		2
10.	Clay	5	
9.	Sandstone	1	8
8.	Shale, clayey		1
7.	Shale, clayey, black	2	9
6.	Coal		9
5.	Fire clay		1
4.	Shale, upper part with numerous nodular bands and several bands of sandstone	13	10
3.	Shale, clayey, dark	1	4
2.	Shale, clayey,	1	
1.	River		

SECTION III.

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. ¼) the outcrop shows.

		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	

SECTION IV.

At the shafts of the mines referred to the following record was obtained. The upper coal corresponds with the coal mentioned as outcropping near the river.

		FEET.	INCHES.
19.	Drift, yellow sands and variegated clays	24	
18.	Limestone, blue, fossiliferous	1	1
17.	Shale, blue, argillaceous	7	
16.	Limestone, fossiliferous		4
15.	Shale, black, fissile	2	
14.	Coal	1	2
13.	Fire clay	3	4
12.	Sandstone, with nodules of black limerock	5	
11.	Shale, gray with streaks of red	7	
10.	Sandstone	8	
9.	Shale, argillaceous	10	
8.	Sandstone	5	
7.	Shale, argillaceous	10	
6.	Limestone		9
5.	Sandstone	3	
4.	Shale, argillaceous	6	
3.	Shale, black, somewhat fissile	2	
2.	Coal	2	10
1.	Fire clay (exposed)	2	

The sandstone above the seam of coal is a continuation of that which is so prominent in the upper part of 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 town.

SECTION V.

The Summerset section (Tp. 77 N., R. XXIII W., Sec. 31, Ne. qr., is as follows.

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

		FEET.	INCHES.
3.	Sandstone, gray	1	6
2.	Shale, gray	1	
1.	Sandstone, heavily bedded	2	

From Summerset to Spring Hill the outcrops in the immediate vicinity of the river are not very numerous.

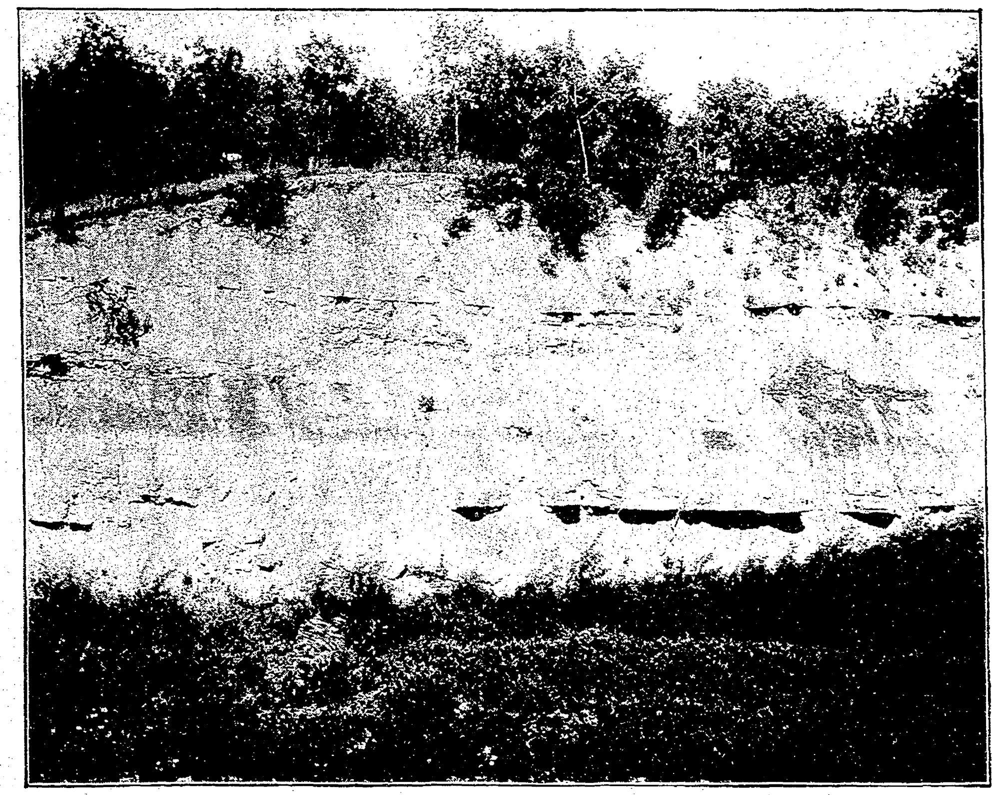


FIG. 51. Exposure at Summerset (Section 31, Ne, qr., Ne. ¼).

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 coal for local consumption.

SECTION VI.

Southeast of Spring Hill (Tp. 76 N., R. XXIV W., Sec. 2, Sw. qr., Ne. ¼).

		FEET.	INCHES.
15.	Not exposed		
14.	Shale, clayey, black	2	
13.	Sandstone, concretionary		6

		FEET.	INCHES.
12.	Shale, clayey, black	1	6
11.	Coal	1	6
10.	Not exposed	47	
9.	Shale, clayey, dark, exposed	1	
8.	Coal		2
7.	Fire clay	1	
6.	Shale, clayey, brown	17	
5.	Shale, clayey, red	15	
4.	Shale, clayey, black	3	
3.	Coal		3
2.	Clay, black	1	4
1.	Clay, white	2	8

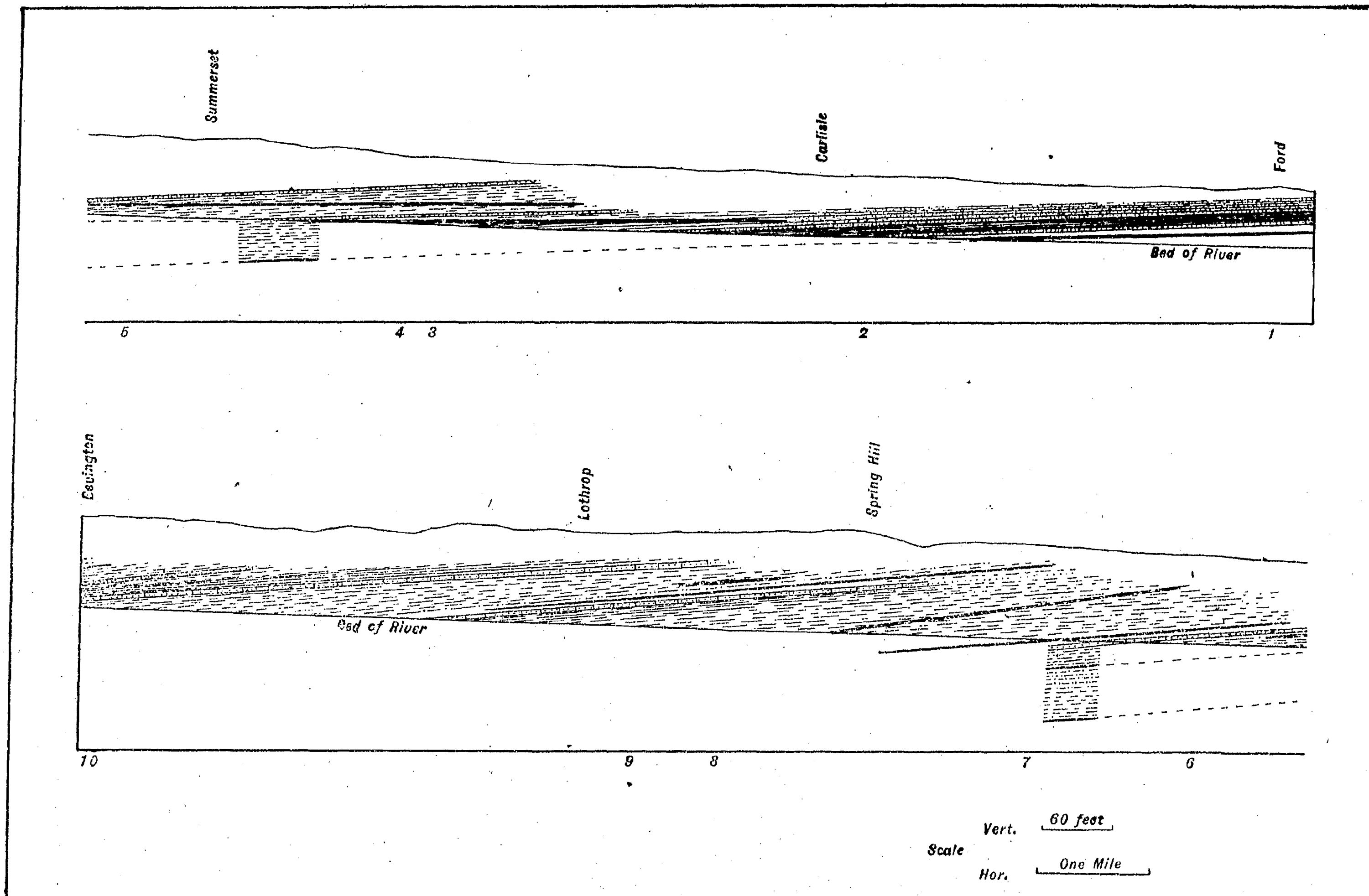
Two miles farther west, in section 9, Nw. qr., Se. ¼ of Tp. 76 N., R. XXIV W., the Earle Brothers have a coal lease. They have kindly furnished the following drill record. The top of this boring is 28 feet above the river bed, so that the first seam mentioned in this record is that which is found to pass beneath the river bed close by.

SECTION VII.

Earle Brothers' Boring.

		FEET.
18.	Soil	3
17.	Clay, yellow	5
16.	Shale, clayey, blue	6
15.	Sandstone	1
14.	Shale, clayey, dark	1
13.	Coal	1
12.	Fire clay	2
11.	Shale, sandy, hard	13
10.	Shale, clayey	4
9.	Sandstone	1¼
8.	Shale, clayey	12
7.	Shale, clayey, black	5
6.	Coal	2½
5.	Shale, sandy, hard	21
4.	Shale, clayey, red and blue	34
3.	Sandstone, dense	1½
2.	Shale, clayey, black	5
1.	Coal	4

Immediately west of Spring Hill an excellent section has been disclosed in opening a seam of coal. Northward in the



GEOLOGICAL CROSS-SECTION ALONG MIDDLE RIVER IN WARREN COUNTY.

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, the main axis of which is directed north and south, the stratum thinning out very rapidly east and west.

SECTION VIII.

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.

		FEET.	INCHES.
10.	Loess	2	
9.	Coal, badly weathered		6
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, gray, black	2	
4.	Coal	1	1
3.	Fire clay	4	4
2.	Sandstone, heavily bedded, gray	1	4
1.	Shale, irregular (exposed)	2	6

Between Lothrop and Bevington, an interval of three miles, few outcrops occur. The scarcity of exposures and the general relations of the strata indicate the absence of any layer that by resisting weathering would protrude through the overlaying 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, implies 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., Nw. ¼.) The upper half of the section is obtained about fifty yards west of the point at which the lower half is found.

SECTION IX.

		FEET.	INCHES.
12.	Sandstone, shaly	2	2
11.	Shale, clayey, gray	1	3
10.	Shale, clayey, reddish	2	3

9.	Sandstone, gray, shaly		5
8.	Shale, clayey, blue		9
7.	Sandstone, fossiliferous	1	3
6.	Shale, clayey, blue		7
5.	Shale, clayey	4	
4.	Limestone, arenaceous, fossiliferous		6
3.	Shale, clayey, 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 is found.

SECTION X.

		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	

These sections with others referred to the bed of Middle river as a base line give plate viii, a diagram of the Middle river cross-section.

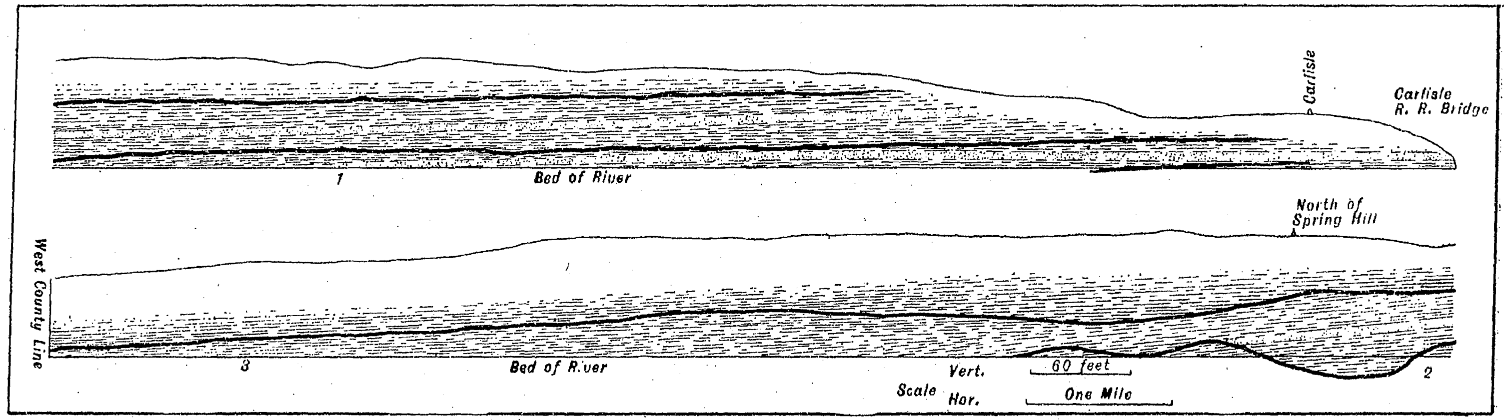
NORTH RIVER CROSS-SECTION.

The outcrops along North river are neither very high nor continuous. For the most part the hills along the south bank against which the river flows are not cut by ravines that offer good exposures for measuring. The best exposure to be obtained is in section 15 of Greenfield township, where a ravine cutting through the southwest quarter of the section offers the following exposures.

SECTION I.

		FEET.	INCHES.
17.	Concealed	49	
16.	Sandstone, gray	6	
15.	Shale, clayey, blue above, black below	5	

*For a continuation of this description of strata toward Winterset, see Geological Section along Middle river, J. L. Tilton, Iowa Geological Survey, Vol. III, pp. 144-145.



GEOLOGICAL CROSS-SECTION ALONG NORTH RIVER IN WARREN COUNTY.

		FEET.	INCHES.
14.	Sandstone, gray, fossiliferous		6
13.	Shale, clayey, black	1	3
12.	Coal, sulphur-bearing	1	
11.	Fire clay	1	
10.	Sandstone, gray, concretionary	1	
9.	Shale, clayey, reddish and blue	36	
8.	Sandstone, reddish-brown		7
7.	Shale, clayey, upper part blue, lower part gray to black with indications of coal	9	2
6.	Hematite		1
5.	Shale, clayey, sandy, gray	25	
4.	Sandstone, gray	1	3
3.	Shale, clayey	1	
2.	Concealed	5	
1.	River		

Where the river washes into a bluff north of Greenbush (Section 30, Sw. qr., Ne. ¼ of Greenfield township), an exposure appears that is continued up to the divide toward Spring Hill by several outcrops along a ravine. The exposure on North river is as follows.

SECTION II.

		FEET.	INCHES.
7.	Loess		
6.	Shale, clayey, white		6
5.	Coal, impure and decomposed		1
4.	Shale, hard above, soft below	30	
3.	Sandstone, gray		6
2.	Shale, clayey, blue, exposed	2	
1.	River with coal just below the river bed		

Beyond the last described section the outcrops are few, the best one occurring in section 32, Sw. qr., Se. ¼, Linn township.

SECTION III.

		FEET.	INCHES.
8.	Sandstone, gray, easily decomposed	1	6
7.	Shale, clayey, blue, jointed	5	
6.	Sandstone, very fossiliferous		7
5.	Shale, clayey, blue, jointed, sandy above		6
4.	Shale, clayey, black		4
3.	Sandstone, nodular, reddish		3
2.	Coal, very good	3	6
1.	Fire clay, exposed		4

Combining these and other smaller sections by their relation to the bed of North river, a section as shown in plate ix is found to exist along the north side of the divide between North and Middle rivers.

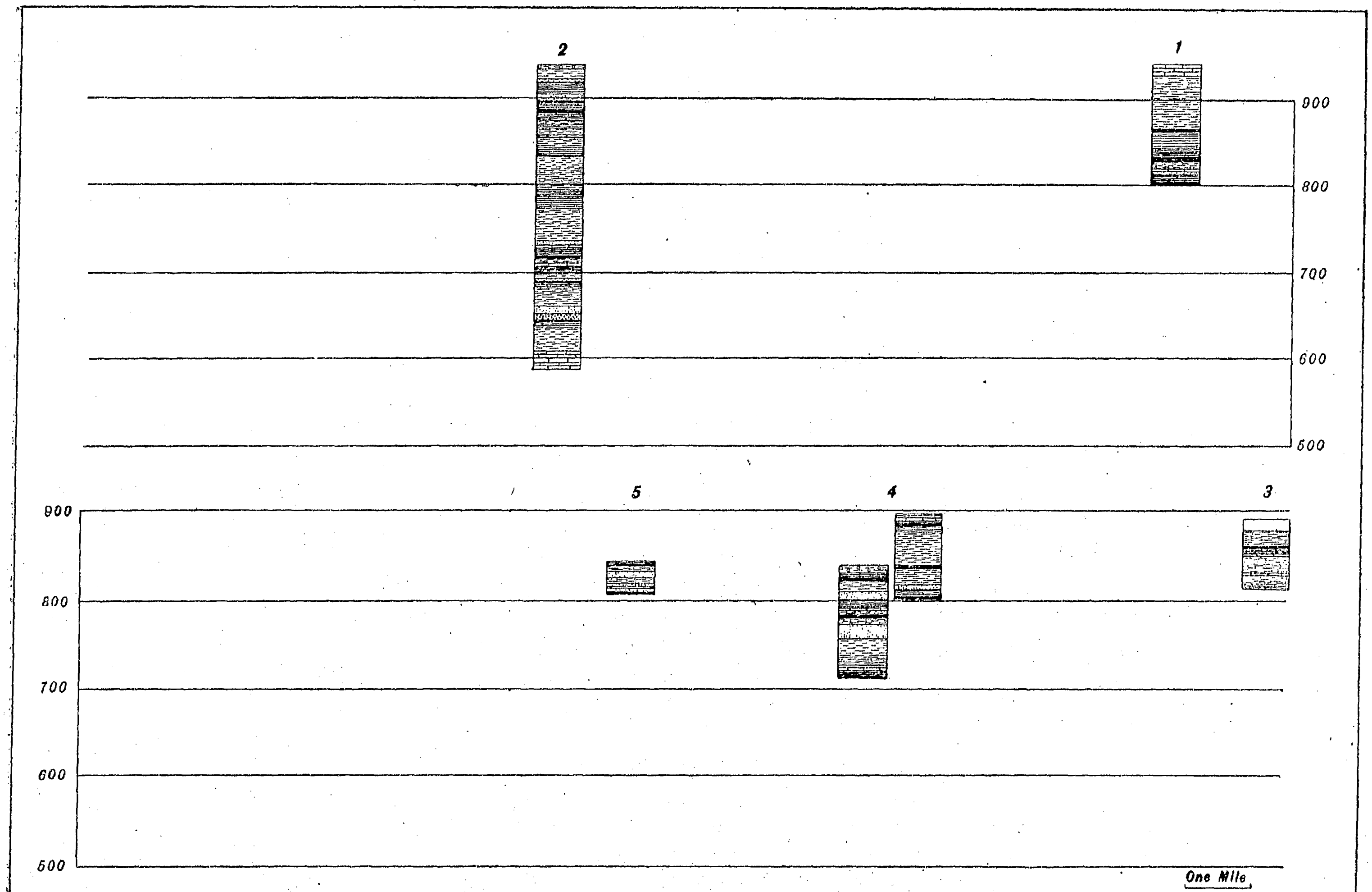
GEFERAL CROSS-SECTION FROM SOUTHEAST TO NORTHWEST.

The cross-section illustrated in plate x was obtained by combining the following records already described: (1) The outcrop southeast of Lacona, Whitebreast creek section; (2) the Milo well record given below; (3) the outcrop south of Indianola, section XI, South river cross-section; (4) the outcrops southeast of Spring Hill, and Earle Brothers' drill record, sections VI and VII, Middle river cross-section; (5) the outcrops west and northwest of Spring Hill, section II, North river cross-section.

The Milo well record is as follows.

STRATA PASSED THROUGH AT MILO, WARREN COUNTY, FOR THE MILO COAL AND MINING COMPANY.

		FEET.	INCHES
54.	Drift deposit	8	
53.	Gray shale	7	
52.	Blue clay shales	5	
51.	Brown sandstone	2	9
50.	Gray shales	4	6
49.	Dark sandstone with shaly partings	21	3
48.	Shale, light blue with bituminous shale at base	8	6
47.	Coal	1	
46.	Light gray shales	7	
45.	Thin-bedded fossiliferous impure limestone	1	
44.	Gray indurated shales	5	8
43.	Black fissile carbonaceous shale	1	
42.	Gray and blue clay shales	12	8
41.	Blue limestone	1	3
40.	Light blue marlite	1	
39.	Bluish clay shale	3	6
38.	Brown and red clay shale	3	3
37.	Shales variegated with thin beds of limestone	8	
36.	Dark carbonaceous shales	2	
35.	Bituminous shale	2	10
34.	Coal		8



GEOLOGICAL CROSS-SECTION FROM NORTHWEST TO SOUTHEAST IN WARREN COUNTY.

		FEET.	INCHES.
33.	Blue clay shale	10	
32.	Gray marl	2	4
31.	Blue limestone		8
30.	Light blue shales	16	6
29.	Fine-grained micaceous shale	7	4
28.	Gray clay shale	16	9
27.	Bluish shales	30	6
26.	Gray clay shales	5	
25.	Sandstone and shales	7	6
24.	Blue shales alternating with thin layers of limestone	18	3
23.	Compact gray limestone	2	2
22.	Bituminous shale		9
21.	Carbonaceous shales	2	6
20.	Light colored, siliceous, shaly marl, with black partings and impure coal and black jack	2	6
19.	Limestone with marl partings	1	6
18.	Clay shales	1	6
17.	Black sand shales	2	
16.	Bluish colored clay shales	6	
15.	Bluish impure limestone	3	
14.	Black clay shale	1	
13.	Dark colored shales with lime partings	1	8
12.	Blue sand shales with sulphur bands	6	3
11.	Blue sand shales	5	6
10.	Dark sandstone	2	6
9.	Black carbonaceous shales	1	8
8.	Gray clay shales	6	
7.	Blue clay shales	6	4
6.	Light blue sand and clay shales, with thin layers of fine-grained micaceous sandstone	16	
5.	Compact gray sandstone, with sulphur partings	6	6
4.	Dark, carbonaceous, sandy shale, alternating with thin layers of sandstone of same color, sulphurous	7	6
3.	Dark carbonaceous sandy shales	26	
2.	Dark blue-black shales	12	6
1.	Limestone, compact, blue and gray with sulphur bands	17	6
	Total	368	6

The top of this boring is thirty-four feet below the railroad station at Milo. The lowest limestone mentioned belongs undoubtedly to the Saint Louis formation underlying the coal measures.

ECONOMIC PRODUCTS.

COAL.

COAL HORIZONS.

Coal horizons are quite independent of the general relations of the strata because of the peculiar conditions under which coal is deposited. A limestone deposit, formed beneath the water under conditions constant for a long time will form a marked stratum over a large extent of country. A sandy shale formed in shallow water may, by slight oscillations of the earth's crust or even by the shifting of currents, become eroded and later perhaps filled in again.

Coal has been derived from vegetable matter deposited in swampy places. In some portions of the swamp a larger amount of vegetable material accumulated than in others. Seaward such a swamp would be bounded by the shore deposits; landward it would gradually thin out and be replaced by the clays alternating with gravels brought down by streams. So also laterally the swamp deposit would thin out though continued for miles as an impure carbonaceous deposit marking a horizon somewhere along which conditions were more favorable for the deposition and preservation of vegetable material.

In the coal of this county the stumps and trunks of trees are not found extending through the coal, but rather an accumulation of leaves, twigs and a broken carbonaceous mass is seen, with here and there, more usually in the shale, large branches, all of the usual type of vegetation belonging to the coal period. Remains of ferns and lepidodendrons are especially abundant. Undoubtedly in the swamps the stumps of large lepidodendrons did exist, but the soft character of the coal and the position of the stumps below the general bottom of the seams of coal have caused their presence to be overlooked by miners.

If, after a time, oscillation, which is constantly going on in the earth's crust, should gradually raise such a swamp and allow it to drain, the vegetable material would gradually decay and disappear, except perhaps a thin black deposit of carbon mixed with earth which might remain to mark the position of the former swamp. If, however, the motion were downward, the vegetable material would become covered by a fine clay deposit, which, as the whole region later became raised above the water, would protect the underlying coal from oxidation. The coal seam may be represented in a general manner as a lenticular mass bent downward in the center where the old swamp was deeper* or along the lines occupied by the sluggish streams that flowed through the swamp.

During the time one swamp was accumulating its vegetable deposit, another a few miles away might exist, connected with the first by a faint carbonaceous streak over less swampy land between, or separated by a stream depositing its varied sediment. A condition of subsidence following, the sea would cover the entire region, and, if conditions were favorable, limestone with its corals, crinoids and brachiopods would form. Finally, all the different deposits, raised by an upward movement of the crust, might again be subjected to the force of erosion, till here and there along the various streams and ravines the coal and accompanying beds would become exposed. Coal may lie in an even seam with little change in thickness for many square miles; it may occupy a narrow winding channel marking the course of an ancient stream; it may mark a swamp of small extent and thickness; it may follow the uneven lines of an old landscape.

The irregularity of relation of one coal seam to another has been purposely emphasized in the above description since in this county the seams do not all belong to successive stages,

*Hence the meaning of the dip given in the table of mines in the county. The coal dips toward thicker parts of the seam and rises toward the margin of the seam.

each marking the prevalence of conditions favorable to the accumulation of vegetable remains over the entire county, and alternating with conditions unfavorable to such accumulations. The distribution of the seams is such that a description of coal horizons would be a description of the position and extent of each particular seam. Through the central part of the county, however, the seams have arranged themselves into groups, one at and below a level of 725 feet, the other at and above a level of 800 feet, while in the shales between these two belong the seams appearing along the ravines in the eastern part of the county.

It is to be regretted there is no topographical map of the county by means of which each outcrop of the various seams can be referred immediately to its proper level. As it is, the irregularity of the seams, the uncertainty of exact level and the lack of uniformity in accompanying deposits, frequently make it uncertain whether a given outcrop may belong to a main seam or to a smaller one just above or below it. At present the elevation of each must be estimated by reference to the table of altitudes and by comparison with records of seams so related to river beds that their exact altitudes are known.

Since all the strata dip with quite uniform regularity toward the southwest over almost the entire area of the county, a line along the strike, that is northwest-southeast, is that along which the strata are level. Consequently a comparison of coal indications afforded by plate x is of special value because of the location of borings along that line.

Coal Seams of the Lower Group.—In this line of strike the borings at Milo and in Tp. 76 N., R. XXII W., Sec. 5, southeast of Palmyra are the only ones, having accessible records, that have pierced the Saint Louis formation below the coal measures. The "Carbonaceous shale" at Milo, at a depth of about 328 feet from the surface or 609 feet above sea level, marks the lowest horizon at which there is now any evidence of coal in the county. It might be regarded as the lowest possible horizon, were it not that the floor on which the coal measures rest is so irregular as to make possible the existence of other coal beds in deeper valleys cut in the old Saint Louis surface. On the other hand the boring at Milo may itself be at a point where the upper surface of the Saint Louis is lower than it is on the average and hence may give a coal horizon that is one of the lowest possible. Southeast of Palmyra, Tp. 76 N., R. XXII W., Sec. 5, the Saint Louis is 329 feet below the uplands or 546 feet above sea level. Records near Lucas to the south prove that in this direction the Saint Louis rises in places much nearer the surface.

The strata are nearly horizontal, the dip rarely reaching as much as two degrees southwest, but because of this slight dip to the southwest and the slope of the surface to the northeast, the several strata gradually approach the surface toward the northeast, and recede farther and farther from the surface toward the southwest. Southeast and northwest the old Saint Louis surface lies as nearly horizontal as any surface carved into ridges and valleys by erosion may be expected to lie.

About sixty-eight feet above this lowest horizon, 531 feet above sea level, are unsatisfactory indications of a second horizon; while a marked third horizon lies 712 feet above sea level, or 225 feet below the upland surface at Milo. This latter horizon is the upper one in the two groups found at and below the altitude of 725 feet above sea level, and marks the upper part of the group of strata in which coal has been found of greatest thickness, near Des Moines on the north and Lucas on the south. At this same level lies the lowest coal penetrated by Earle Brothers, in section 9, southeast of Spring Hill. At this same level also lies Caldwell & Cassidy's mine, in section 31, just west of Summerset; and in section 28, east of Summerset, Jones & Benham have mines where there is a local thickening of the coal, if not an independent basin.

To a continuation of this same horizon belongs the seam of coal in the bluff at Ford. This particular horizon, then, is marked by evidences of coal so widespread and of such thickness (two and a half to three feet) that the horizon may be considered as one especially rich in coal.

Coal Seams of the Upper Group.—All seams, evidences of which have been found above the horizon last described, outcrop along ravines at different points in the county. The first of these, the lowest of the group, is to be found in the central part of the county, at and above a level of 800 feet. It lies at the level of Middle river, east of Spring Hill, in section 2, and at the level of North river, in sections 19, 20, Greenfield township. On South river it is about on a level with the river bed* south of Indianola, but it dies out before reaching Milo. Another seam, a few feet below the position of the one last mentioned, is at Summerset, about the level of the railway tracks. East of Summerset it is frequently drifted as a surface seam. Another seam on this same horizon appears at the level of the Whitebreast creek, in section 35 of Whitebreast township.

These upper seams mark quite an important coal horizon. The coal, under favorable conditions, is quite uniformly eighteen to thirty inches thick.

Above this horizon, in the west central part of the county, two others exist over quite an area, the first about thirty-five feet above it, the second forty-five still higher up. The lower of these two seams furnishes an easily accessible supply of coal in Jefferson township, the upper seam appearing only at the higher points along the divides. The horizons of these two seams are also marked, in White Oak, Otter and Liberty townships, by indications of coal. The upper seam is drifted in a few places, while the lower of the two horizons is drifted in the vicinity of Milo and in the south central part of Belmont township. Both horizons appear in the ravine of

*Since the above statement was written a shaft has been sunk to this seam, near the river, south of Indianola.

section 26, southeast of Lacona, and the lower of the two is mined a mile north of Lacona.

Intermediate Coal Seams.—Between these two groups of seams, one at and below a level of 725 feet in the central part of the county, the other at and above 800 feet—belong the seams outcropping along the ravines in southern Richland, Palmyra and Union townships, where they are frequently drifted for local use. These latter seams frequently present a thickness of eighteen inches of good coal, and are more nearly related to the upper of the two groups of seams in the central part of the county than to the lower group.

The carbonaceous material found in the well at Milo at a depth of 150 feet from the surface, or at an elevation of 775 feet, suggests, together with the position of coal in Palmyra and Union townships, a coal horizon that may be looked for at a corresponding level in the southeastern part of the county.

A fair idea of the succession of the coal seams that reach the surface is obtained by an examination of the section along either South or Middle river. Along South river it will be observed coal seams outcrop at nine different levels.

In the southwestern part of the county the single coal seam that exists will not afford very profitable mining, nor are there local indications that there are seams to be reached by shafts of moderate depth. The nearest coal seam to the northeast would, if extended beneath Virginia township, lie about thirty feet beneath the river bed at the mouth of Limestone creek. To the east of Limestone creek nothing but sandstone appears till the vicinity of Squaw creek is reached.

To the west the succession of strata contain no coal beyond slight traces. There is merely the evidence that as the coal period progressed the land was here sinking, till finally open sea conditions prevailed. It is not known how far to the west open sea conditions existed when these strata were laid down since they are now covered up westward by the Missouri stage, and this, farther west is overlain by Cretaceous strata.

There is now no evidence whether in the progress of events strata now at a depth of one or two hundred feet were for a time favorably situated for the formation of coal.

A good record of a 200-foot diamond drill boring at the mouth of Limestone creek will furnish more important information than a record of a well sunk anywhere else in the county.

STATISTICS ON COAL MINING.

The following table indicates the points at which coal has recently been mined. Of these eighty-three places on which data are presented nineteen require shafts from fifteen to eighty feet deep, nine have slopes, and the remainder are drifts, or in some cases strippings. It is thus evident that most of the mines in the county are farmers' banks in the surface seams. Most of them are worked only in the winter time, each requiring from one to five or six men. In some cases the data express nothing but the fact that evidences of digging for coal were observed.

Table of Mines.

Township.	Range.	Section.	Qr.	¼.	OWNER OR MINER.	Thickness of coal.	Dip.	REMARKS.
77	22	8	SW	SE	Mr. McNeilly........	3½ ft.	....	Drift.
77	22	9	SE	SE	Fordville Coal Co...	3½ ft.	....	Drift.
77	22	27	NW	NE	Mr. Miller..........	....	....	Drift.
77	22	35	NW	NW	F. Wellings.........	....	....	Drift.
77	22	35	NW	SE	Mr. Ghost..........	3-3½ ft.	....	Drift.
76	22	2	NW	SE	S. A. Gose..........	....	....	An old drift.
76	22	9	NW	SE	Mr. Long...........	20 in.-3 ft.	S	Drift.
76	22	10	SE	NW	E. Coulslin..........	3 ft.	S	Shaft, 24 feet
76	22	12	NW	SE	Mr. Greenway.......	12 in.	....	Slope, abandoned; long, E-W; narrow, N-S.
76	22	14	SW	SW	Mr. Spurgeon........	14-16 in.	SW	Drift.
76	22	16	NE	SE	B. F. Heiny..........	18 in.	No dip	Drift.
76	22	20	NE	NE	Mr. Reeves..........	2 ft.	W	Drift.
76	22	15	SE	SE	Mr. McCormick......	....	....	Drift; gave it up because of no roof.
76	22	26	NW	SE	Mr. Anthony........	20 in.	....	Drift.
76	22	26	SW	SW	Mr. Bassett..........	18-20 in.	SW	Drift.
76	22	27	SW	SW	Mr. Beaman..........	18 in.	N	Drift.
76	22	30	NE	SW	L. C. Hodson.........	18 in.	....	Drift.
76	22	30	NW	S	S. G. Mosher.........	9 in.	....	Drift.
75	22	1	SW	NW	A. W. Mosher........	20-24 in.	No dip	Drift.
75	22	2	NE	NE	Mr. Sims.............	18-20 in.	....	Drift.
75	22	4	NE	NW	Mr. Williams........	16 in.	....	Drift.
75	22	23	SW	NE	J. A. Killer.........	18 in.	SE	Drift.
75	22	23	SW	SW	J. E. Rawson........	18 in.	SE	Drift.
75	22	25	SE	NW	Mr. Thompson.......	....	NW	Drift; about level.
75	22	25	SW	NE	R. R. McNair........	18 in.	E	Slope.
75	22	28	NE	SW	Mr. Griffin...........	2¼ ft.	W	Drift.
75	22	28	SW	NE	Mr. Hennen..........	2½ ft.	W	Shaft, 28 feet.

Table of Mines—Continued.

Township.	Range.	Section.	Qr.	¼.	OWNER OR MINER.	Thickness of coal.	Dip.	REMARKS.
75	22	33	NE	NE	Mr. Hannen	2½ ft.	W	Drift.
75	22	33	NW	SW	Mr. Williams	2½ ft.	N	Drift.
74	22	3	NW	NW	Mr. Horr	2 ft.	SE	Drift.
74	22	4	NE	NE	Mr. Clamer	2 ft.	SE	Drift.
74	22	9	SW	NW	Mr. Shaffer	8 in.-2 ft.		Drift.
74	22	21	NE	NE	William Smith			Slope.
74	22	22	NW	NW	Mary Higbee			Shaft, 26 feet deep.
74	22	24	SW	C	L. Fouch			Shaft.
74	22	35	NE	C	G. E. Sharp	16-18 in.		Drift.
77	23	7	SE	SW	William Lumsden	30 in.		Slope.
77	23	7	SE	SE	Mr. Moore			Slope.
77	23	8	NW	C	J. S. Anderson			Drift.
77	23	8	NE	C	J. S. Anderson			Drift.
77	23	21	SE	SW	O. H. Sayers			Shaft.
77	23	27	NE	W	L. D. McClintic			Drift.
77	23	27	NE	E	R. Wade			Drift.
77	23	28	NE	NW	W. S. Benham	2½-3 ft.		Shaft.
77	23	28	NW	NE	D. K. Jones	2½-3 ft.		Shaft.
77	23	31	NE	NE	Mr. Lumsden			Shaft.
77	23	31	NW	SE	Caldwell & Cassidy	3¼-4 ft.	N	Shaft.
77	23	35	NW	NE	G. C Gardner		S	Drift.
76	23	2	NW	SE	A. B. Creighton			Drift; mined years ago.
76	23	7	NW	C	J. Malone. Sr			Shaft.
76	23	32	NW	SE	J. Lord	15 in.	W	Drift.
76	23	36	NW	NW	I. Jamison			Shaft.
75	23	14	SW	NE	Henry Clark			Drift.
75	23	14	SW	SW	A. J. Conner			Drift.
75	23	21	SE	SE	Mr. Hutt	18 in.		Drift.
75	23	23	NW	NW	A. J. Conner	12-14 in.	NE	Drift.
75	23	23	SE	SE	Mr. Bales	24 in.		Shaft, 30 feet.
75	23	24	SE	NW	Mr. Whilliken		NE	Slope.
75	23	25	NW	NE	Joe Mitchell	18 in.	W	Drift.
75	23	25	NW	NW	Johnson & Bryant		NE	Shafts, 15 feet.
75	23	32	SE	E	J H. Dyke			Drift.
75	23	34	NW	SW	Mr. Bales	18 in.	SW	Drift.
75	23	34	NW	SW	Mr. Bales	13 in.	SW	Shaft, 16 feet.
75	23	34	SW	NE	C. L. Burgit	14-16 in.	SW	Drift.
75	23	34	SE	SE	C. L. Burgit	14 in.	NW	Drift.
74	23	5	SW	SW	Mr. Williams	18 in.	E	Drift.
74	23	8	NW	NW	J E Chistenden	14-18 in.	SW	Slope.
74	23	29	NE	NE	H. McNeil	16 in.	S	Drift.
74	23	29	NE	SE	Mr. Hall	16 in.	S	Drift.
77	24	19	SW	NE	Earle Bros.			Drift.
77	24	20	SE	SE	Faust, also Huffman	3. ft 8 in.	S	Slope.
77	24	21	SW	SW	George Dillard			Slope.
77	24	22	N		J. A. Bishop			Drift.
77	24	29	NE	NW	C. W. Reeves			Shaft.
77	24	30	SW	NE	J. A. Lockridge			Shaft.
76	24	2	SE	C	D. Beem			Drift.
76	24	2	SW	NE	E. Van Pelt			Drift.
76	24	9	NW	SE	Earle Bros.			Shaft.
76	24	14	NE	NW	J. H. & G. M. Basler.			Drift.
75	24	10	NW	SW	John W. Randolph			Shaft.
76	25	2	SE	C	Jacob M. Dillard. Jr.			Shaft, also drifts.
76	25	12	SW	NE	Earle Bros.	13 in.		Drift.

The output of coal for each year is expressed in the following table, prepared from the mine inspector's reports for the various years. It will be noted that this estimate does not include all the country banks.

YEAR.	TONS.	YEAR.	TONS.
1881	12,987	1884	13,727
1882	11,081	1885	12,825
1883	12,828	1886	23,332

YEAR.	TONS.	YEAR.	TONS.
1887	24,796	1892	9,570
1888	17,013	1893	14,575
1889	15,583	1894	25,454
1890	17,923	1895	12,000
1891	15,604		

WATER SUPPLY.

RAINFALL.

The weather observations recorded for the county are as follows.

PRECIPITATION, WARREN COUNTY.*

MONTH.	1892	1893	1894	1895
January	1.21	.34	.68	1.15
February	1.24	.90	.77	.20
March	1.31	.80	2.99	.52
April	3.96	5.05	1.79	2.35
May	10.47	4.78	1.03	3.64
June	4.14	6.87	1.29	1.92
July	2.50	--------	.40	--------
August	1.92	--------	.95	4.01
September	1.43	2.76	4.53	2.17
October	2.34	.20	1.09	.28
November	.79	1.68	.83	1.03
December	1.57	1.10	.90	3.55
Total	32.88	--------	17.25	--------

The following table gives the rainfall for Des Moines as recorded at the government office in that city. Since Des Moines is but five miles north of Warren county, the Des Moines rainfall may be taken as a fair average of rainfall in Warren county.

PRECIPITATION AT GOVERNMENT STATION, DES MOINES, 1879-1895.

MONTH.	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895
January..	.69	.70	1.55	.63	1.72	.85	1.00	3.47	.83	1.15	1.22	2.62	1.82	1.60	.56	1.09	1.30
February.	1.90	.17	2.68	1.21	2.51	1.92	.42	.52	1.65	1.51	.27	1.17	1.13	1.35	1.28	1.39	.60
March....	1.68	.70	1.78	2.28	.57	2.24	.04	1.41	1.79	3.09	.11	.91	2.25	2.47	1.15	1.78	.50
April.....	1.03	1.56	3.36	3.47	3.48	2.97	3.62	4.32	2.48	1.45	2.66	.78	2 12	3 36	5.61	1.70	3.41
May......	4.74	5.84	3.82	8.53	9.76	4.34	1.70	4.01	2.31	7.84	4.84	3.00	3.29	8.77	2.84	1.41	2.86
June.....	6.69	4.11	15.79	12.16	7.75	3.84	5.03	1.21	2.25	2 32	4.39	4.91	5.60	3.41	4.69	1.67	5.26
July.......	.29	3.82	5.57	4.78	2.37	7.16	6.55	.27	1.94	3 42	4.37	1.10	2.78	8.64	3.55	.29	3.10
August...	1.98	6.69	5.29	3.14	2.83	3.84	5.10	1.10	2.66	4.52	2.25	3.35	4.22	2.45	1.60	1.89	3.57
Septemb'r	2.79	5.34	4.70	.15	1.88	5.46	4.82	7.93	5.36	.48	3.41	1.57	1.64	1.12	1.33	4.46	3.20
October..	3.15	4.90	6.45	5.94	4.42	5.33	4.18	2.62	1.40	.84	.52	4.48	2.41	2.54	.22	2.24	.29
Novemb'r	6 49	1.97	3.97	2.81	1.32	1.26	.61	1.86	.52	2.09	1.29	.74	1.34	.76	1.51	.99	.85
December	1.39	.86	1.85	2.50	1.08	1.93	1.96	.81	1.41	2.44	.57	.11	1.54	1.95	1 30	1.15	1.86
Total.	32.82	36.66	56.81	47.60	39.69	41.14	35.03	29.53	24.60	31.15	25.90	24.74	30 14	38.42	25.64	20.06	26.80

*These observations were made 1892-94 by the writer, and July, 1894, to July, 1895, by Prof. L. A. Youtz. The records for July and August are incomplete because of the absence of observers.

In studying these tables it is well to note that in the judgment of the office of the state weather bureau, if the ground is well wet in early spring, oats will mature a heavy crop if, during the two months oats are growing, there is a precipitation of four inches per month. A good crop of corn will mature if there is a precipitation of two inches per month during the months the corn is growing, provided the precipitation occurs at intervals as needed.

WELLS.

SURFACE WELLS.

Few wells in the county are more than thirty feet deep, consequently in some places they end in the drift and in other places in the coal measure shales just below the drift.

Pure well water contains no organic matter, but contains mineral matter dissolved from the strata the water has passed through. The wells that end in the drift contain in solution, gypsum (Calcium sulphate) together with a trace of carbon dioxide. If surface water has had access at all to the well a trace of chlorine and also of ammonia may be found. If, however, the well is polluted by wash from the surface the chlorine and ammonia become abundant, so much so that a determination of the amount of chlorine and ammonia (both free and combined in organic compounds) may be taken as an indication of the purity of the water for drinking.

Carelessness in the location and care of a well is of frequent occurrence. The purity of drinking water is of such great importance to health that too much emphasis can not be placed on the advisability of great care in the protection of wells from pollution. Not only may the material itself which washes into a well be objectionable, but even material that of itself seems unobjectionable, may in its decay furnish conditions favorable to disease.

There are two areas in the county where the strata are such as to have a marked influence on the wells. The first is in the northern part of the county from the eastern side as far south as Hartford; westward to the center of Greenfield township. In this area the surface is underlain by a sandstone eastward and a sandy shale westward that receives water from the soil, leaving shallow wells quickly susceptible to drouth. In White Oak township west of Cedar creek the soil is underlain by sand for a moderate depth and this sand by clay. Evidently it is here desirable that the wells pass through the sand to the clay.

DEEP WELLS.

As the coal measures contain many beds of sandy shale and clay of irregular thickness and extent, all dipping south and west at an average rate of about two degrees, the conditions are favorable for finding water in the sandy shale, since the water works its way downward along the direction of dip. These conditions are so favorable that anywhere in the county it is fair to expect that a well from 150 to 250 feet deep will be quite sure of obtaining all the water necessary to meet the demands of any stock farm; but the water is just as sure to be "sulphur water."

Below the shales of the coal measures no single water horizon can be depended on to furnish a large supply, though various strata as far as the Saint Peter and Saint Croix sandstones may contribute more or less to wells passing through them.

From such data as is obtainable it may be estimated that the Saint Peter lies about 1,000 feet below sea level in the central part of the county, or from 1,800 to 2,000 feet below the surface of the uplands. About 200 feet below the Saint Peter sandstone lies the Saint Croix sandstone that furnishes a considerable portion of water to the Y. M. C. A. artesian well at Cedar Rapids, and to other wells in that part of the state. The measurements obtained, especially at Cedar Rapids, Sigourney, Centerville and Grinnell, indicate the rate of dip to the southwest and furnish other data from which it is possible to estimate the distance the sandstone is below the surface in Warren county. At Cedar Rapids the Saint Peter sandstone is 212 feet below sea level; at Grinnell, 677 feet below sea level; at Sigourney, 615 feet below sea level, and at Centerville 627 feet below sea level. Sigourney and Grinnell are in the same line of strike and Centerville and Indianola also in another line of the strike. Sigourney is about half way between Cedar Rapids and Centerville, and Grinnell occupies the same position with reference to Cedar Rapids and Indianola. In the various borings that have been made it is found that the surface of the Saint Peter sandstone first dips rapidly southwest, then becomes more nearly horizontal. From Cedar Rapids to Sigourney the Saint Peter sinks 403 feet, from Cedar Rapids to Grinnell it sinks 465 feet. From Sigourney to Centerville the fall is but twelve feet, from Grinnell to Indianola probably something more than twelve feet. This would make the Saint Peter sandstone 1,668 feet below the surface at Indianola. This estimate may be considered an inside estimate, while that previously given, based on the thickness of the strata where they outcrop, may be considered an outside estimate. We may say then the Saint Peter sandstone is approximately 1,800 feet beneath the surface at Indianola. As other wells are sunk to the Saint Peter sandstone the correctness of these figures can be tested.

The quality of the water can be determined from analyses of samples obtained from the borings mentioned. An analysis of the water obtained at Grinnell yields the following.*

	Grains per gallon.
Calcium carbonate	7
Calcium sulphate	41.1
Magnesium sulphate	30
Sodium sulphate	27.34
Sodium chloride	.87
Silicate of iron and alumina	.7
Total solids at 120° C	120.75

This analysis indicates a water very "hard," even more objectionable than the ordinary well water for culinary pur-

*Record of the Grinnell deep boring, A. J. Jones, Proc. Iowa Acad. of Sci., 1894, p. 35.

poses and for use in boilers. As a drinking water the mineral constituents are no more injurious than those of ordinary well water. The water is absolutely free from organic impurity. The quantity obtained from the wells at Cedar Rapids and Grinnell is as follows: Cedar Rapids, 86,400 gallons every twenty-four hours; Grinnell, 12,800 gallons every twenty-four hours in the winter months, in the summer more without exhausting the flow.

OIL AND NATURAL GAS.

It has long been thought that at some time conditions favorable to the collection of oil and natural gas may be discovered in Iowa. So far as structure is concerned the following conditions must be satisfied: (1) there must be the unbroken crest of an anticline with (2) an impervious layer underlain by (3) a porous stratum in which the oil or gas as it rises can collect.

In the northeastern part of the county is the arch of an anticline extending through sections 10, 12, 13 and 24 of Richland township in a northwest and a southeast direction. Beneath the drift is a soft sandstone underlain by clay, and clays alternate with sandstones down to the Saint Louis. Here is the only place in the county where the conditions are at all favorable to the preservation of oil and natural gas, and yet it is by no means sure that these substances occur at this point. One condition only is known to be satisfied; the other equally important conditions may prove to be entirely unsatisfied.

MINERALS.

Minerals found in the county are such as commonly occur in the drift and in the coal measures of the state. In the drift, quartz and agate are common; rarely, pieces of copper and of iron pyrite have been found. In the coal measures are calcite, selenite, celestite, marcasite, pyrite, hematite and limonite in small quantities.

The decomposition of the sulphides of iron (pyrite and marcasite) sets free the sulphur and stains the water with the oxides of iron. None of the above minerals are in sufficient quantity and purity to be of commercial value.

BUILDING STONE.

Warren county is not well supplied with building stone. Nearly all the sandstone yields readily to oxidation, which, aided by frost, decomposes and disintegrates it very readily. There are, however, three strata that deserve especial notice because of the manner in which they withstand erosion. The first is the stratum of arenaceous limestone, fairly free from iron, that, where not eroded or covered up, may be found outcropping in the ravines from the northern part of Otter and White Oak townships northwestward into Greenfield and Jefferson townships. The outcrops of this sandstone are particularly marked in Tp. 76 N., R. XXII W., Sec. 30; Tp. 76 N., R. XXIII W., Sec. 36; Tp. 75 N., R. XXIV W., Sec. 14; Tp. 76 N., R. XXV W., Sec. 12 and Sec. 13. It is not easily accessible, except in various places along ravines and southeast of Ackworth, in the hills of section 30. This limestone is, on the average, about a foot thick, though where it grades into sandstone, in section 30, it occurs as a bed three feet thick. Farther southwest it should not be confounded with the eight inches of cap-rock that occurs above a seam of coal.

In section 22 of White Oak township occurs a large mass of sandstone. While resisting oxidation fairly well, it is too soft to make a good, permanent building stone.

In the northern part of section 17, in Virginia township, the sandstone has been quarried at several points. Another stratum, about thirty-five feet below the one opened up, is to be seen in section 18, near the road north on the eastern side of the section. The same two strata of rock are to be found on the south side of the river, where they occur five feet higher above the river bed and thirty-five feet apart. The best section is to be found in the ravine at Hilton's, in the southern part of section 17. By comparing the strata in the neighborhood with those of section 17, the limestone seen in a ravine in the eastern part of section 19 is seen to be the upper one found in section 17. The limestone of section 28 and farther west on Limestone creek is also the upper one of section 17. The lower limestone of section 17 was found in a well on a hillside close to the eastern boundary of section 16. Eastward to Squaw creek these rocks are completely eroded, or are covered up by drift, but the heavy sandstone of section 17 (Tp. 74 N., R. XXIII W.), northwest of Liberty Center, is judged to be the equivalent of the lower limestone of section 17.

CLAYS.

While but little of the stone of Warren county is suitable for building purposes, the clays furnish an inexhaustible substitute. There is no satisfactory reason why the cheaper grades of hand-made brick may not be manufactured in each community to supply the local demand. There is also excellent material for the manufacture of brick of finer quality.

The clay that can be used is derived from three sources: first, the loess; second, the alluvial deposits along the rivers; and third, the coal measure shales.

Nearly all the soil is a part of the loess, blackened by a large amount of vegetable mould. This vegetable material burns out in the process of firing the brick, causing the latter to be too porous. If the black soil be first removed and the loess just beneath used for brick, one cause of the porous condition of the brick is avoided.

The loess just beneath the soil makes the best deposit of brick and pottery that we have. It is fine sediment, probably laid down at some time during the melting of the great sheet of ice that extended over the northern and eastern part of our continent.

The following analyses were made by Prof. G. E. Patrick, chemist to the survey. No. 1 is the loess taken just beneath the soil. No. 2 is the dark gray material found below the upper or yellow loess. Both samples were taken from the pit of the Indianola Brick & Tile Co. (Tp. 76 N., R. XXIII W., Sec. 19, Sw. qr., Ne ¼).

	No. 1.	No. 2.
Hygroscopic water	1.70	3.76
Combined water	3.33	6.89
Silica $Si\ O_2$	72.24	63.31
Alumina $Al_2\ O$	12.58	16.51
Iron oxides as $Fe_2\ O_3$	4.02	4.06
Maganese oxide Mn O	0.00	0.49
Lime Ca O	1.40	1.11
Magnesia Mg O	.99	1.10
Soda $Na_2\ O$	2.60	2.20
Potash $K_2\ O$	1.54	.96
	100.40	100.36

Analyses of the same clays were made by Prof. L. A. Youtz and are published in the proceedings of the Iowa Academy of Sciences for 1895. The results were very similar to those given above though not so complete.

The lower loess differs somewhat from the upper loess in that its silica is combined; not free as in the upper loess. Other differences may be noted on comparison of the analyses here given, but any difference due to the amount of titanic acid present cannot be stated since the titanic acid is here estimated with the silicon dioxide.

Along the river valleys, especially along Middle river and the lower courses of North and South rivers, are numerous filled up lagoons. These were formed by the river, which at some time in shortening its course by cutting across a narrow strip of land, left the bend as a cut-off that at every high water was filled by the streams carrying an abundance of fine sediment. Various lagoons may be found representing all stages in the filling up process. This fine alluvial deposit is good material for brick.

The shales of the coal measures are very variable in character. Not only do the deposits themselves vary in composition so that a bed of clay in one place may found as a bed of sand in another, but they also alter on exposure to the weather. Usually it is better to mix the shale with a portion of loess in the proportion of two parts of the clay to one of loess.

It is to be hoped that the durability of a good brick and its freedom from decay will lead to its universal use for well curbing, foundations for houses, and walls of cellars and caves.

The demand for tiling is at present largely supplied by manufacturers outside the county. Since January 1, 1893, there have been shipped into the county from outside sources about 253,720 feet of tiling in sizes as follows:

Sizes in Inches.	Feet.	Sizes in Inches.	Feet.
3	38,840	7	30,950
4	64,560	8	12,100
5	53,780	10	11,000
6	42,490		

If the movement toward the building of good roads now under discussion in various parts of our country ever receives attention in this county, the clay deposits may be looked to furnish either a cheap ballast, to make better roadbeds or vitrified brick for paving.

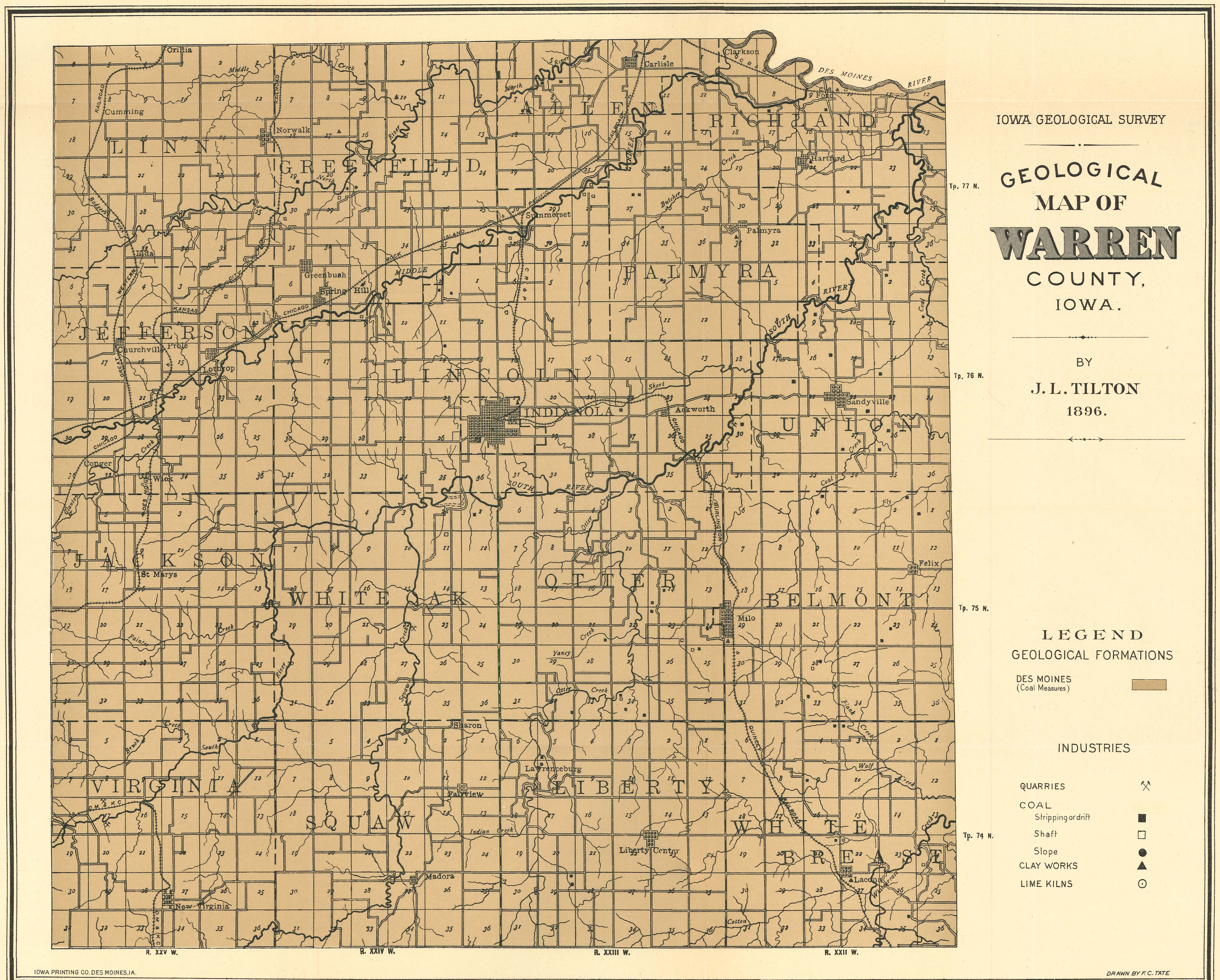
CLAY WORKING PLANTS.

POTTERY.

There are two places in the county where pottery is manufactured; Carlisle and Hartford. At both of these places the manufacturing is for the local market only. At Carlisle Mr. Burney burned 21,000 to 22,000 gallons in 1894. Generally he burns ten kilns, each kiln of 6,000 gallons capacity. At Hartford Mr. William Kurtz burns two kilns a year, each kiln of 2,500 gallons capacity.

BRICK.

Until recently the Indianola Brick & Tile Co. was engaged in the manufacture of brick. They used the loess and drift clay, first carefully removing the soil. For the preparation of the clay there is a plant consisting of a Penfield machine


IOWA GEOLOGICAL SURVEY
GEOLOGICAL MAP OF
WARREN
COUNTY,
IOWA.
BY
J. L. TILTON
1896.
LEGEND
GEOLOGICAL FORMATIONS
DES MOINES
(Coal Measures)
INDUSTRIES
QUARRIES
COAL
Stripping or drift
Shaft
Slope
CLAY WORKS
LIME KILNS
Tp. 77 N.
Tp. 76 N.
Tp. 75 N.
Tp. 74 N.
R. XXV W.
R. XXIV W.
R. XXIII W.
R. XXII W.
LINN
GREENFIELD
ALLEN
RICHLAND
JEFFERSON
LINCOLN
PALMYRA
UNION
JACKSON
WHITE OAK
OTTER
BELMONT
VIRGINIA
SQUAW
LIBERTY
WHITE BREAST
DES MOINES RIVER
MIDDLE RIVER
SOUTH RIVER
Orilla
Cumming
Norwalk
Carlisle
Clarkson
Hartford
Summerset
Palmyra
Ada
Greenbush
Spring Hill
Churchville
Prole
Lothrop
INDIANOLA
Ackworth
Sandyville
Conger
Wick
St Marys
Milo
Felix
Yancy
Sharon
Lawrenceburg
Fairview
Liberty Center
Madora
Lacona
New Virginia
IOWA PRINTING CO. DES MOINES, IA.
DRAWN BY F. C. TATE

run by a twenty-five horse power engine, and in burning one up draft and two down draft kilns are used. This firm also has a pottery kiln witha capacity of 30,000 gallons.

At Glassock's Mills Mr. Glassock manufactures hand-made brick for local trade. The material used is an old alluvial deposit of Middle river.

In four localities hand brick are made from the soil: northeast of Spring Hill by Mr. H. I. Hoover (Tp. 77 N., R. XXIV W., Sec. 17, Ne. qr., Sw. ¼); south of Spring Hill by Mr. Faust (Tp. 76 N., R. XXIV W., Sec. 4, Sw. qr., Ne. ¼); at Milo by Mr. C. E. Gross; at Lacona by Mr. S. D. Kirkheart. The brick are hand made from loess, the soils being scraped off and thrown aside. The total amount of brick burned in the county in 1894 was 365,000. This represents the average production.

TILING.

The only tiling manufactured at present in the county is made by O. Fenton at Palmyra. The different sizes manufactured range from two to six inches in diameter.

SOIL.

The description of the drift was in a measure a description of the soil. The natural porosity of the soil and the ease with which it is tilled are due to the structure of the drift. The thousands of acres of corn with their rich increase are only possible because of the drift. Were coal and stone far more abundant and valuable than they are, still Warren county would exist as chiefly a region of fine farms. The broad, rich lowlands have not required much tiling, and the uplands are not too dry for fine crops. The soil over the entire county consists of loess modified in places by mixture with underlying shales.

MAP.

The data for the streams and various ravines represented on the accompanying map were obtained from the map of the original government survey now in the auditor's office at Indianola, and from a county plat-book. The data of the roads were obtained from an atlas of Warren county (Harrison and Varner) and the county records to date at Indianola.

GEOLOGY OF APPANOOSE COUNTY.

BY

H. FOSTER BAIN.

GEOLOGY OF APPANOOSE COUNTY.

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INTRODUCTION.

LOCATION AND AREA.

Appanoose county is located on the southern boundary of the state a little east of the middle. Davis county joins it on the east, while Monroe and Wayne counties join it on the north and west respectively. In shape it is an approximate parallelogram; it extends twenty-four miles from east to west and a little more than twenty-one miles from north to south. The west county line is slightly longer than the east line, owing to the fact that the southern boundary of the state is not quite parallel to the section lines.

In all Appanoose contains twelve complete congressional townships with parts of four more. The total area of the county is 658 square miles. This is divided into seventeen civil townships which are named on the accompanying map with the exception of Center, which lies wholly within Vermillion township and is co-extensive with the city of Centerville.

PREVIOUS GEOLOGICAL WORK.

The earliest geological survey of the state—that conducted by Dr. David D. Owen under the auspices of the Federal government—was not extended into this county. Upon the map published as a result of this survey the region now known as Appanoose county is represented as within the coal measures. This is the first information published bearing on the geology of the area under consideration. The work of the Hall survey was confined to the region east of this county, though on the map of the eastern part of the state published as a result of Hall's work, Appanoose is again represented as lying within the coal field.

In 1867 both Dr. White and Mr. St. John visited the county and made a few brief observations.* A few years later C. J. Norwood, while engaged in a geological survey of neighboring counties in Missouri, examined the coal outcrops near

*First and Second Ann. Repts. of State Geologist, p. 40. Des Moines, 1868. Report of Geol. Surv. Iowa, Vol. II, p. 270. Des Moines, 1870.

Hilltown.* More recently, Winslow† has reviewed the geology of neighboring counties in Missouri; incidentally throwing considerable light on the geology of Appanoose.

Up to the organization of the present survey no detailed examination of the structure of the county had ever been made. The field work which forms the basis of this report was carried on during portions of the summers of 1893 and 1895. Several short preliminary papers‡ were published at the close of the first season.

PHYSIOGRAPHY.

TOPOGRAPHY.

Appanoose county is well up on the divide, between the Mississippi and Missouri rivers. The actual watershed lies to the west of the county. It is not, however, a marked physiographic feature, and finds expression rather as a high plain than as a ridge. In this county the plain slopes gently towards the east. There is a second and much slighter slope towards the south. The inequalities which were developed in the surface of this plain, by erosion during preglacial times, have been to some extent obscured, but are occasionally encountered in mining operations. The present surface is a drift surface. The topographic forms are engraved forms, cut in the even surface by erosive forces. Embossed forms have so far not been observed. Foldings and flexures of the strata, while present, are not of sufficient intensity to have influenced the topography.

The general surface of the country is a flat, even plain. This is cut into and divided by the river valleys. The divides, however, present an unbroken, even surface. In crossing a stream one leaves the open prairie, descends and traverses a relatively narrow bit of broken and low-lying country, and then reascends to a plain corresponding to the one from

*Rept. of Geol. Surv. Mo., 1873-1874, p. 295. Jefferson City, 1874.
†Geol. Surv. Mo., Prelim. Rept. on Coal Deposits. pp. 54-56. Jefferson City, 1891.
‡Proc. Iowa Acad. Sci., Vol. I, pt. iv, pp. 33-36. Des Moines, 1894.
American Geologist, Vol. XIII, pp. 407-411. Minneapolis, 1894.
See also Keyes: Coal Deposits of Iowa, Iowa Geol. Surv., Vol. II, pp. 406-424. Des Moines, 1894.

which he descended. The valleys are not narrow, sharp gorges, however, but are relatively wide and bounded by gently curving hillsides; yet, as compared with the width of the divides, they are much narrower.

The general character of the plateau surface is excellently shown south and west of Centerville, along the Chicago, Rock Island & Pacific railway.

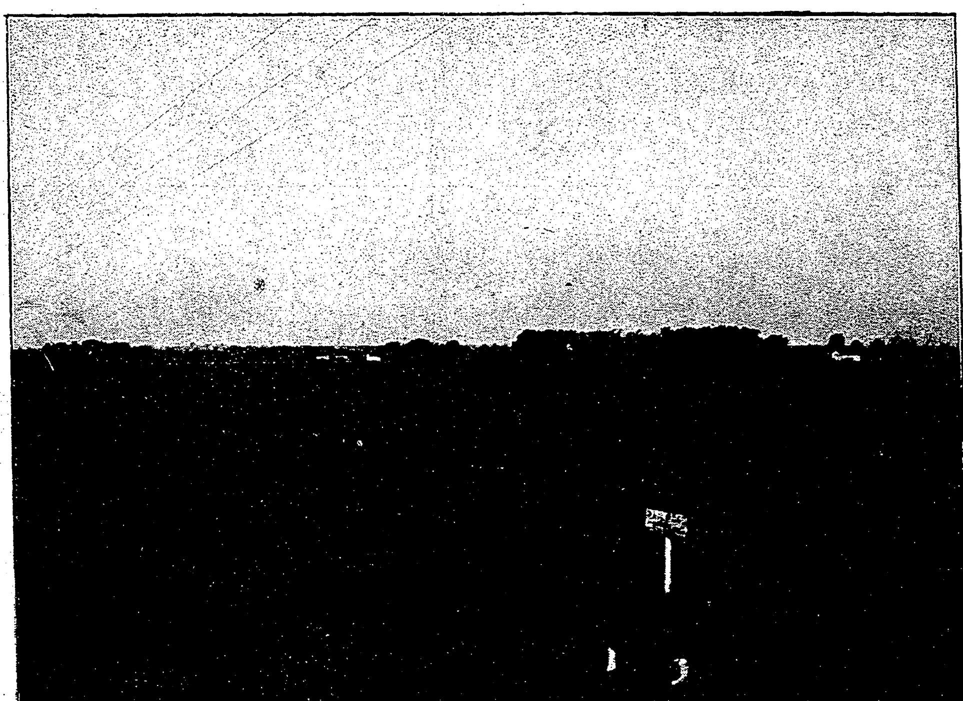


FIG. 52. General view of plateau surface near Eldon mine No. 2; southwest of Centerville.

The divide between North Shoal and Cooper creeks, along which the railway runs from Centerville to Seymour, is typical. The Chicago, Milwaukee & St. Paul railway runs over a similar plain from Seymour to Jerome, and again from Moravia to Trask. The Iowa Central traverses the latter plain from Albia to Maine, and the Keokuk & Western runs over the tableland between Walnut creek and South Chariton river from Garfield to Promise City. Over these drift plains railway construction is simple. The line follows the most easily purchased right of way rather than any line of grade. The wagon roads are laid out along land lines and require but little grading. The farm fences run in straight lines, and the fields are large and right-angled.

The separate areas of upland plain are essentially all portions of one continuous surface. They rise to the same general level, and when standing upon the plain an even sky-line is seen. Cut into this plain is the rather broad valley of the Chariton river, running from northwest to southeast across the county. Leading back from it to the southwest are the valleys of South Chariton, Walnut, Cooper, and several minor streams. Along these streams are numerous side branches, usually coming into the main stream at right

FIG. 53. Valley of Manson branch near Centerville. The shaft house of the Centerville Block No. 8 may be seen near the center of the picture.

angles. Manson branch, a small tributary of Cooper creek, joining it near Centerville, is a good representative of the minor streams. It has a rather narrow, though not sharply cut valley, bounded in the main by gently sloping drift-veneered hills, as shown in figure 53.

TABLE OF ELEVATIONS.

In the following table of elevations the altitudes as given by the Chicago, Rock Island & Pacific railroad profile have been taken as a basis. The elevations of points not reached by that road are given as shown upon the profiles of the various other roads, plus or minus the amount necessary to bring them into harmony with the chosen basis. At railway crossings the differences were obtained by carefully checked barometric readings. Where two elevations are given, the upper is from the profile, the lower from the barometer reading.

Brazil	1,017
Centerville.	
C., R. I. & P. depot	1,017
K. & W. depot	1,007
Chariton river bridge.	
C., M. & St. P. Ry.	983
Iowa Central Ry.	927
C., R. I. & P. Ry.	866
K. & W. Ry.	821
Cincinnati	1,027
Cooper creek bridge, Iowa Central Ry.	867
Darby	1,048
Dean	819
Dennis (bridge)	927
Eldon Mine No. 2	1,032
Exline	1,005
Forbush	1,067
Garfield	1,039
Guinn	939
Iowa Central crossing.	
C., M & St. P. Ry.	1,051
Iowa Central Ry.	1,076
Jerome	1,059
Keokuk & Western crossing.	
C., M. & St. P. Ry.	1,059
K. & W. Ry.	1,037
Maine	977
Moravia	1,041
Moulton	983
Mystic	1,006
Numa	1,041
Plano	1,069
Relay	897
Sedan	821
Seymour	1,079

Udell	1,000
Unionville	940

DRAINAGE.

The waterways of Appanoose county belong in part to the Mississippi and in part to the Missouri system. Across the northeastern corner of the county Soap creek flows. This stream has its source in Monroe county and flows south and east to the Des Moines river reaching that stream just below Eldon. In Appanoose county there are two branches, North Soap creek and South Soap creek. Neither of these is a very large stream, but each has a considerable number of small tributaries. The region through which they flow is rough and heavily wooded.

In Udell and Washington townships the north and south forks of Fox river originate. This is a longer and more important stream than Soap creek and flows into the Mississippi river a short distance below the mouth of the Des Moines.

The largest stream in the county is the Chariton river, which flows across it from northwest to southeast. This stream is formed by the union of two branches, one of which rises in the southeastern part of Clarke county, and the other in the northwestern part of Wayne. The two forks unite soon after entering Appanoose county and form a rather large and important stream. This river has, in this region, frequently cut through the drift and often to a considerable distance into the coal measures. Important exposures occur along its banks.

The valley of the Chariton is quite wide. From the highland near Udell to the highland east of Centerville is about six miles. The bottomland itself is often of considerable extent. Near Sedan and from there to Dean and beyond the flood plain stretches out nearly two miles east of the river. A considerable portion of this region is occupied by a shallow lake or marsh. Similar, though smaller, lakes occur at other points along the stream.

The Chariton is the most easterly of the small group of rivers which flow down over the nose of the divide between the Mississippi and Missouri. East of it, with the exception of a few minor streams in central Missouri, the creeks and rivers turn toward the Mississippi and flow into that river above the mouth of the Missouri. In the upper portion of its course the Chariton has the same general direction as this group of rivers, but as it leaves Iowa it turns due south and follows the divide from that to the Missouri river, which it reaches near Glasgow. A few rivers lying west of it take the same general course, but within a short distance the drainage runs along the normal southwest lines to the Missouri.

Within the county the river receives a number of tributaries, the larger ones being from the west. From the east the branches received are small and rather unimportant. Honey creek flows in in Chariton township, Buck creek in Walnut township, and Indian and Long Branch in Wells township. Big Walnut is the main tributary from the west; this stream rises in Wayne county, flows north and east and empties into the Chariton near Dennis. Near its mouth it receives Little Walnut.

Cooper creek is also a rather large and important creek. It rises in Wayne county near Seymour and flows into the Chariton northeast of Centerville. Near Centerville it receives Hickory creek from the north.

The southwestern part of the county is drained by Shoal creek and its branches. The main branch rises in Wayne county and flows east, then south, then east again to the Chariton river in Putman county, Missouri.

ORIGIN OF PRESENT PHYSIOGRAPHY.

The origin of the present topography of Appanoose county is a matter of some doubt. It seems clear that the present valleys are entirely the result of river action. There are no faults, folds or other structural features which have determined them. It is also probable that the upland drift plains have not been essentially modified since the ice of the glaciers melted away. At several points shafts or borings upon these plains indicate that the underlying rock surface is quite irregular and that the present surface features are largely a result of the filling in of these irregularities by the drift. At the same time it is clear that the valleys of the Chariton river, Walnut, Cooper, Soap, and other creeks, including all the more important and many of the minor streams of the county, flow in what are essentially preglacial channels. At many points along these streams undisturbed drift is found in their valleys; while shafts, borings or wells show that the coal measures rise in the bordering hills some distance above the water.

At many points the streams flow over drift, and apparently the river valleys have at some time been deeper at these points. At others, while the channels are evidently preglacial, there is no evidence that they were ever of any great depth. Walnut creek, near Mystic illustrates this well. The rivers do not altogether follow their preglacial channels, nor are all the preglacial channels occupied by present rivers. In Douglas township (Tp. 70 N., R. XVII W., Secs. 33 and 34) three diamond drill borings, carried to depths of 47, 76 and 120 feet respectively, show nothing but drift. The exact elevation of this land is not known but it does not differ greatly from equally high ground upon which coal measures occur at much less depths. At Dennis the coal measures are exposed in the bluff of the river to a height of more than 25 feet. Back on the bluffs (Sec. 7, Se. qr., Sw. ¼) a hole 135 feet deep failed to go through the drift. Running from this point south and passing east of Forbush is a buried channel in which bore holes, 100, 95, 105 and 124 feet deep, have failed to touch bottom. On each side of this channel coal is found at depths of 49, 65, 67, 14 and 52 feet. The mine at Forbush is 65 feet deep. Only a portion of this depth is in drift, and yet a short distance southeast (Tp. 69 N., R. XVII W., Sec. 18, Sw. qr., Ne. ¼) a bore hole 100 feet deep on lower ground failed to pass through the drift. The Chariton river, in this portion of its course, has evidently been thrown far out of its old channel. The depth to the bottom of the old channel is not known, but it is estimated that the present river is at least 100 feet above the old river bed. Its location, so far as known, is marked on the geological map accompanying this report by the absence of the usual coal seam.

At many other points in the county buried channels have been encountered. Such a channel lies between the Lodwick and old "Sandbar" mine at Mystic, another was encountered in sinking the Gladstone shaft northeast of Jerome, and Winslow* mentions a similar channel at Lucerne, Mo. These preglacial channels are quite troublesome in mining operations in the region surrounding Pearl City. At Moulton the drift is known to be of considerable thickness. Possibly this is due to the presence of an old channel.

It would seem that while the major and many of the minor features of the present topography had their origin in preglacial time, there have been many and important changes in the positions of the rivers since; and that the drainage level was at one time at a considerably lower plane. The deeper channels are not always, perhaps are rarely, followed by the present rivers.

Any explanation of the origin of these rivers must not require any great degree of long-continued stability, but must take into account the very great changes in the direction and position of the streams which occurred during the glacial period. Except for this fact the explanation given by Tilton† for the rivers of Warren county would seem to apply equally well for those of Appanoose county; the Chariton being then regarded as a subsequent, and Walnut and Cooper creeks as obsequent streams. This would, however, appear to imply a much greater degree of stability in the drainage lines than can, in view of the facts presented by this immediate region, be conceded. Later studies may remove this objection.

*Prelim. Rept. on Coal, Mo. Geol. Surv., p. 58. Jefferson City, 1891.

†Iowa Geol. Surv. Vol. V, pp. 310-313. Des Moines, 1896.

However much older the present topography may be, it is certain that in many of its most minute details it was developed before the loess-silt was deposited. The latter deposit is shown in many railway cuts and exposures mantling an older drift surface, and in very many particulars this older surface has the same form as that now existing. This is well shown in cuts near Moravia in which the dividing line between the drift and the loess-silt is conspicuous. This line is in most instances approximately parallel to the contour of the present surface; though the loess-silt is usually slightly thicker on the crest of the divides than farther down the slope.

STRATIGRAPHY.

Geological Formations.

The formations of Appanoose county belong to two different periods. The indurated rocks represent the Des Moines terrane of the coal measures, and the overlying unconsolidated beds are referred to the Pleistocene. The following classification shows the taxonomic rank of the strata present.

Classification of Formations.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.		Alluvium.
		Glacial.		Loess-silt.
			Kansan.	Drift.
Paleozoic.	Carboniferous.	Upper.	Des Moines.	Chariton. Conglomerate. Appanoose beds.

CARBONIFEROUS.

The Carboniferous strata of the Mississippi valley are divisible into two great series; the Lower Carboniferous or Mississippian series and the Upper Carboniferous or Pennsylvanian series. The rocks of the latter alone outcrop within the district under consideration. The Saint Louis limestone, which is, in Iowa, the topmost member of the Mississippian series, is exposed along the Des Moines river near Ottumwa and in the vicinity of Eldon. At Ottumwa it lies at an elevation of about 680 feet. As shown in the cross-section along the Chicago, Milwaukee & Saint Paul railway, the rocks have a gentle dip to the southwest of about ten feet per mile. If this dip is constant, as seems probable, the total fall between Ottumwa and Centerville would be about 220 feet. If to this be added the difference in altitude between the highest outcrops of Saint Louis near Ottumwa and the railway station at Centerville, 137 feet, the distance to the top of the Saint Louis at the latter point would be about 357 feet. Near Cleveland, in Lucas county, borings have shown that the Saint Louis lies much nearer the surface than is compatible with the hyphothesis of a simple, regular, southwestern dip. While the surface of the Saint Louis is known to be exceedingly irregular, it is not thought that these irregularities alone will account for the nearness to the surface of the Mississippian rocks in western Lucas county. It seems much more probable that in this immediate vicinity the southern component of the dip is more important than the western. If this be true, the depth to the Saint Louis at Centerville would be importantly increased.

In the deep well put down at Centerville some time since the upper surface of the Lower Carboniferous, as pointed out by Norton,* was not well marked. So far as the samples show, it might be at almost any depth between 500 and 1,240 feet. In the well put down in the summer of 1895 it is thought that the Lower Carboniferous was encountered at about 600 feet, though the exact depth cannot be told without a much fuller examination of the drillings.

The importance of the location throughout this region of the upper surface of the Saint Louis arises from the fact that

*Iowa Geol. Surv., IV, page 174. 1895.

limestone marks the base of the coal measures. Throughout the region north and east of Appanoose county the coal measnres are almost entirely free from limestone, so that in prospecting it is comparatively easy to tell where the drill passes into the lower rocks. The lithological change which the Lower Carboniferous undergoes to the southwest, whereby the heavier limestones, seen at the surface in Wapello, Van Buren and neighboring counties, are replaced by shales and thin-bedded limestones,* introduces a new element of difficulty and uncertainty into all deeper prospecting in this region. This conclusion rests, however, upon comparatively slight evidence, and it is possible that later borings may show different results. For the present, it must be considered probable that the base of the coal measures is within about 600 feet of the surface at Centerville, and that it probably lies at a considerably less depth at points in the northeastern portion of the county.

Upper Carboniferous.

The Upper Carboniferous is the great coal-bearing series of the continental interior. It is divisible in Iowa into two members—an upper, the Missouri stage, and a lower, the Des Moines stage. The strata of the Upper Carboniferous represents a continuous sequence. There is no absolute dividing line between the shore-laid deposits of the Des Moines and the maritime beds of the Missouri formation. The relations between the shore and open sea deposits are particularly intimate in the region under immediate discussion. The difference, however, between open sea beds of the more typical exposures of the Missouri terrane and the shore deposits seen in typical areas of the Des Moines terrane is quite striking, and the division of the Upper Carboniferous into two stages. is of the highest practical utility. The dividing line between the two is at the base of the Winterset limestone of Iowa, which is probably, continuous with the Bethany Falls lime stone of Missouri.

*See Norton; op. cit.

The beds of Appanoose county afford excellent illustrations of the fact that the minor differences in faunas are due to local conditions of life, which conditions may now be inferred from the character of the strata then laid down. Certain forms present in the thin limestones of this county occur much more abundantly in the later beds of the Missouri terrane, not so much because the beds are later as because they are limestones, and hence were formed under marine conditions.

The fossils found in the limestones of the region indicate close relationship between the Appanoose beds and the Missouri formation. In the interbedded shales, however, forms characteristic of the Des Moines strata are found, and the fact that the beds are below the Winterset limestone necessitates their reference to the Des Moines formation.

DES MOINES STAGE.

As has been stated, the indurated rocks of Appanoose county are below the Winterset limestone, and hence belong to the Des Moines terrane. They include representatives of both the groups of strata formerly known as the lower and middle coal measures. Practically, the entire county is covered by beds formerly referred to the latter group.

The typical strata of the lower coal measures are exposed and mined at Foster, in Monroe county, just beyond the limits of Appanoose. The only beds referable to this group known to be exposed in Appanoose county are on Little Soap creek in Udell township (Tp. 70 N., R. XVI W., Sec. 32, Sw. qr.). At this point there is by the side of the road about twenty feet of very sandy shales, with a three-inch band of good sandstone near the base.

These lower coal measures are marked throughout the state by great irregularities in the thickness and lithological character of the individual strata, as well as by the presence of numerous thick though discontinuous seams of coal. They represent the more common facies of the Des Moines terrane.

APPANOOSE BEDS.

A less usual or perhaps wholly anomalous facies of the Des Moines formation is seen in the beds underlying the greater part of Appanoose county. These beds form a group of strata which, for practical convenience in description, may be called the Appanoose beds. Taxonomically the Appanoose beds are a sub-stage of the Des Moines terrane. They are in many important particulars sharply set off from the remaining strata of the Des Moines stage.

The Appanoose beds contain the Mystic coal and related strata. Among the latter are certain limestone bands known

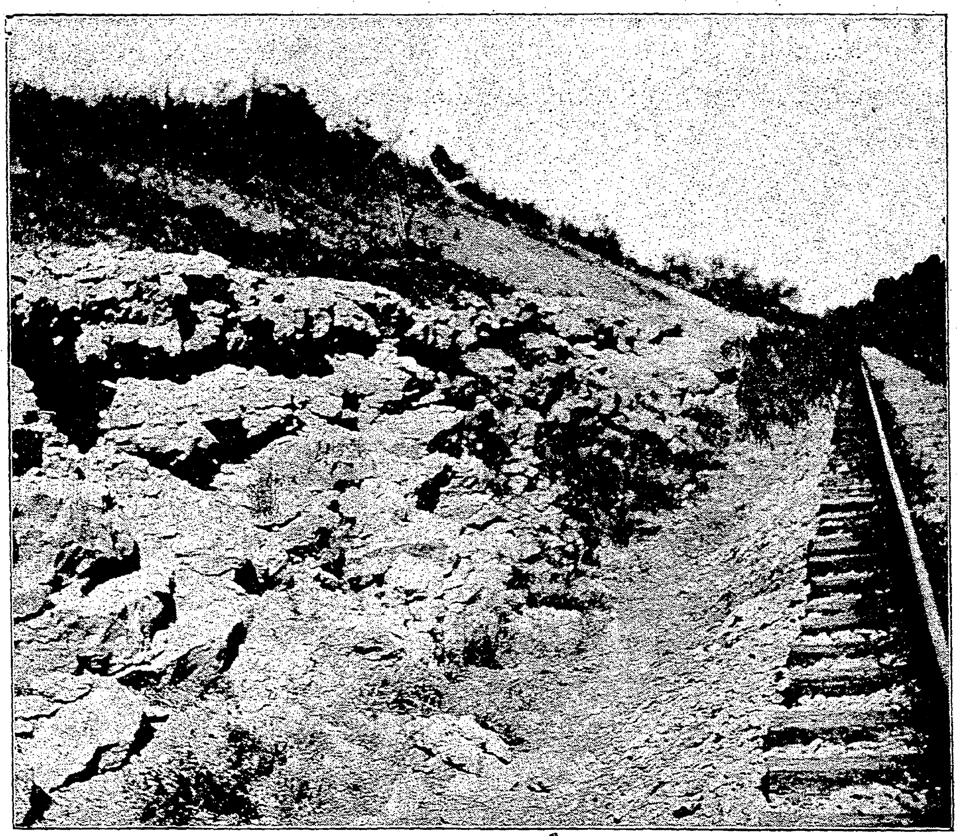


FIG. 54. Fifty-foot limestone in railway cut near Rathbun.

locally as the "floating rock," "fifty-foot limestone," "seventeen-foot limestone," or "little rock," the "cap rock" and the "bottom rock." Throughout the region these limestones maintain their normal sequence. In certain cases the rocks run together; at points some of them may, as a result of present or preglacial erosion, be absent. In the latter case they are of course found wanting from the top downward. The uniform presence and remarkable regularity in the character of these limestones, features shared by the coal seam as well, are what give the wholly anomalous character to the Appanoose beds.

The following records of diamond drill borings will give an excellent idea of the order and character of the different beds. These records are chosen from a large number made under the direction of Messrs Clarke & Peatman of Centerville, and kindly furnished by them. The agreement which may be noticed between these records is characteristic of the whole number of the borings. Numerous additional borings, shafts and natural exposures, show that the same sequence obtains throughout the county and over a considerable portion of the surrounding area.

BORING NO. 1.

(Tp. 69 N., R. XVII W., Sec. 19, Sw. qr., Ne. ¼).

		FEET.	INCHES.
26.	Surface dirt	2	
25.	Yellow clay	12	
24.	Limerock	6	
23.	Shale, argillaceous, blue	4	
22.	Shale, argillaceous, gray	16	
21.	Shale, gray	14	
20.	Limerock	4	
19.	Shale, argillaceous, blue	7	
18.	Limestone	1	
17.	Shale, blue	4	
16.	Limestone	2	
15.	Shale, bituminous	2	3
14.	Coal	2	5
13.	Clay		3
12.	Coal		10
11.	Fire clay		3
10.	Shale, argillaceous, blue	7	
9.	Shale, gray, hard	12	
8.	Limestone	1	
7.	Shale, black	3	
6.	Shale, gray	3	

		Feet.	Inches.
5.	Shale, blue	5	
4.	Limestone	2	
3.	Shale, gray	3	
2.	Shale, black	3	
1.	Shale, gray	8	

This boring is of exceptional interest in a few particulars. In it the coal is much thicker than is usual. The cap rock is apparently divided by a bed of shale (No. 17). The clay between the coal and the bottom rock (No. 8) is of more than usual thickness, though it is probable that a portion of the shale (No. 9) in reality belongs with the bottom rock. This boring is one of the very few which have been carried to any considerable depth beneath the coal, and is of particular value in indicating that the same regularity of structure which is found above the coal obtains, for some distance at least, beneath it. The presence of black shales beneath the coal bed now worked indicates the probable presence of coal horizons.

BORING NO. 2.

(Tp. 69 N., R. XVII W., Sec. 17, Nw. qr., Nw. ¼.)

		Feet.	Inches.
27.	Surface dirt	2	
26.	Yellow clay	5	
25.	Sand	2	
24.	Yellow sandy clay	10	
23.	Boulder		6
22.	Yellow sandy clay	12	
21.	Boulder		6
20.	Yellow sandy clay	9	
19.	Blue clay	9	
18.	Boulder		6
17.	Blue clay	1	
16.	Sand	1	
15.	Sandy clay	8	
14.	Sand	2	
13.	Sandy clay	11	
12.	Limestone	1	
11.	Shale, arenaceous	21	
10.	Shale, gray	3	
9.	Shale, argillaceous	6	

		FEET.	INCHES.
8.	Limestone	4	
7.	Shale, gray	15	
6.	Limestone	2	
5.	Shale, bituminous	3	
4.	Coal	1	2
3.	Clay		3
2.	Coal		5
1.	Fire clay	1	

This boring shows an unusual thickness of drift and a less than usual thickness of coal; the difference in the latter being in the lower bench.

BORING NO. 3.

(Tp. 70 N., R. XVIII W., Sec. 35, Se qr., Ne. ¼.)

		FEET.	INCHES.
20.	Surface dirt	11	
19.	Yellow clay	2	
18.	Sand	3	
17.	Yellow sandy clay	3	
16.	Limestone	5	
15.	Shale, argillaceous	9	
14.	Shale, gray	10	
13.	Sandstone, blue	2	
12.	Shale, argillaceous, blue	4	
11.	Shale, gray	6	
10.	Limestone	1	
9.	Shale, argillaceous	9	
8.	Limestone	1	
7.	Shale, argillaceous	4	
6.	Limestone	1	
5.	Shale, bituminous	2	
4.	Coal	1	7
3.	Clay		3
2.	Coal	1	1
1.	Fire clay	1	6

In this boring the coal is shown in its normal thickness. The cap rock is again split by shale as noticed in boring No 1.

BORING NO. 4.

		FEET.	INCHES.
19.	Surface dirt	2	
18.	Yellow clay	10	
17.	Yellow sandy clay	6	

		FEET.	INCHES.
16.	Boulder		9
15.	Yellow clay	11	
14.	Boulder		6
13.	Sandy clay	8	
12.	Sand	5	
11	Sandy clay	7	
10	Shale, argillaceous, gray	20	
9.	Limestone	2	
8.	Shale, blue	14	
7.	Coal		9
6.	Clay		2
5.	Coal		10
4.	Clay		6
3.	Coal		8
2.	Clay		10
1.	Fire clay	1	

This boring is not far from the Chariton river, and the thickness of the drift is indicative of the former greater width of the valley. The cap rock is probably represented in No. 8, not having been distinguished from the shale. The most unusual feature shown by the boring is the division of the coal by two mud bands rather than one, and the wholly exceptional thickness of the lower band. Such a lower band is known at numerous points, but is usually of insignificant thickness.

These borings show fairly well the normal sequence of strata as found in this county. From a study of them and numerous shaft records and exposures, the following somewhat generalized section has been made out.

		FEET.	INCHES.
17.	Limestone, gray, sub-crystalline, seen in the railway cut near Anchor No. 1 mine at Centerville, and known among the miners as the "floating rock"	2 to 4	
16.	Shale, argillaceous, color variable	12 to 30	
15.	Limestone, heavy ledges, exposed along Manson branch and Cooper creek at Centerville, as well as at numerous other points in the county, the "fifty-foot limestone"	4 to 10	

		FEET.	INCHES.
14.	Shale, argillaceous, blue and red in color	14	
13.	Shale, arenaceous, frequently forming a well defined sandstone, as in boring No. 3 (No. 13), and the Rock Valley shaft	8	
12.	Shale, argillaceous, blue to gray	10	
11.	Limestone, somewhat variable in thickness; exposed along the C., M. & St. P. railway, between Mystic and Brazil, known as the "seventeen-foot limestone" or "little rock" 1 to	3	
10.	Shale, sometimes gray, frequently bituminous and pyritiferous	7	
9.	Limestone, sometimes gray, and coarsely sub-crystalline as at the Lodwick mine, Mystic; sometimes fine-grained, bituminous, and grading into the shales above and below, as at the Thistle mine, Cincinnati; known as the "cap rock," 2 to	4	
8.	Shale, usually bituminous, and known as "slate;" occasionally in part soft and clay-like, then known as clod; at times heavy and homogeneous non-fissile, in which form it is known as "black bat" 1 to	3	
7.	Coal, upper bench, usually	1	8–10
6.	Clay parting "mud band"		2–3
5.	Coal, lower bench, usually		8–10
4.	Clay parting the "dutchman"		½
3.	Coal, frequently not so pure		2–3
2.	Fire clay 1 to	6	
1.	Limestone, "bottom rock," well exposed along Walnut creek at Mystic	3	6

The details of this section may vary from point to point, but the general sequence remains the same over a considerable extent of territory. It will be seen that the coal seam has several characteristics which make its recognition easy and the correlation of the various outcrops secure. The presence of the two mud bands, of which the upper is the more regular and conspicuous, with the limestones found above and below the coal, afford the best possible basis for correlation. To this is added a most remarkable uniformity in the physical character and general appearance of the coal itself. The Mystic coal,* as it has been called by Keyes, from the excellent surface exposure occurring at that place, is thought to underlie, in workable condition, about 1,500 square miles of land in Iowa and Missouri. There is also a considerable additional area which may be ultimately proved to be underlain by this seam. The area, as now known, extends over portions of Appanoose and Wayne counties in Iowa, and Schuyler, Putman, Adair and Sullivan counties in Missouri.

The following sections, taken from widely scattered points in the field, show the close similarity between the exposures.

(1.) Section measured as exposed along Walnut creek at Mystic, in the north central part of Appanoose county.

	FEET.	INCHES.
7. Limestone, massive, gray (seen in Lone Star drift)	2	6
6. Shale, bituminous	1	
5. Coal	1	6
4. Fire clay		2
3. Coal	1	
2. Fire clay	1	3
1. Limestone	2	10

(2.) Section as seen in a mine at Seymour, Wayne county, at a depth of 242 feet.

	FEET.	INCHES.
7. Limestone "cap-rock"	2	
6. Shale, bituminous	1	6
5. Coal	1	6
4. Clay		2
3. Coal	1	
2. Fire clay	1	2
1. Limestone bed-rock		

(3.) Section examined in a mine at Centerville, Appanoose county, at a depth of 150 feet.

	FEET.	INCHES.
7. Limestone		
6. Shale, black	1	
5. Coal	1	5

* Keyes: Iowa Geol. Survey, II, 408. 1894.

		FEET.	INCHES.
4.	Fire clay		3
3.	Coal	1	2
2.	Fire clay	1	8
1.	Limestone		

(4.) Section at Blackbird Coal company's shaft, two miles north of Unionville, Putman county, Missouri.

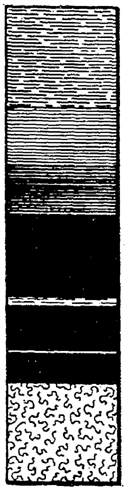
		FEET.	INCHES.
7.	Limestone, hard gray	3	
6.	{ Clayey gray shales (clod)		6–8
	{ Black fissile shale	1	
5.	Coal	1	8–10
4.	Clay parting		1–3
3.	Coal		10–12
2.	Clay	3	
1.	Limestone		

(5.) Section of coal bed at Stahl, Adair county, Missouri.*

		FEET.	INCHES.
7.	Limestone	1	10–12
6.	{ Clay (clod)		2–3
	{ Black fissile shale	1	6–12
5.	Coal	2	
4.	Clay parting		1–3
3.	{ Coal	1	
	{ Clay		1–2
	{ Coal		1–2
2.	Clay	1	4–6
1.	"Bottom rock"	1	6

The details of the strata found between the cap rock and the bottom rock are well shown in the following section measured in a small mine in the southeastern part of Appanoose county.

*Sections IV and V, taken from Missouri Geol. Sur., Prelim. Rep. on Coal, pp. 56 and 61. Jefferson City, 1891.



		FEET.	INCHES.
9.	Clay shale, gray, very hard	2	
8.	Shale, drab, clayey ("clod")	1	2
7.	Shale, black, fissile	1	
6.	Coal	1	8
5.	Clay parting		2
4.	Coal		10
3.	Clay parting, with pyrite		½
2.	Coal		2
1.	Fire clay, gray	2	

FIG. 55. Coal bed at the Troublesome mine.

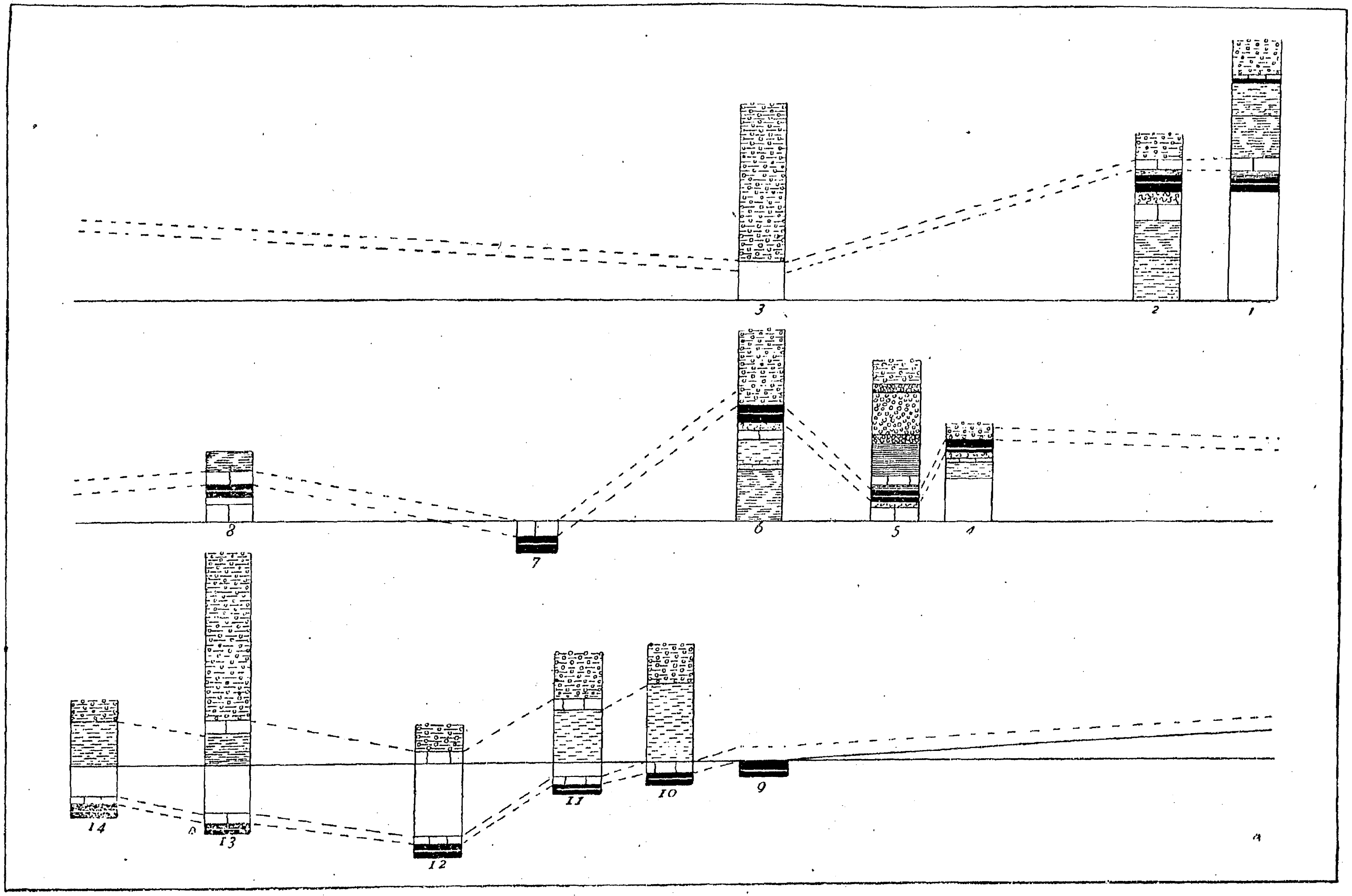
The total amount of shale overlying the coal is not usually so great. It is probable that the gray clay shale (No. 9) in part represents the cap rock. The black fissile shale immediately over the coal, usually called "slate," is quite constant. The development of the clod is on the whole exceptional. The lower mud band (No. 3) is known as "the dutchman," and is usually pyritiferous. The coal as a whole is quite free from pyrite. It is clean, soft, though brittle, breaks with a conchoidal fracture, and gives bright, glistening surfaces. It is traversed by cleat planes filled with gypsum, which cause it to break readily into cubical pieces, and it is hence a "block" coal.

The general character of the exposures of the Appanoose beds is illustrated by those occurring along the Chariton river. These exposures together form plate xi. In detail they are as follows.

(1.) *Exposure on the east side of Chariton river near Hilltown (Tp. 67 N., R. XVI W., Sec. 16, Sw. qr., Sw. ¼).

		FEET.
7.	Drift	10+
6.	Cap rock	2
5.	Mystic coal	2½
4.	Fire clay	4
3.	Bottom rock, yellow arenaceous limestone	2½
2.	Blue clay shale	8
1.	Sandy shale	10

*On plate xi figure 1 is incorrectly drawn.



GEOLOGICAL SECTION ALONG CHARITON RIVER.

(2.) Exposure on the Chariton near preceding exposure (Sec. 16, Ne. qr., Sw. ¼).

	Feet.	Inches.
6. Drift	10+	
5. Limestone, cap rock	2	
4. Mystic coal	2	8
3. Fire clay	1	2
2. Limestone, bottom rock	1	3
1. Shales, in part sandy, in part clayey	28	

(3.) Exposure on the west side of Chariton below Sedan (Tp. 68 N., R. XVI W., Sec. 35, Ne. qr.).

	Feet.
3. Yellow clay	20
2. Blue boulder clay	18
1. Talus of boulders containing large blocks of limestone	8

(4.) Exposure near the mouth of Snort creek (Tp. 69 N., R. XVII W., Sec. 9).

	Feet.	Inches.
5. Drift	3	
4. Mystic coal	2	10
3. Fire clay	1	2
2. Limestone	1	
1. Shales, argillaceous, gray	4	

There are a number of dump heaps in the vicinity indicating that the coal has been worked for local purposes. A short distance above this creek is an exposure (No. 5) showing the normal sequence of coal and enclosing limestones covered by the Chariton conglomerate, which will be later described.

(6.) Dennis Mill exposure (Tp. 69 N., R. XVII W., Sec. 7, Ne. qr., Sw. ¼).

	Feet.	Inches.
7. Drift	18	
6. Mystic coal and slate	4	8
5. Fire clay	2	2
4. Limestone	1	8
3. Shales, arenaceous, green	6	
2. Sandstone, yellow, local		10
1. Shales, argillaceous, gray	12	

The cap rock, and in some places some of the coal has been removed by the erosion preceding the drift. The exposure to weathering has caused the coal to swell up to more than its normal thickness.

(7.) Darby. At Darby the coal lies a few feet below the level of the river. The limestones outcropping in the vicinity belong to the upper series and their correlation may be seen in the section along the Milwaukee road.

(8.) Near Little Walnut creek (Tp. 70 N., R. XVIII W., Sec. 26, Sw. qr., Se. ¼) coal has been mined by shallow shafts and drifts. The sequence is normal, as shown by boring No. 3 already given. There is a considerable drift covered interval between the mouth of Little Walnut and the mouth of South Chariton. In the region near Milledgeville however, there are numerous exposures.

About a mile southeast of the Milledgeville bridge (exposure 9, Tp. 70 N., R. XIX W., Sec. 15, Ne. qr.) coal has been obtained by stripping in the bed of the stream. In the same section is the following exposure.

(10.) Exposure on Chariton near Milledgeville (Tp. 70 N., R. XIX W., Sec. 15, Nw. qr., Ne. ¼).

		FEET.
2.	Drift	10+
1.	Shale, arenaceous	18

A few rods farther up the stream a similar exposure (No. 1) shows these shales to be covered by a three-foot bed of limestone. Presumably the same limestone is seen in the river near the Milledgeville bridge (exposure 12). Above this bridge there are two exposures showing essentially the same.

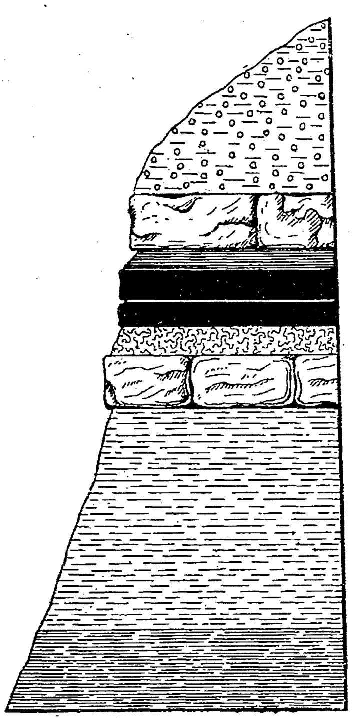
(13.) Exposure west of Milledgeville (Tp. 70 N., R. XIX W., Sec. 8, Sw. qr., Nw. ¼).

		FEET.
4.	Drift	20+
3.	Black shale fragments	½
2.	Limestone	3
1.	Shale, argillaceous	7

A short distance beyond (exposure 14, Sec. 6, Se. qr., Se. ¼) the same shales may be seen.

The Appanoose beds, as defined above, underlie all of the southwestern half of the county and not improbably a considerable portion of the eastern half. Except where removed by erosion, the strata are continuous and may be seen wherever the streams have cut deep enough to expose them. The coal is extensively mined at Centerville, Cincinnati, Forbush, Brazil and along the C., M. & St. P. railway from Jerome to Darby.

The valley of Walnut creek is one continuous mining camp, known under the different names, Jerome, Diamond, Mystic, Clarksdale, Rathbun and Darby. At Mystic and Brazil, owing to the presence of a marked anticlinal, the beds are excellently exposed. At the former point the following typical section may be seen.

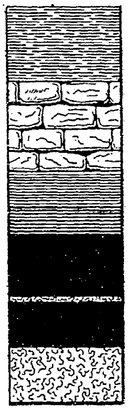


	FEET.	INCHES.
10. Drift	12	
9. Limestone, heavily bedded, gray, fossiliferous	2	10
8. Shale, bituminous, fissile	1	
7. Coal	1	6
6. Clay parting		2
5. Coal, with some pyrite near base	1	
4. Fire clay	1	6
3. Limestone, heavily bedded, fossiliferous	2	10
2. Shale, gray, clayey	11	
1. Shale, blue, clayey (exposed to water level)	4	

FIG. 56. Bluff on Walnut creek. Mystic.

At Centerville the coal lies at a lower level. The fifty-foot limestone is exposed along Cooper creek and Manson branch.

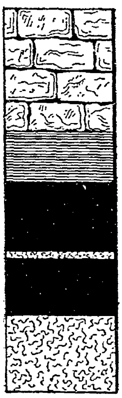
The beds as measured in the Centerville Block Coal Co.'s mine, No. 1, represent the average.



	Feet.	Inches.
8. Shale, dark blue to black, with some pyrite	2	
7. Limestone, thinly bedded, fossiliferous	2	6
6. Shale, drab, clayey ("clod")	1	
5. Shale, bituminous, fissile		8
4. Coal	1	7
3. Clay parting		2
2. Coal	1	2
1. Fire clay (exposed)	1	6

FIG. 57. Base of Centerville block shaft, No. 1. Centerville.

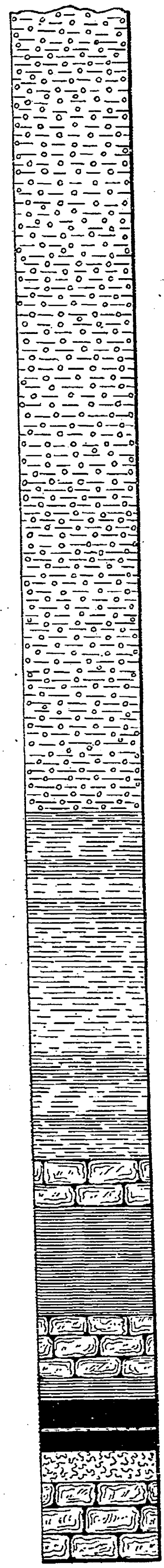
Four miles north at Forbush the coal is extensively mined. The following section measured in the Whitebreast mine No. 19, gives the thickness at this point.



	Feet.	Inches.
6. Limestone, gray to black, with pyrite in lower part	2	6
5. Shale, gray to black	1	
4 Coal	1	5
3. Clay parting		2
2. Coal	1	2
1. Fire clay, exposed	1	6

FIG. 58. Coal seam at Whitebreast No. 19. Forbush.

In the southern portion of the county the coal is mined at Hilltown (see figure 55), near Exline, and at Cincinnati. At the latter place there are a number of mines reaching the coal at depths of from 60 to 160 feet. The Albert shaft, sunk in 1893, supplies the following representative section.

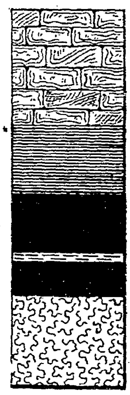


		FEET.	INCHES.
11.	Drift	57	
10.	Shale, gray to black, varying in character and hardness	22	
9.	Limestone, thinly bedded, gray, fossiliferous	3	
8.	Shale, black, with pyrite in part	7	
7.	Limestone, gray, heavily bedded	4	
6.	Shale, black, fissile	1	4
5.	Coal	1	8
4.	Clay parting		2
3.	Coal	1	3
2.	Fire clay	2	
1.	Limestone, hard, heavily bedded (exposed)	5	

FIG. 59. Section of Albert shaft. Cincinnati.

Farther south, near Pearl City and Mendota, Mo., the coal comes nearer the surface and is worked by drifts.

At Numa the normal thickness of coal is found at depths of 145 feet and less. Near Livingston and northwest of Jerome it comes nearer the surface. In the northwestern part of the county and near Confidence in Wayne county the coal outcrops at numerous points and is opened up by a considerable number of slopes and shallow shafts. The section at the Young mine is representative.



		FEET.	INCHES.
6.	Limestone, gray, fossiliferous	2	6
5.	Shale, bituminous	1	6
4.	Coal	1	3
3.	Clay parting		2
2.	Coal		9
1.	Fire clay (exposed)	2	

FIG. 60. Coal bed at Young mine. Milledgeville.

East of Chariton river there are few exposures except in the immediate vicinity of Snort creek. Along Mormon creek, southeast of Moravia, at one or two points limestone ledges may be seen. Near one such exposure (Tp. 70 N., R. XVII W., Sec. 1, Se. qr., Nw. ¼) deserted slopes and dumps indicate that coal has been found. On the land of John Macyntire (Tp. 70 N., R. XVII W., Sec. 2, Se. qr., Nw. ¼) coal was formerly mined both by slope and shaft. In sinking the shaft the drift was found to be eighteen feet thick, below this was a limestone two feet thick, and about sixteen feet still lower down and just above the coal, was a second limestone one foot six inches thick. The coal bed itself showed two benches separated by a mud band as follows.

		FEET.	INCHES.
3.	Coal	1	6
2.	Clay		4
1.	Coal		6

Still farther northeast, at Foster in Monroe county, there is a coal seam, formerly worked by a slope and lying about forty feet above Soap creek. An examination of the slope in 1893 showed the following section.

		FEET.	INCHES.
4.	Shale, argillaceous, drab	2	
3.	Coal, weathered	2	3
2.	Clay		7
1.	Coal	?	

Miners who have worked this bed declare that No. 1 of the above section is coal and runs from nine to ten inches thick. They also state that the clay is usually somewhat thicker than shown at this exposure. In a small ravine near by there is a limestone bed resembling in appearance and fossils the fifty-foot limestone of the Appanoose beds and lying at the proper distance above the coal. While in character this Soap creek seam is somewhat different from the Mystic coal, and while there are no good records of its presence between Darby and Moravia, the probability of its identity is considered sufficiently strong to justify the representation of the two seams as the same. (See plate xiv.)

There is one other area east of the Chariton in which there is a very strong probability, if not indeed a certainty, of the presence of the Mystic coal. Udell station on the Chicago, Rock Island & Pacific railroad lies on a level plain at an elevation of about 1,000 feet. In the summer of 1894 local parties did some boring in search of water. In all, four borings were put down with a churn drill; all being upon the plain referred to. In each, a seam of coal two and one-half to three feet thick was encountered at a depth of 175 feet. The drift extended down to 150 feet and below this was gray shale and limestone to the coal. Immediately above the coal the drilling was hard, indicating the presence of limestone. A few inches below the coal a second rock layer was encountered. Sometime earlier a hole was drilled on lower ground about three miles southwest of Udell. Coal was reported in this hole at a depth of seventy-five feet. These figures agree well with what a geological section along the Chicago, Rock Island & Pacific railway shows to be probable.

It seems probable that the major portion of the county lying east of the Chariton was originally underlain by the Mystic coal. Probably that seam will be found still present under a part of the area. A considerable portion of the region has, however, been subjected, since the deposition of the coal, to erosive action of sufficient intensity to remove from large areas the coal and associated strata. This erosion was in two widely separated periods, the first being in Des Moines time and immediately preceding the deposition of the Chariton conglomerate, and the second occupying the very long period between the close of the Carboniferous and the advent of the ice age.

CHARITON CONGLOMERATE.

Along the Chariton river near the mouth of Snort creek, a small stream which is also known as Ullam's branch, there is a series of beds totally unlike those which are typical for the county and which have been called the Appanoose beds. This second and later series is, at present, known from a very few exposures only. Indeed the areal extent of the beds is almost unknown, though there is reason to believe that it is limited. The typical section, exposure No. 5 of the Mystic river cross-section (Tp. 69 N., R. XVII W., Sec. 9, Se. qr., Sw. ¼) shows the following beds.

		FEET.	INCHES.
10.	Drift	10	
9.	Coarse conglomerate	2	
8.	Fine conglomerate	10	
7.	Coarse conglomerate	2	
6.	Shale, black fissile	.8	
5.	Limestone, cap rock	2	
4.	Shale, black fissile	1	
3.	Mystic coal	2	10
2.	Fire clay	1	6
1.	Limestone, bottom rock	2	

Strata 1 to 6 belong to the Appanoose beds, 7 to 9 represent the Chariton conglomerate. The latter has a matrix of reddish, ferruginous sandstone in which are imbedded small water worn pebbles and brecciated blocks of gray, drab and white limestone. The latter were evidently derived from the cap rock and associated limestones of the Appanoose beds.

FIG. 61. Chariton conglomerate; coarse grained facies.

As seen at this particular exposure the rock shows two facies, one fine-grained and the other coarser. The latter is the more typical and is represented in figure 61. The rounded water worn pebbles seen in this specimen and also illustrated in figure 62 are of fine-grained, white to gray limestone, and present all of the physical characteristics as well as the more usual fossils found in the immediately subjacent limestone. The pebble shown in figure 62 was dug out of the soft matrix of the conglomerate. Its form shows undoubted water rounding. The weathering of the matrix and the pebbles is of course unequal, so that they are usually sharply contrasted. In addition to the rounded pebbles there are numerous smaller sharp-cornered flakes of limestone, bits of crinoid stems, and broken pieces of brachiopods found in the conglomerate. The matrix is only in part arenaceous and is quite

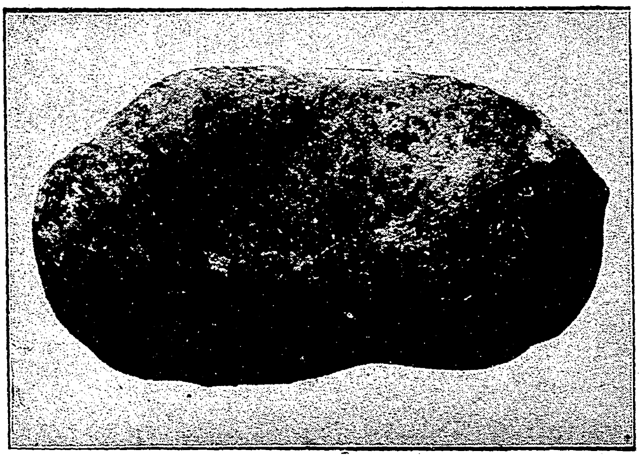


FIG. 62. Pebble from Appanoose beds taken from Chariton conglomerate.

largely made up of earthy, magnesian limestone. In the fine-grained facies this is particularly true. Small particles of coal, having all the well marked physical properties of the Mystic seam, occur in the fine-grained beds. This fact, with the general character of the pebbles as well, would seem to indicate that at the time the conglomerate was formed there were considerable inequalities in the surface, and that the preceding erosion had cut down into, if not through, the coal bed.

The wide extent and uniform character of the Mystic coal, the numerous bands of limestone of more or less regular thickness, the presence in the latter of a pelagic fauna, the total absence of cross-bedding, current action, and heavy sandstone beds, the thick deposits of infra-littoral clay and shale deposits, and the almost total absence of arenaceous material, except as disseminated in shales, all indicate that the Appanoose beds represent a period of extreme quiet, and, unless the coal seam itself be taken as the sole evidence to the contrary, a total freedom from shore conditions. This period of quiet and uniform disposition was evidently followed by one during which the strata were elevated and eroded. The eroded fragments were gathered together and redeposited, making up the Chariton conglomerate. That this later erosion and redeposition took place during the Carboniferous rather than at some later period would seem to be indicated by the intimate relation between the fragments in the conglomerate and neighboring ledges, the apparently local nature of the phenomena, the known presence of numerous other local unconformities in the coal measures, and the large number of crinoid stems and other Carboniferous fossils found in the conglomerate in such a fresh condition as apparently to preclude the idea that they are not indigenous.

In addition to the conglomerate exposure already described the rock is known only at two other points. In the quarry of Mr. Wm. Duval (Tp. 70 N., R. XVII W., Sec. 1, Nw. qr., Sw. ¼), the stone, showing the coarse facies only, has been opened up. The quarry is along a small ravine opening off of Morman creek. The rock outcrops fifty to a hundred feet along the stream and shows a thickness of twenty-five feet or more. It lies at least fifteen feet above the stream. The rock shows the same characteristics that mark it at the typical exposure.

The third known outcrop of the conglomerate is in Monroe county, about four miles south of Albia (Tp. 71 N., R. XVII W., Sec. 3, Se. qr.). It has been quarried a little here, and used for foundation work at Foster and neighboring towns. The probable position of this conglomerate in the Ottumwa-Seymour section is indicated on plate xiv.

The uncertainty as to the extent of the erosion which preceded the deposition of the conglomerate, as well as that which preceded the drift, has made it seem inadvisable to attempt to map the areas east of the Chariton, which are underlain by the Mystic coal. Beyond the general probability of its presence, under a portion at least of the uplands, nothing can be stated. The actual delimitation of the coal-bearing areas must be left to future prospecting. It is evident that, with the large reserve areas of coal land west of the river yet untouched, it will be many years before the more problematic areas east of the river will be opened up.

The line drawn upon the map as marking the eastern limit of the Appanoose beds merely marks the limit of known territory. The coal may, and at many points probably does, extend beyond this line. It is merely intended to indicate that south and west of the line as drawn there is every reason to believe the coal present under every acre of territory where the topographical configuration does not already show its absence — except over areas of limited extent, some few known, and more perhaps unknown, where it has been removed by erosion or interfered with by faults. In Caldwell township a considerable area has been marked as barren. Prospecting over a part of this area has been carried on by the different parties. One reported the coal absent in part, though the limestones were present; the other reported the coal present. Inasmuch as the exact limits of the barren area are not known, it has seemed better to map the whole as doubtful. That is, the coal though probably present over most of the area, may be found to be absent at any point.

Geological Structure.

FAULTS.

Faults of two kinds interrupt the continuity of the coal seam within the area indicated. The first are true geological faults, and are known to the miners as slips. Figure 63 illustrates one found in the Thistle mine at Cincinnati. The throw in a majority of cases is a few inches only, and these

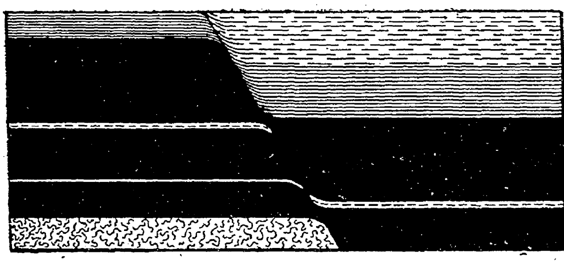


FIG. 63. Fault in Thistle mine. Cincinnati,

slips offer no serious obstacles to mining. Akin to them are the clay-filled fissures, such as shown in figure 64.

But one serious fault has been so far encountered in the field. This occurs in the Scandinavian mine and is illustrated in plates xii and xiii. The coal in the Scandinavian mine

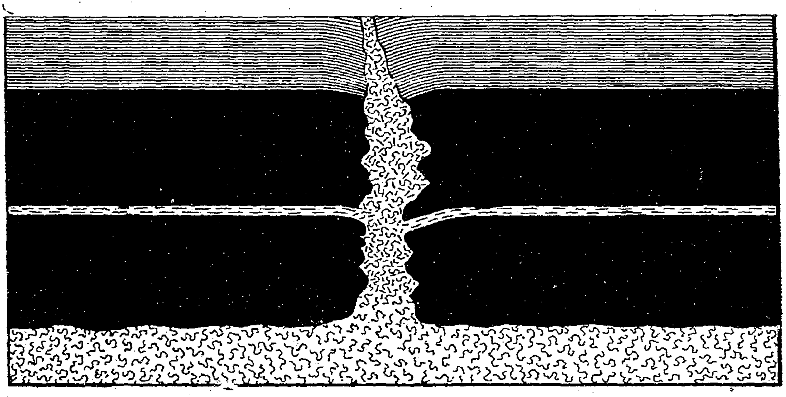


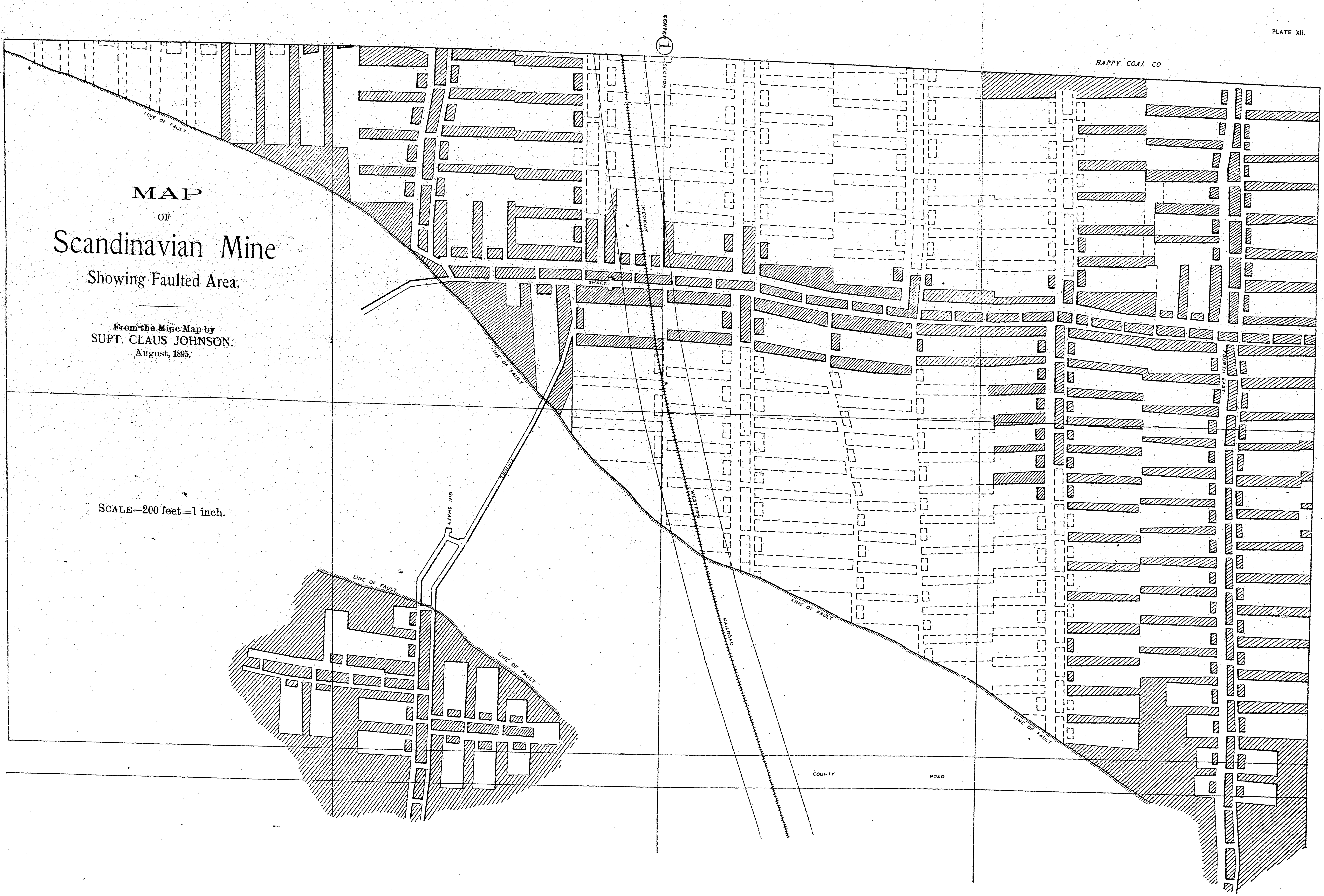
FIG. 64. Fissure in seam at Thistle mine. Cincinnati.

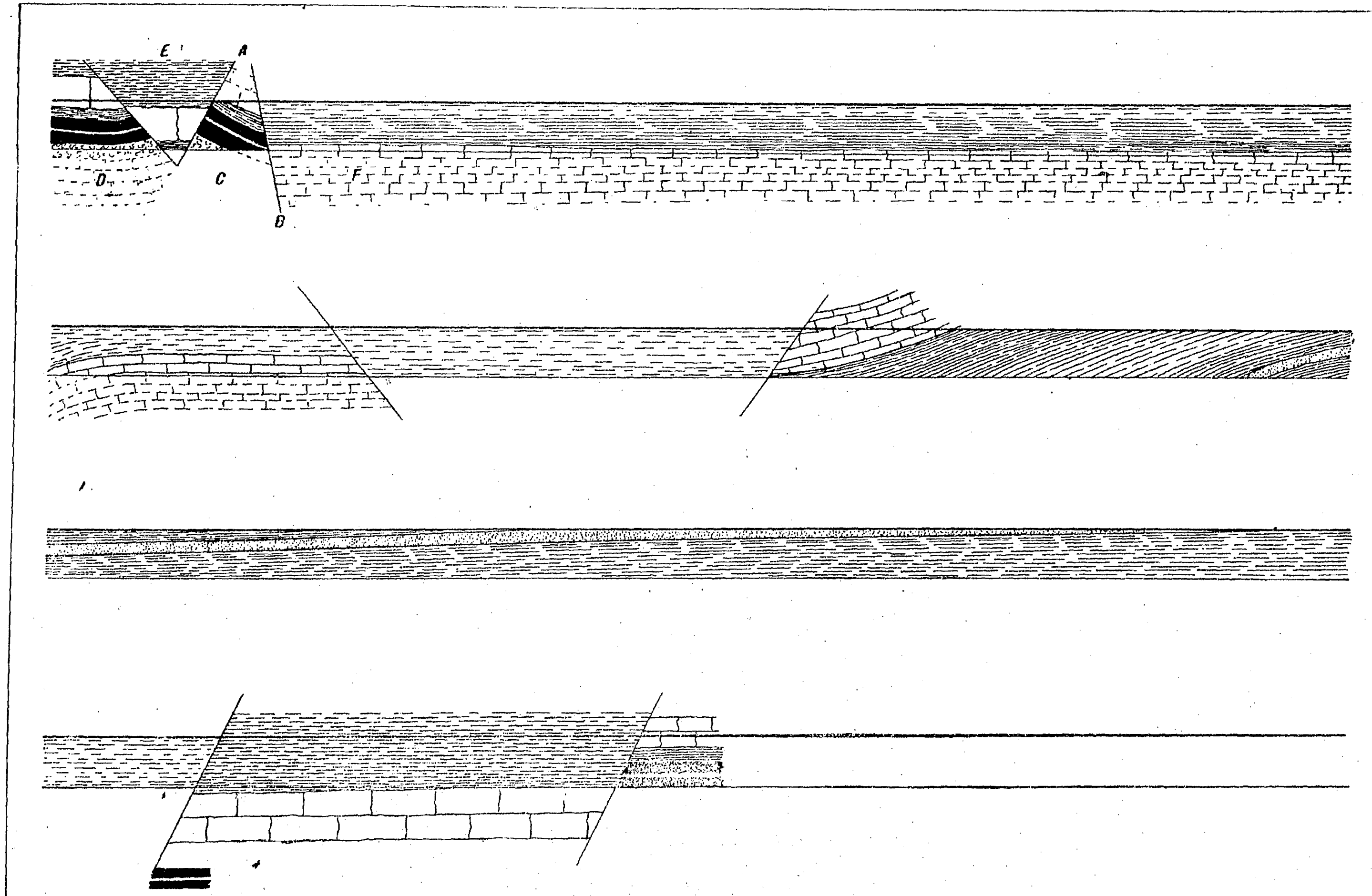
shows the usual characteristics. There was no indication in the earlier workings of the presence of a fault. In working south and east, however, it was found that the coal was cut off, and later workings show that the direction of the fault is about as indicated on the map. Up close to the line of fault the coal was, at most points, uninjured. It did not show the weathered surface so commonly found when the bed has been cut through by preglacial erosion, but was simply cut sharply off and replaced by limestone or slate. Since it was known that in the National mine, located to the southeast of the Scandinavian, a fault of some description had at one time been encountered in the west workings, a few bore holes were put down in the doubtful territory. Coal of the usual character and at nearly the correct level, was found at one point. A gin shaft was sunk, but when the drifting begun the coal was soon found to be cut off to the southeast. It was relocated and the tunnel driven across the entire fault to the new workings.

In the area beyond, the coal near the fault is badly broken; but the rooms driven south and east show good coal. The map, plate xii, shows the condition of this portion of the mine in August, 1895. It will be noticed that the fourth east has been driven nearly 150 feet beyond the point at which it might be expected that the fault would appear. This indicates that the fault has either run out or changed direction. The latter is quite possibly the correct hypothesis, though it has been believed that the absence of the usual coal seam in the two deep wells put down northeast of the Scandinavian was due to a prolongation of this line of disturbance.

In working the Standard mine a "fault" was encountered about 1,000 feet north of the south line of their lease, and running east about 1,000 feet. At this point it turns to the northeast and continues to the line of the unoccupied eighty acres east of the Standard lands. It has not been traced beyond this line. Along this fault, which cannot now be examined, the roof is reported to be poor, the coal soft and in places replaced by white clay. No sticks or stones, the usual signs of preglacial erosion channels, are reported. Near the Keokuk & Western depot a local mine, now abandoned, is said to have struck a similar fault.

These facts would seem to indicate that the Scandinavian fault turns toward the east and is continuous with that encountered in the Standard mine, though in the absence of an opportunity to examine the latter this cannot be stated certainly, and there must be some doubt whether after all the Standard "fault" is not a preglacial erosion channel.


MAP
OF
Scandinavian Mine
Showing Faulted Area.
From the Mine Map by
SUPT. CLAUS JOHNSON.
August, 1895.
SCALE—200 feet=1 inch.
HAPPY COAL CO
CENTER
SECTION
LINE OF FAULT
SHAFT
KEOKUK
WESTERN
RAILROAD
FOURTH EAST
COUNTY
ROAD



SECTION ACROSS THE SCANDINAVIAN FAULT.

It will be noticed, from a study of the section along the tunnel at the Scandinavian mine, plate xiii, that there is no gain in altitude on either side of the faulted area. There is merely a long, narrow block of strata that has dropped down, as if a broad crack had opened out and allowed the strata along one edge to slip down into the opening. Essentially the same thing in miniature is shown at the point where the fault is first entered by the tunnel. The slipping of the strata along the line A–B has pushed the block C over against D and allowed the block E to drop into the resulting

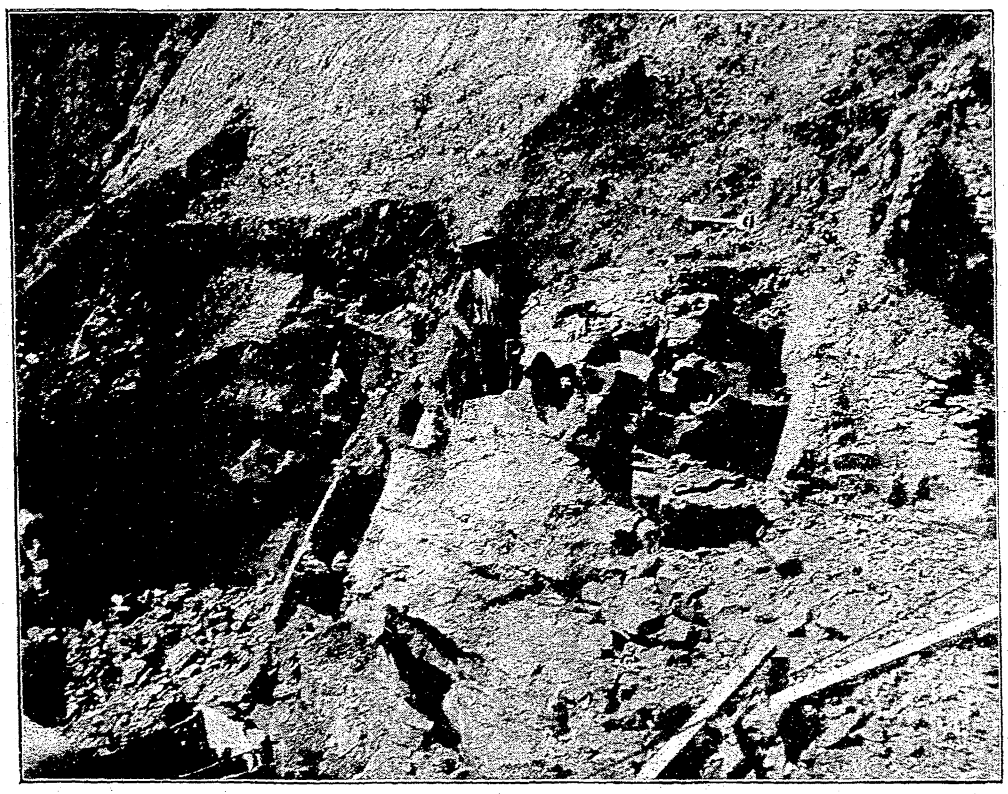


FIG. 65. Shales in pit of the Centerville Brick & Tile Co., showing disturbance due to Scandinavian fault.

crack. Hence a wedge of the cap rock occupies a position between two blocks of coal. The pressure of C against the lower portion of D has produced the anomaly of strata bending upward towards a down-throw fault.

The amount of displacement is about fifty feet, as is shown by the presence of the fifty-foot limestone, F, beyond the line of slip A-B. This limestone is recognized by its thickness and character as well as by the character of the attendant shales and the succession in which the various beds are traversed by the tunnel.

The presence of a faulted area of this size, at least three-quarters of a mile long and 450 feet wide, and having a throw of fifty feet, is unusual in the Iowa coal measures. Indeed, this is believed to be the first clearly proven instance of so great a true fault.

The time at which this disturbance took place is unknown. In the pits of the Centerville Brick & Tile Co. located on the same property, the disturbance shows in the overlying shales, as seen in figure 65.

It did not then take place until after the whole of these coal measures was deposited. Despite local belief to the contrary, there are no topographic indications distinguishing the faulted area, and the drift shows no disturbance over the fault. It must then have preceded the ice invasion. More than that it is impossible to say.

NUMA DOME.

The Appanoose beds have a general dip to the southwest. This is on the whole about ten feet to the mile, and is in a general way conformable to the upper surface of the Saint Louis. It is interrupted in this county by a broad, low anticlinal, or more probably dome-like structure, which is crossed nearly at right angles to its greatest length by the section from Ottumwa to Seymour. It is quite possible that this dome should be represented upon that section as extending farther west, and that the resulting dip to Seymour should be greater. Since, however, the data for the exact amount of this western expansion are not at hand, it has not been represented. Toward the north, along the Chariton river, the anticlinal seems to die out, or possibly bears off to the northwest. Southward it is quite apparent.

At Numa the coal is about 90 feet higher than at Centerville, while at Seymour it is something more that 100 feet lower. At Cincinnati the coal is about fifty feet above the same seam at Hilltown, directly east. These various levels show the presence of a broad low dome reaching its maximum elevation not far from Numa.

DEEPER COAL SEAMS.

The presence or absence of deeper coal seams in this region is a matter of considerable scientific and economic import. The strata which lie below the Appanoose beds represent the more typical phases of the Des Moines terrane. This phase, in the regions north, east and south, contains numerous workable beds of coal usually of greater thickness than the Mystic seam but of more limited extent. In the section from Ottumwa to Seymour (plate xiv) it will be seen that there are, between the Saint Louis and the Mystic coal, three horizons along which coal of workable thickness has been found, as well as one minor horizon which may, or may not, show coal of a thickness sufficient to be valuable. The lowermost of these horizons is 425 feet below the Mystic coal and from ten to fifty feet above the Saint Louis. It is first seen in an exposure (No. 2) on Bear creek just south of the railway mile post 325 (Tp. 72 W., R. XIV W., Sec. 28). The section at this point shows the following beds.

		FEET.	INCHES.
11.	Kansan drift sheet	12	
10.	Shale, gray, clayey	30	
9.	Limestone, bituminous		6
8.	Shale, bituminous	8	
7.	Coal	1	
6.	Shale, black, fissile	13	
5.	Limestone, bituminous		3
4.	Shale, black, fissile	4	
3.	Coal	1	
2.	Shale, gray	2	6
1.	Shale, arenaceous	25	

About two miles west is an exposure (No. 3) of sandstone covered by bituminous shale, probably representing the horizon of the upper coal seam on Bear creek, and underlain by a coal bed which lies probably along the same horizon as the lower coal seam at that exposure. This lower coal seam has been worked near Bidwell, by a number of small mines in which it is reported to be four to four and one-half feet thick. A bed lying at about the proper level to be its continuation has been reported in borings (No. 5) at Appanoose.

The coal worked at the latter place is about four feet thick and seems to represent the horizon lying 300 feet below the Mystic coal, though it is here fifteen feet nearer the lower seam than usual. If the dip be regular, and there is no evidence at hand indicating the contrary, the coal at Appanoose belongs to the horizon worked at the Deep Vein mine (No. 7) at Foster. Above it, at Appanoose, are two veins which have their representatives at Foster in beds eight and thirteen inches thick. The thicker bed represents the horizon 150 feet below the Mystic coal. How far west from Foster these various beds continue can not be positively stated, but borings made between that place and Moravia during the summer of 1895, show that they are present for some distance at least.

When the boring already referred to was carried on at Udell, one hole was carried to a depth of 300 feet. It is reported that it ended in a bed of coal which, while exact measurements can not be given, was certainly thicker than the upper vein. If the correlations already suggested be true, this lower vein at Udell would belong to the horizon 150 feet below the Mystic coal, though at this place it is a few feet above its normal level.

In Putman county, Missouri, there are two seams of coal, one two feet four inches, and the other one foot six inches thick, which, according to Broadhead,* are stratigraphically 105 and 125 feet respectively below the Mystic coal. Whether these beds extend in workable condition under the latter seam can only be told by drilling.

So far but two bore holes have been carried through the Mystic coal down to the Saint Louis within the area under

*Geol. Surv. Mo., 1873-74, pp. 280-283. 1874.

consideration. Both of these were at Centerville. Of the former no complete record is at hand, though the lower portion has been admirably worked out by Norton.*

The drillers' notes for the second well down to the Saint Louis are as follows.

		FEET.
19.	Drift	90
18.	Rock	2
17.	Shale, variegated	18
16.	Rock	2—3
15.	Shale	8
14.	Rock	5
13.	Shale	75
12.	Rock, fossiliferous limestone	2
11.	Shale, black to variegated	30
10.	Shale, arenaceous	15
9.	Coal	1½
8.	Shale, arenaceous	74
7.	Rock	2
6.	Shale, variegated	170
5.	Shale, white	30
4.	Rock	34
3.	Shale, variegated, a few thin harder bands	44
2.	Shale, arenaceous	28
1.	Limestone	

This record is exceptional in that the upper portion does not show the normal succession of strata. It is merely inserted as of possible future value in connection with later drillings; no attempt can be made at its correlation. The only coal noted is at about 115 feet below the level of the Mystic bed and in that particular the record agrees with the other borings and sections mentioned. The beds spoken of above as "rock" are probably, in most cases at least, limestone. Pieces from several of the layers greatly resemble the limestone ledges outcropping in the vicinity.

In what has been said in regard to lower horizons, it must be bornê in mind that the lower coal horizons of the Des Moines formation are characteristically non-persistent; and that it is not to be expected that coal, if present, will be uniformly

*Iowa Geol. Surv., Vol. III, pp. 205-210. 1895.

distributed along any of them. The horizons indicated simply represent planes of greater probability, and the horizons 150, 300 and 425 feet below the coal now worked, are considered as most favorable. In any event there are between the Mystic coal and the Saint Louis from 500 to 600 feet of strata in which the prospects for finding coal are as good as in any unprospected territory in Polk or Boone counties.

PLEISTOCENE.

The Pleistocene beds of this region include representatives of the Kansan drift sheet, a loess-silt and certain small areas of alluvium. The entire thickness of these beds is not great except along lines of preglacial drainage. At many points the coal measures come to the surface and over large areas they are only thinly covered by drift. This is not true, however, of the region east of the Chariton, for here the surface is heavily drift covered. Indeed the divide between the Chariton and the waters of the Fox river and Soap creek is apparently very largely a drift divide. At Udell the drift is 150 feet thick. Near Moravia it is probably not much less, since the deep streamways in the immediate vicinity of the town show no exposures of the indurated rocks.

KANSAS DRIFT SHEET.

The heavy drift or till beds of the county may be referred to the Kansan age. They are excellently exposed at many points and may be studied in almost any ravine in the county. Fundamentally this drift sheet is here, as in regions farther north, a blue clay; but the upper portion is often yellow or even reddish-brown. Below, the drift is stiff and hard. Above it is more usually arenaceous, open and friable. It contains a considerable amount of local material and bits of wood and coal are not uncommon. In digging the shaft at the Anchor mine No. 2, the following section was passed through.

		FEET.
6.	Surface clay	20
5.	Sand	12

		FEET.
4.	Conglomerate	1
3.	Sand	4
2.	Blue clay	20
1.	Indurated rocks	

Numbers 2 to 5 inclusive may be referred to the Kansan drift. The blue clay here contained an unusual wealth of local material including wood, shales, limestone, pyrites and coal. No. 4, probably represents a locally indurated gravel bed.

The boulders of the drift are usually of small size. Large boulders are very infrequent. The rocks present are largely basic and show many planed and striated surfaces. They are badly weathered and may frequently be easily crushed. Along Shoal creek north of Cincinnati, and Manson branch near Centerville, large numbers have been segregated by steam action.

The upper surface of the drift, where it is covered by the loess-silt is marked by a zone of reddish-brown sandy material. It shows weathering action and the loose open character of soil. Where the drift is not covered by loess-like silt, this upper, weathered portion is usually blackened to a depth of six to eight inches.

LOESS-SILT.

The upper surface of the drift is topographically, almost parallel to the present surface. Over a considerable portion of the county it is the present surface. In other portions the drift is covered by a later deposit of loess-like silt which, in character and origin, seems much like the white clays of the Ohio valley, as described by Leverett.* The loess-silt forms a mere veneer over the drift surface. It may be examined in the various railway cuts, particularly those near Moravia already mentioned.

The deposit caps the hill upon which the public square at Centerville is located and may be seen on the high drift plain between Cooper and Shoal creeks. As seen at the former

*Amer. Geologist, X, 18-24. 1892.

point it shows particularly well its clay-like features, as contrasted with the more open porous nature of the loess proper. The loess-silt is not everywhere present. At many points the coal measures themselves form the surface rocks; at others the drift alone covers them. The loess-silt rests upon both coal measures and drift though more usually upon the latter.

ALLUVIUM.

Along the Chariton river and many of the minor streams, true alluvial deposits occur. The beds are characterized by a loose open texture, a normal sandy constitution, and a usual black color. They are usually of excellent agricultural capabilities except that certain portions of the broad flood plains need artificial drainage. In part the latter are subject to overflow.

DESCRIPTION OF PLATES.

PLATE XI.

Sections exposed along the Chariton river. The number under each exposure refers to a corresponding number in the text.

PLATE XII.

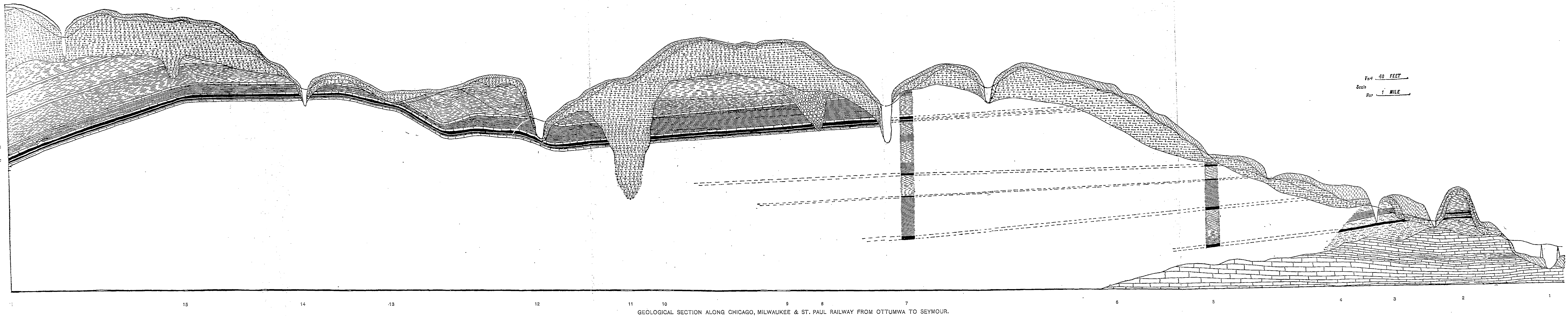
Map of the Scandinavian fault. Drawn from the mine map of Superintendent Claus Johnson. The shaded areas represent coal remaining. The land lines divide the area into forty acre tracts. The scale is about 150 feet per inch.

PLATE XIII.

Section across the Scandinavian fault. This section is based upon the exposures along the tunnel connecting the old and new workings. The vertical and horizontal scales are the same—twenty feet to the inch.

PLATE XIV.

Geological cross-section, Ottumwa to Seymour. The numbers at the bottom refer to localities as follows: (1) Des Moines river, Ottumwa; (2) exposure on Bear creek; (3) sandstone near Bidwell; (4) Bidwell; (5) Appanoose mine; (6)



GEOLOGICAL SECTION ALONG CHICAGO, MILWAUKEE & ST. PAUL RAILWAY FROM OTTUMWA TO SEYMOUR.

Blakesburg; (7) Deep Vein Mine at Foster; (8) Chariton conglomerate; (9) Moravia; (10) Preglacial valley; (11) Iowa Central crossing; (12) Chariton river at Darby; (13) Mystic; (14) Big Walnut creek; (15) Jerome; (16) Seymour. The formations are referred to by letters as follows: (a) Saint Louis limestone; (b) Mystic coal with cap and bottom rocks; (c) eighteen-foot rock; (d) fifty-foot rock; (e) floating rock; (f) Kansas drift; (g) loess-silt. The railway grade is represented by a continuous black line.

ECONOMIC PRODUCTS.

COAL.

COAL LANDS.

The whole of Appanoose county may be considered to be coal land since there is no portion of it which is not legitimate ground for prospecting. The area, however, which is already known to contain coal is somewhat less. The area underlain by the Mystic coal is, so far as now known, delimited upon the accompanying map. It includes in all 298 square miles, or 190,720 acres. The coal will average about two and one-half feet in thickness for the entire area, and upon the basis of 1,200 long tons per acre for each foot of thickness, should yield 3,600 short tons per acre.

Estimates made from the amount of royalty actually received show that near Cincinnati about 2,240 tons per acre is obtained in actual mining practice. The work upon which the estimates is based represents average room and pillar work as carried on in the region. According to these figures only 62 per cent of the coal is hoisted. The Pennsylvania Coal Waste Commission estimated* that in the anthracite region of that state the coal won since the opening of the mines has been not more than 35 per cent. The important differences in the thickness of the beds and the dip of the strata in the two regions, as well as many other circumstances, are favorable to the Iowa field.

*Rept. Coal Waste Comm., p. 148. Philadelphia, 1893.

Of the total area indicated as underlain by the Mystic coal, about 18,457 acres is owned or leased by mining companies or is held as coal land. This includes 16,510 acres held by mining companies and now under development, though of course not all of this area can be reached by the shafts now opened. The areas held by the local mines are in only a few instances included, since such leases are in many cases not recorded and hence are not accessible. The leases held by these companies are for small areas and the sum would not greatly increase the figures given above. In addition to the 16,510 acres now being developed 1,947 acres are held as coal lands and taxed as such. The remainder of the region is held as farm land only; although of course a considerable portion is owned by people who will eventually open it up for mining. According to these figures a little less than 10 per cent of the known coal land of the county is now taken up. A number of the companies own the land which they are developing. Others merely own the coal. Most of the mines are probably worked on leased ground. Where the coal alone is bought it costs about $10 per acre, with the option of prospecting. Coal land already prospected usually sells for about $15 per acre. Over the greater portion of the region it is not now customary to prospect with any thoroughness, if indeed any drilling at all be done. Where the land is leased the royalty is 4, 5, 5¼ or 6¼ cents per ton. Early leases were sometimes as high as 12½ cents. At 6¼ cents the royalty amounts to from $125 to $150 per acre, with an average probably of $140 with ordinary room and pillar workings. The amount obtained under long-wall working can not be stated.

CHARACTER OF MYSTIC COAL.

The Mystic coal is a non-caking, free-burning coal. It is of quite uniform texture, breaks in block form, and presents clean conchoidal surfaces. It is fragile and will not stand rough handling or long continued exposure.

The following analyses may be taken as fairly representative except in the matter of moisture. The samples were, unfortunately, unequally dried so that the moisture content should be neglected. As arranged these analyses show first the result as obtained from analyses; in the second column the analyses have been calculated on a dry basis; in the third they are calculated on a moisture basis of 7 per cent, which is about the average for Iowa coals. The analyses were made by Professor G. E. Patrick, chemist to the survey.

ANALYSES OF MYSTIC COAL.

Thistle Mine, Cincinnati.

	Analyzed.	Calculated to dry basis.	Calculated 7 per cent water basis.
Water	5.80	....	7.00
Volatile combustible (by difference)	37.71	40.03	37.23
Fixed carbon	53.00	56.26	52.32
Ash	3.49	3.71	3.45
Sulphur unoxidized	2.97	3 15	2.93
Sulphur in sulphates	.05	.05	.05

Diamond Mine, C. B. C. Co. No. 1

Water	10.12	....	7.00
Volatile combustible (by difference)	35.63	39.64	36.87
Fixed carbon	48.04	53.45	49.71
Ash	6.21	6.91	6.42
Sulphur unoxidized	2.20	2.45	2.28
Sulphur in sulphates	.07	.08	.07

The coal is in demand for domestic purposes over a wide territory. Large quantities go to the markets at Omaha, Sioux City and Sioux Falls, as well as numerous other points in Iowa, South Dakota and Nebraska. Some of the Iowa product is marketed in Missouri and Kansas, though that territory is largely supplied by the Missouri mines.

While used to a considerable extent for steaming purposes, the main portion of the coal must always be sold for household use. It has never been used for gas or coke except experimentally. At one time the Diamond Coal Co. of Centerville, now succeeded by the Centerville Block Coal Co., made some crude experiments to determine the coking value of the coal. The coal was burned in a surface heap and produced a rather light coke of good appearance but low strength. The experiment seemed to indicate that the lower bench was better than the upper. Near Confidence, in Wayne county, the same coal has been coked. Here, as at Centerville, the product was of low crushing strength. The coal is not a normal caking or coking coal. It does not melt and run together in burning; so that any coke made from it by ordinary burning would be of only moderate strength at most. It is possible that some of the newer ovens, by securing a deposition of the excess of volatile matter, might make a good grade of coke from the coal. If so, this seam would offer an excellent opportunity for the development of a coke industry since its purity and regularity guarantee a steady supply of coal having uniform coking value.

MINING METHODS.

There are three general plans of mine work in this region. The first is regular longwall, which is now used in some of the largest and best mines, and is being rapidly introduced throughout the region. The second is room and pillar, and the third is a modified form, developed in this region and for a time used largely in the smaller mines. It is known as semi-longwall.

In room and pillar work in this field, as carried on in most of the mines by hand labor, the cross-entries are driven 300 feet apart. The pillars along the main roadways are usually twenty-four feet thick. The entries are eight feet wide and taken from cap rock to bottom rock. The rooms are 150 feet long and forty to fifty feet wide. In the summer of 1895 the scale of prices was as follows.

Room work—	
Coal to October 1st (screened)	$ .70
After October 1st	.80

Narrow work—Summer—	
Yardage	$ 1.10
Lifting bottom and shooting down top	.90
Coal, per ton	.70
Narrow work—Winter—	
Yardage	1.20
Top and bottom	1.00
Coal	.80

There has been a change, and the prices paid are somewhat different. At the old price a yard of entry work in summer cost about $3.40, and in winter $3.80.

In working with machines, as carried on in three of the mines of the Centerville Block Coal Co., the entries are driven ten feet wide and the cross-entries are run at distances of 400 feet. The machines in use are the Legg and the Harrison. They are used mainly in driving entries and turning rooms. But little room work proper is done by them. Compressed air, at eighty pounds, delivered from a Norwalk compressor, is used. In entry driving and turning rooms the Legg machine does the under-cutting, and is followed by a Harrison, which cuts the corners. The coal is then wedged down.

The Legg machines have a three and one-half foot bar, and are supposed to make a five-foot cut. They average, in actual work, four feet eight inches. Three cuts are made to an entry, each taking about ten minutes. The under-cut is five and one-half inches high. Two men are employed at each machine. As quick as the under-cutting is done at one point the Legg machine moves on to the next and is followed by a Harrison, which cuts out the corners. The Harrison machine requires two men, a runner at $2.30 per day and a helper at $1.60. Each machine is expected to cut sixteen corners, the equivalent of eighty entry cuts per day, which would make the cost of each forty-eight cents. Very frequently, however, as many as twenty-one cuts are made, and this reduces the average cost to about the figures given below. Measurements of cuts made in actual work show lengths of 52, 52½, 61 inches each. In shearing, a cut about four inches wide is made.

One cut, or "rib," furnishes about three tons of coal and three cars of dirt. The dirt is hoisted and dumped in narrow work, but in room work is usually gobbed. In narrow work the two machines will make eight to ten entry cuts per day of ten hours, and keep from four to six followers busy. In wide work, where there are twelve under-cuts to a room, they make about thirty cuts per day and keep eight to ten men busy. A four-foot eight-inch cut on a ten-foot entry, ready for track, costs about as follows.

Under-cut	$ .24
Shearing	.37
Coal, three tons, at thirty-four cents	1.02
Brushing top	.84
Total	$2.47

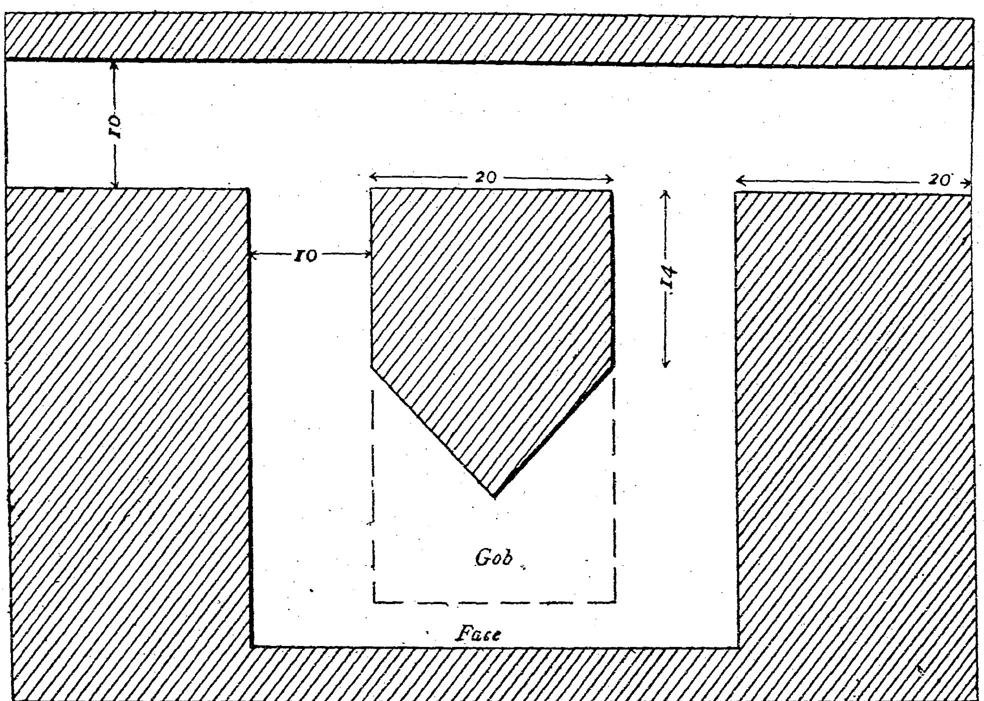


FIG. 66. Room and pillar work in Mystic coal.

In comparing these figures with hand labor it must be remembered that a machine cut is forty-eight, and a hand cut thirty-six inches. On the other hand the machine must bear the cost of repairs, depreciation, interest, etc.

In turning rooms two ten-foot doors are driven in fourteen feet, and then opened out as shown in the diagram above.

After the doorway has been cut in this distance, the room is turned over to the miners, who drive it forward by undercutting, shearing and wedging, till the room from the opposite cross-entry is met. The rooms are then left till that portion of the mine is about to be abandoned, when the pillars are pulled. By that time, usually two years or more, much of the coal is not worth saving.

In mine No. 19 of the Whitebreast Fuel Co., located at Forbush, a number of different machines were formerly used in working the coal. As they were mainly used in entry driving, a change to longwall work made them unnecessary. Two Stanley headers were used most. These machines cut out by bits a five-inch line around a circle five feet in diameter and bore a two-inch hole in the center; resembling in effect an immense auger. The machine moves forward about two feet, when a light charge of powder is used to bring down the coal. The machine is mounted on rails and driven by air at sixty pounds pressure. Three men are employed at each machine; a runner, and front and rear loaders. It makes in the Mystic coal an average of about ten feet a day, though as high as fiteen feet have been made. Detailed estimates of cost are not at hand, but the superintendent of the mine expressed himself as well satisfied with the results attained. In the same mine the Mitchell machine was at one time used to some extent.

In the semi-longwall work no machines are used, and the method is itself being gradually superseded by regular longwall. As seen in the Lodwick brothers' mine, the former work is about as follows. The usual cross-entries are driven at suitable distances along the main entry. The rooms are turned as usual with the exception that no pillar is left between adjoining rooms. As a result the work opens up as shown in figure 67.

As the work moves forward each man mines forty feet of face with his roadway in the center. He builds his own pack walls and sets the timbers. The coal is cut under one and one-half to two feet and held up temporarily by sprags. No powder is used, as the weight brings the coal down as fast as it can be used.

The large number of mines in the district which have changed or are changing to longwall workings makes the

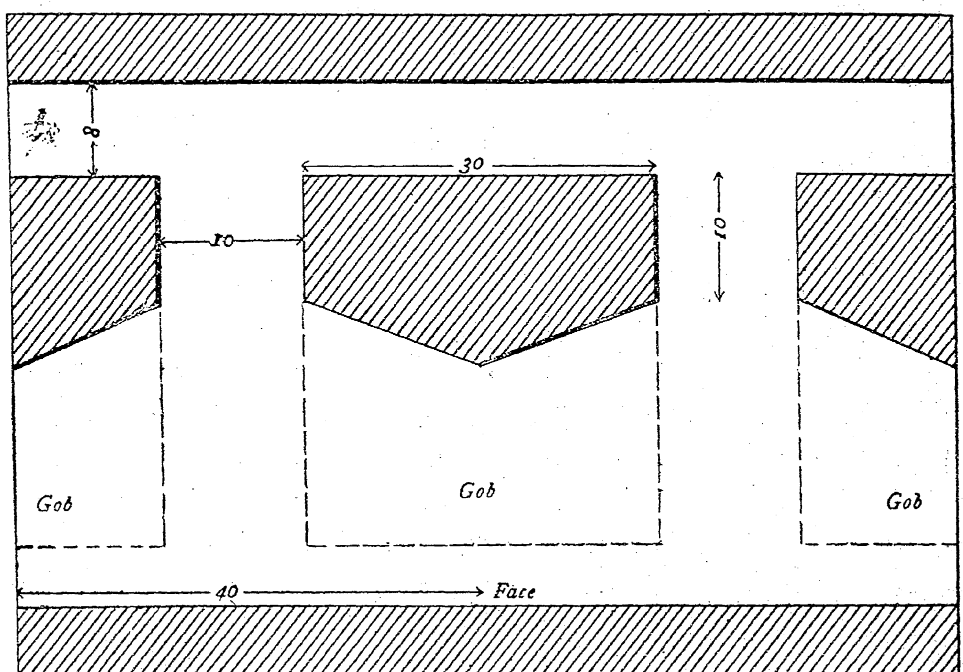


FIG. 67. Semi-longwall workings in Mystic coal.

success of a longwall machine a matter of some importance. The Peerless Coal Co. have been for some time experimenting on such a machine, but as the patents have not yet been allowed any description would be premature.

MINES.

The Appanoose county mines are scattered throughout the southwestern half of the county. They are located on the accompanying map by numbers corresponding to the following descriptions. No attempt has been made to locate all of the local banks, though it is believed that most of them appear on the map. The ease with which coal is obtained, and the small capital necessary for opening such a mine, make the number of country mines exceptionally large.

These properties, however, change hands so frequently and are worked so intermittently, that an exact list is impossible.

CENTERVILLE BLOCK COAL CO.

This company was organized in 1894 by the consolidation of several previously independent companies. Other mines have been leased and a new one opened, until now the company has nine mines of its own, and in addition operates the National.

Number 1 was formerly known as the Diamond No. 1. It is just east of Centerville on the Chicago, Rock Island & Pacific railroad and has also a switch from the Keokuk & Western. The coal lies at a depth of 138 feet and measures as follows in a representative section.

		FEET.	INCHES.
6.	Cap rock limestone	2	6
5.	Clod	1	
4.	Slate		8
3.	Clay		2
2.	Coal, including "the Dutchman"		12
1.	Fire clay		

This mine is particularly well equipped. The plant includes a tail rope system, the usual hoisting plant, and a compressed air plant with a Norwalk 24–20 compressor. In the mine three Harrison and four Legg machines are in use. The machines are used principally on narrow work. The coal lies level except toward the north where a rather heavy dip, presumably local, has been encountered.

Number 2 is located at Numa just west of town. It is a shaft 140 feet deep and was formerly the property of the Diamond Coal Co.

Number 3 was formerly known as the Relay mine and belonged to the Centerville Coal Co. It is a shaft 107 feet deep sunk in the valley of Cooper creek between the Iowa Central and the Keokuk & Western railroads. The company loads on both tracks. The equipment is good. Legg and Harrison machines are used as in No. 1. It was near this mine that the old workings at Talbot's Mill, mentioned by

White, were located. At one time these workings were broken into by the Relay entries. In the Relay mine has been encountered one of the heaviest dips found in the field. In a distance of 1,944 feet the coal rose thirty-six feet.

Number 4 is located at Brazil, opposite the Phœnix. It was formerly known as the Philby mine and is a slope, worked on the semi-longwall plan.

Number 5 was originally known as the Hawkeye mine. Later it passed into the hands of the Walnut Block Coal Co., and eventually came into the possession of the present company. It is a slope on the east side of the K. & W. at Brazil, and lies betwen the Phœnix and the Tipton.

FIG. 68. Mine No. 9, Centerville Block Coal Co. Taken from the rear and showing boiler house, tipple, engine room, etc.

Number 6 was formerly known as the Silknetter mine. It is on the east side of the K. & W., north of the Phœnix.

Number 7 is a slope mine at the K. & W. crossing, north of Brazil. Coal is loaded on the Keokuk & Western railroad. The mine was at one time known as the Enterprise mine, and later as Walnut Block No. 3.

Number 8 (61) is a small mine just south of Number 3. It was formerly known as the Richardson and the Ulrich mine. The shaft is sixty-eight feet deep, starting well down in the valley of a tributary of Manson branch. The fifty-foot rock is exposed in the creek near the mine, and the cap rock, while absent at the shaft, comes in a short distance away.

The coal is hoisted by horse power gin. The mine is now operated by the City Coal Co. on a lease from the Centerville Block Co.

Number 9 is a new mine opened north of Number 3. It is on the Iowa Central railway down in the valley of Cooper creek. The shaft is seventy-two feet deep, the upper twenty-two feet being drift. At the bottom a measured section showed.

	FEET.	INCHES.
11. Cap rock	1	6
10. Clod		7
9. Slate		7
8. Coal	1	6
7. Clay		2
6. Coal		12½
5. Clay and pyrite; the "Dutchman"		1
4. Coal		1½
3. Fire clay	1	2
2. Bottom rock		10
1. Shale, soft, sandy		

Farther in the mine the bottom rock is thicker. The fire clay is usually also thicker though in the first south of the west side, it is, at one point, barely a foot thick. Near the air shaft the clod disappears, and the slate is only about eight inches thick. The cap rock is more argillaceous and air-slacks some. The thickness of the coal varies slightly as shown by the following measurements, being taken at various points in the mine.

I.

	FEET.	INCHES.
3. Coal	1	6
2. Clay		1–2
1. Coal; to "Dutchman"	1	2

II.

	FEET.	INCHES.
3. Coal	1	7
2. Clay		2
1. Coal; to "Dutchman"	1	

III.

	FEET.	INCHES.
3. Coal	1	5
2. Clay		2
1. Coal; to "Dutchman"	1	3

IV.

		FEET.	INCHES.
5.	Clod		9
4.	Slate	1	
3.	Coal	1	6
2.	Clay		2
1.	Coal; to "Dutchman"	1	

A short distance from where the last measurement was taken the clod disappears and the slate is only ten inches thick. Faults of great extent have so far not been encountered. A few minor slips do however occur. In one case a thicker bit of "black bat" has been pushed down into the coal. The mine is well arranged and equipped for hoisting a large output. Legg and Harrison machines are in use in driving entries and turning rooms. The shaft is larger than is common in this field, being 7 by 14 instead of 6 by 12, the usual size.

(13) NATIONAL FUEL CO.

The National mine is one of the older mines of the district and was formerly known as the Watson. It is now operated by the Centerville Block Coal Co. The shaft is 147 feet deep and is located on the C., R. I. & P. railway a short distance south of the station. The mine is well equipped with new topworks replacing those burned in 1892. The coal is regular and of the usual thickness. In working north and west a fault was encountered which cut off the coal.

(12) STANDARD COAL CO.

The Standard mine is located in the southeast quarter of Centerville. The coal averages about thirty to thirty-two inches clean, and lies 135 feet below the surface. The cap rock and other overlying beds are found in place. The coal is brought to the foot of the shaft by a tail rope operated from the surface. The hoisting plant is of the usual character. The company loads upon both the C., R. I. & P. and K. & W. railways.

(11) RAVEN COAL CO.

The Raven mine is a new shaft, located a mile east of Centerville, on the C., R. I. & P. railroad. In sinking the shaft rather more than the usual thickness of drift was encountered, ninety feet being found in the main shaft. The first shaft was sunk a short distance east of the present location, but was abandoned at a depth of seventy-two feet because of the water which came from a sand layer in the drift. The coal lies at a depth of 150 feet. The regular sequence of strata is present in normal thickness, with the exception of the cap rock, which is, at the shaft, only one foot thick. The bottom rock is also thinner than usual, and below it is found sandstone.

ANCHOR COAL CO.

The Anchor Coal Co. operates two mines, No. 1 (9) being located in the southwest quarter of Centerville, on the K. & W. railway, and No. 2 (10) being two and a half miles south on

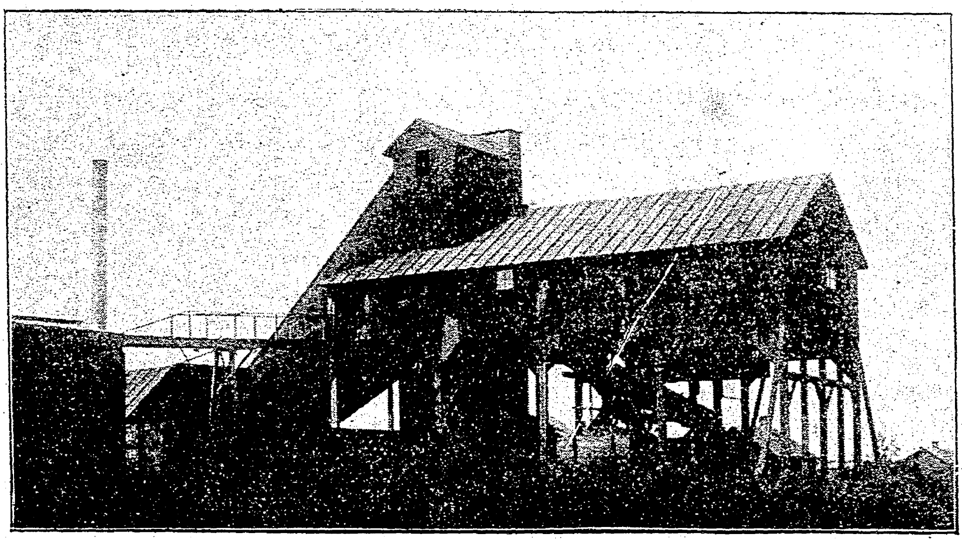


FIG. 69. Eldon mine No. 2, the usual type of top works seen in the region.

the C., R. I. & P. (Tp. 68 N., R. XVIII W., Sec. 13, Ne. qr., Nw. ¼). No. 1 is in the valley of Manson branch and reaches the coal at seventy feet. No. 2 is on the open plain, lying southwest of Centerville, the coal being found at 155 feet. The coal in each is of the usual character, and no faults of especial importance have so far been encountered. The section of the drift as found in sinking No. 2 has already been given.

(45) ELDON COAL CO.

The Eldon Coal Co. of Ottumwa has two mines; No. 1 is in Davis county, near Laddsdale, and No. 2 is in Appanoose, about three miles southwest of Centerville, on the C., R. I. & P. railroad. The latter mine is located on the high prairie, and reaches the coal at 145 feet. The drift extends in the air shaft down to the fifty-foot rock, which was struck at a depth of ninety feet. The little rock is twenty feet above the coal, and is only one and one-half feet thick. The coal has a slight general dip to the west.

(14) SCANDINAVIAN COAL CO.

The Scandinavian mine is located in the southwestern portion of Centerville, on the K. &. W. railroad. The mine has been operated under different names for about fourteen years, and in that time about 120 acres have been exhausted. The coal lies 100 feet below the K. & W. track, with the usual limestone rocks above. In the creek bed, near the mine, the fifty-foot rock and some of the underlying shales are exposed. The coal within the mine does not vary greatly, except in the vicinity of the fault which has been already described.

LOCAL COAL CO.

The Local Coal Co. is composed of representatives of the separate companies which mine coal for the local market at Centerville. It is not a mining company, but sells the output of the individual mines. The companies represented in it are the Monitor, Rock Valley, Star, Scandinavian, North Hill, Happy, and City.

(56) MONITOR COAL CO

The Monitor mine is a gin shaft, located within the town limits, a short distance northeast of the postoffice. The company has only a small lease, less than five acres, and hoists coal for the local trade. The coal runs level and lies at a depth of 140 feet, the mouth of the shaft being but little below the general level of the plateau upon which that portion of the city is built. The shaft is the usual size, having two hoisting compartments, which measure 4x4 in the clear.

(57) HAPPY COAL CO.

The Happy mine is a small shaft worked for the local trade. The lease includes twenty acres surrouded on three sides by the Scandinavian land, and on the west joining that of the Anchor No. 1. The shaft is 106 feet deep to the bottom of the coal. The workings have been cut through to connect with those of the Scandinavian.

(58) NORTH HILL COAL CO.

The mine operated by the North Hill Coal Co. is a shaft opened in 1893, and at one time was known as the Frisby mine. It is located in the northwestern quarter of Centerville. The lease covers six and three-fourths acres, and the coal is reached at 120 feet, starting some distance below the level of the public square. The coal near the bottom of the shaft measures as follows:

	FEET.	INCHES.
9. Cap rock		
8. Clod		4
7. Slate		8
6. Coal	1	8
5. Clay		2
4. Coal		11
3. Clay		½
2. Coal		1½
1. Fire clay		

The middle clay parting (No. 5) is at one place barely a half inch thick, but a short distance down the entry it has its normal thickness. The coal is hoisted by gin and goes to the local market.

(59) ROCK VALLEY COAL CO.

The Rock Valley mine is a gin shaft eighty feet deep. The shaft is a little larger than usual in local mines. It is divided into three compartments measuring in the clear 5′x4′ 8″, 5′x4′ 8″ and 5′x2′ 4″. The smaller compartment is used as an air shaft. The company operates on a lease of thirty-three acres and the coal runs from 28 to 32 inches in thickness. The mouth of the shaft is located on the hillside. In the bed of the ravine near by the fifty-foot limestone is well exposed. The strata penetrated in sinking the shaft were as follows.

		FEET.	INCHES.
11.	Drift	20	
10.	Fifty-foot limestone	10	
9.	Shale, in part blue argillaceous, and in part sandy	28	
8.	Seventeen-foot limestone	4	
7.	Black argillaceous shale	10	
6.	Cap rock, gray, argillaceous limestone	4	
5.	Clod and slate	1	3
4.	Coal	1	6
3.	Clay		2
2.	Coal, including the "Dutchman"	1	
1.	Fire clay		

It will be noticed that the seventeen-foot rock is quite well developed and lies eighteen feet above the coal. Both the fifty-foot and the cap rocks are fossiliferous. The coal lies level and is free from faults.

(60) STAR COAL CO.

The Star mine is just inside the east city line of Centerville. It is a gin shaft, hoisting coal for the city trade. The coal land consists of a small tract of less than five acres. The coal is reached at a depth of seventy-four feet and is about thirty-two inches thick. The normal succession of strata occurs.

WALNUT BLOCK COAL ASSOCIATION.

This association was formed in 1895 by the various mines in Appanoose county loading on the C., M. & St. P. railway. It is not a mining company, but controls the output of all but three of the mines. The general offices of the association are located at Mystic. The mines represented are as follows: The Superior Block Coal Co., the Darby Block Coal Co. and the American Coal Co. of Darby; the Star Coal Co. at Rathbun; Clark & Sons, Orr Bros., the Iowa Block Coal Co., the Lodwick Brothers, the Iowa and Missouri Coal Co., the Peerless Coal Co., C. L. Arnot, Brown & Bowers, the Mystic Fuel Co., the Lone Star Coal Co., the Walnut Creek Coal Co., the

Herl Coal Co., the Columbia Coal Co. and the Hazelton Coal Co. of Mystic; with the Gladstone Coal Co. and the Big Four Coal Co. at Jerome. The Carlton Coal Co., west of Mystic, while independent, sells some coal through the association. The Twin Coal Mining Co. and the Co-operative Coal Co. are the only ones who market their own output.

(16) THE SUPERIOR BLOCK COAL CO.

The Superior Block slopes are at present the extreme easterly mines of the group working along Walnut creek. The coal lies near the surface and is reached by two slopes, loading on the C., M. & St. P. railway.

(17) THE DARBY BLOCK COAL CO.

The Darby mine is a shaft fifty feet deep located at Darby, south and west of the Superior Block. The coal is loaded on the C., M. & St. P. railway.

(18) AMERICAN COAL CO.

The mine operated by the American Coal Co. was opened by the Evans Coal Co., and is known as the Evans mine. It is a shallow shaft mine, having a switch from the C., M. & St. P. railway, and lying to the north of the track, about half way between Darby and Rathbun. The coal is hoisted by a horse-power gin, and the bed is of the usual thickness. The cap rock and the little rock may be seen in the air shaft.

(19) STAR COAL CO.

The Star Coal Co. of Streator, Ill., operate the mine located at Rathbun. The shaft is eighty-two feet deep, and the coal is worked on the longwall plan.

(20) CLARK & SON.

Clark & Son operate a mine at a place called Clarksdale lying about two miles east of Mystic, on the C., M. & St. P. railway. The coal is reached at a depth of seventy feet. It is hoisted by a horse-power gin. Near the mine are good exposures of limestone along the railway track.

ORR BROTHERS.

Orr Brothers operate two mines. Number 1 (26) is a small slope lying on the south side of Walnut creek at Mystic, and loading on the Turkey river switch. Only a small tract of about fifteen acres is controlled here and the area is almost entirely mined out. Number 2 (21) is a shaft mine immediately west of Clarksdale and lying on the north side of the

FIG. 70. Floating rock near Clarksdale.

railway track. A large tract of land is under lease at this point. The coal is reached at seventy feet.

(22) THE IOWA BLOCK COAL CO.

The Iowa Block Coal Co. has a good territory under development on the south side of the railway west of Orrs' mine and east of Mystic. The coal is reached by a double track slope timbered with 8 by 8 timber and divided into two compartments each five and one-half feet wide at the top.

The double track continues into the mine about 500 feet. The coal is brought out by an endless rope driven by an Ottumwa engine. As a rule three cars are brought out in a trip, being attached by means of a Leavenworth grip. No conductor is required and a trip comes out in about three minutes. The cars are carried on a trestle over the creek to the tipple, where the coal is loaded on a switch from the main line of the Chicago, Milwaukee & St. Paul railway.

(23) LODWICK BROTHERS.

The Lodwick Brothers Coal & Mining Co. operate two slopes in the eastern edge of Mystic, loading on the reservoir switch. Coal is taken from both the east and the west side of the ravine. Recently a very carefully driven slope had been opened on the east side and it is proposed to connect both mines with this and load all the coal from one tipple. The slope is six feet high, ten feet wide at the top and twelve feet at the bottom, measured in the clear. At the mouth it is timbered for thirty yards with 8 by 8 stuff backed with two inch lumber. The next sixty yards merely requires a row of props in the middle, while beyond that, there is no timber of any kind. The slope is driven due north and carries two tracks. The cost was about $7 per yard for the first thirty yards, $3.75 for the following sixty, and $3.50 for the remainder.

The slope is an excellent piece of work and can be used to handle a very large output. Ultimately steam haulage will be put in. The coal is mined by the modified longwall plan. A face is being driven to the east from the main entry.

In working this mine a preglacial channel, now filled with drift, has been encountered and traced some distance in a northeasterly direction. It seems probable that it is the same that was encountered in working the old Sandbar mine toward the northwest. If so the channel would be about 1,200 feet wide. In certain parts of the mine the drift has been encountered where it does not cut down into the coal.

(46) IOWA & MISSOURI COAL CO.

The Iowa & Missouri Coal Co. operate a large slope mine immediately east of the Mystic railway station. The main entry is driven north. The slope is single track and the coal is brought out by a tail rope.

(25) C. L. ARNOT.

Starting southeast from the depot and running along the east side of Walnut creek is what is known as the Turkey river switch of the C., M. & St. P. railway. There are three mines, loading on this track. The first, from the depot, is the Orr slope already described, the second is the Arnot mine, and the third the Peerless. The Arnot mine is a small slope working about seventy acres on the modified longwall plan.

(26) PEERLESS COAL CO.

The Peerless Coal Co. is at present operating only one mine, though other land is held by the company. The mine from which they now load coal is the farthest east of those on Turkey river switch. West of it and near the Arnot mine is a second slope from which coal was formerly loaded. The output of this latter mine is now handled through the eastern slope. The Peerless mine was originally opened as the Henrietta and passed through several hands before being purchased by the present owners. The mouth of the slope has been recently retimbered, and a neat brick engine room has been built. The coal lies nearly level, the dip, which is northward, being four and one-half inches to the hundred feet. The mine is worked on the longwall plan by machinery. The machine in use was invented by Messrs. Lee, the proprietors, and has proven quite efficient. It is driven by a Thompson-Houston dynamo. For the present, mule haulage alone is used in the mine. A box car loader of a new pattern is under development.

(29) CO-OPERATIVE COAL CO.

Running west from near Mystic depot is a track known as the Catfish switch. There are three mines loading on this track. The first is now known as the Co-operative and was formerly worked by the Peerless Co. It is a slope mine, on the north side of the track.

(28) BROWN & BOWERS.

The Brown & Bowers mine is a small slope, nearly opposite the Co-operative, and like it loading on the Catfish switch. West of the Brown & Bowers is a tract of undeveloped land held by the Peerless Co.

(29) MYSTIC FUEL CO.

The Mystic Fuel Co. controls a considerable area lying at the end of the Catfish switch. They load by means of a tramway running from the slopes down to the tipple on the railway track. This company now has the property formerly held by the Blackrod Coal Co.

(27) LONE STAR COAL CO.

The Lone Star mine is almost directly opposite the depot at Mystic. The coal is brought out through a drift on the south side of Walnut creek and carried over the creek on a

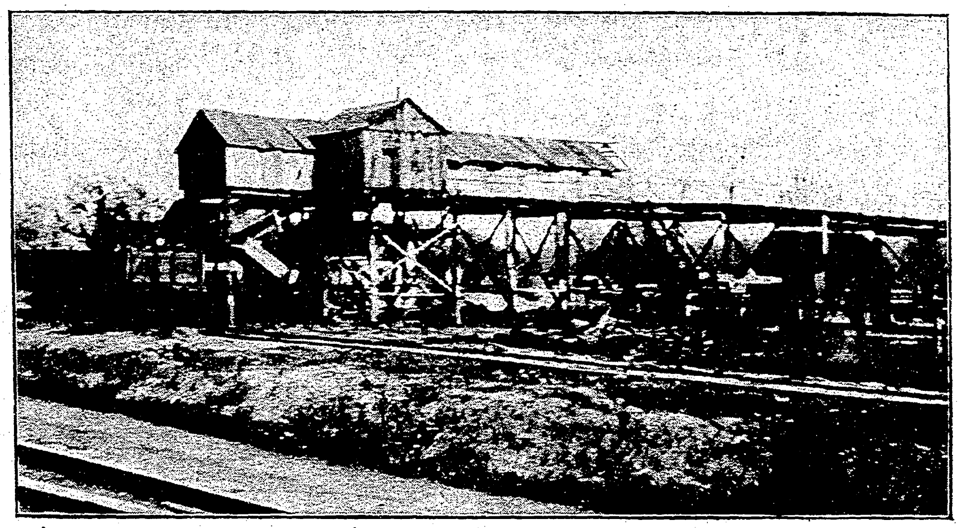


FIG. 71. Tipple at the Lone Star mine; representative of the smaller mines.

trestle to the tipple. A section of the coal as exposed near here has been already given.

(31) WALNUT CREEK COAL CO.

The Walnut Creek Coal Co. has recently obtained, and now operates, the Stormfeldt & De France mine. It is a slope, located on the south side of the C., M. & St. P. railway, about half way between Mystic and the K. & W. crossing.

(32) TWIN COAL MINING CO.

The Twin Coal Mining Co. operate what are known as the Twin mines, and which formerly belonged to the Peerless Coal Co. The mines are two shafts sunk a short distance apart and having underground connection. They have a switch from the C., M. & St. P. railway and are located near the K. & W. crossing. The coal is reached at a depth of forty feet.

(33) HERL COAL CO.

The Herl Coal mine is a shaft thirty feet deep lying just west of the Twin mines and formerly known as the Peerless No. 4. It loads on the C., M. & St. P. railway.

(34) CARLTON COAL CO.

The Carlton mine is a shaft fifty feet deep lying on the north side of the C., M. & St. P. railway, about a mile west of the K. & W. crossing. It is sometimes called the Diamond mine. For some time electric mining machines were used here. The mine is now operated by the Tipton Coal Co. and is on the same land that is worked by their mine Number 2.

(35) COLUMBIA COAL CO.

The Columbia mine is a slope on the south side of the railway track a short distance southwest of the Carlton mine.

(36) HAZLETON COAL CO.

The Hazelton mine is on the south side of the track about a mile west of the Columbia mine. The coal is reached by a slope as well as by a shaft seventy feet deep.

GLADSTONE COAL CO.

The Gladstone Coal Co. operate two mines, Number 1 (38) lying east of Jerome and Number 2 (39) west. The former is 100 feet deep. In sinking it the upper limestones were not found in the regular shaft, though present in the air shaft. Their absence in the one case is probably due to preglacial erosion. Mine Number 2, west of town, was sunk in 1893 and is a well equipped shaft mine.

(37) BIG FOUR COAL CO.

The Big Four mine is at the eastern edge of Jerome, and is a shaft 125 feet deep. It loads on the C., M. & St. P. railway from the north side of the track.

TIPTON COAL CO.

The Tipton Coal Co. operates two mines at Brazil. No. 1 (40) is a drift located on the east side of the K. & W. railway, immediately south of the Centerville Block No. 5. It has been open for some years. No. 2 (41) is a slope located at the crossing of the K. & W. and the C., M. & St. P. railways, and was opened up by the Philips Fuel Co. of Ottumwa.

(42) BRAZIL COAL CO.

The Brazil mine is a slope lying west of the K. & W. railway. It has been open for a number of years and has passed under a number of different names. The territory belonging to the company is itself limited, but they have a lease of eighty acres from the Centerville Block Coal Co.

(43) PHŒNIX COAL CO.

The Phœnix is one of the older mines, located at Brazil. It is a drift, and lies between the Centerville Block mines 5 and 6. The company has recently leased additional land, so that the available territory is sufficient for some time to come.

(44) LANE COAL CO.

The mine of the Lane Coal Co. is located on the K. & W., at a place called Laneville, between Brazil and Centerville. It is a shaft mine and reaches the coal at a depth of seventy-five feet. Robert Campbell (62) and E. Stern (63) operate small mines for the local trade at Brazil.

(76) COAL VALLEY COAL CO.

At Numa, in addition to the Centerville Block Co.'s mine No. 2, is the shaft of the Coal Valley Coal Co. This mine is located south of town and sells largely to the local trade.

(49) APPANOOSE COAL CO.

At Cincinnati, in the southern part of the county, and on the C., B. & K. C. railway, there are a number of mines. In the eastern portion of the town is the Appanoose mine. The shaft is 180 feet deep, and the coal shows the normal thickness.

(47) THISTLE COAL CO.

The Thistle mine is east of Cincinnati, beyond the Appanoose shaft and on the north side of the railway. The shaft is 110 feet deep, and the coal is of the usual thickness. No faults of any economic import have been encountered, but a number of small slips of scientific interest occur in the mine.

(48) MERCHANTS COAL CO.

The Merchants, or, as it is locally known, the Hyatt shaft, lies south of the Thistle, and has an outlet over a spur from the C., B. & K. C. railway. The mine is a new one, opened in 1893, and is well equipped.

(50) ALBERT COAL CO.

The Albert shaft is south of Cincinnati and on the west side of the railroad. A section of the strata at the shaft has already been given.

(51) STREATOR BLOCK COAL CO.

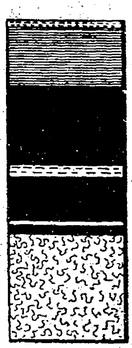
The Streator mine lies south of the Albert, and the shaft is on the east side of the track. At this point it is eighty-six feet to the coal, the mouth of the shaft being thirteen feet above the track.

(52) CINCINNATI COAL CO.

The Cincinnati mine is a shaft sixty feet deep lying in the northern portion of the town. It, with the Kansas City (53) and Hocking Valley (75) mines south of town, is worked mainly for local trade, though some coal is wagoned to the cars and shipped by each.

(74) PEARL CITY COAL CO.

The Pearl City mine is located very near the state line. It is a small shaft about twenty feet deep and shows the following strata as measured by Mr. A. C. Spencer.



		FEET.	INCHES.
8.	Shale, drab, clayey (exposed)		2
7.	Shale, black, highly bituminous	1	2
6.	Coal	1	6
5.	Clay parting		3
4.	Coal		10
3.	Clay parting		1
2.	Coal		2
1.	Fire clay (exposed)	2	

FIG. 72. Coal bed in Pearl City mine. Four miles south of Cincinnati.

(54) ROYAL COAL CO.

Near Exline there are two mines in operation. The larger is the Royal, located about two miles east of the station and loading coal on to the C., B. & K. C. railway. The mine is a drift and the coal is brought to the railway, by means of a tail rope. The second mine is the White Oak (55), a small shaft worked almost exclusively for the local trade, and located about three-fourths of a mile northwest of the station.

(15) WHITEBREAST FUEL CO. MINE 19.

The Whitebreast Fuel Co. own a large tract of land north of Centerville. Their mine No. 19 is located upon this land about four miles from the town mentioned, at a place called Forbush. The mine is large and well equipped and ships over the Iowa Central railway. Many details of the work at this place have already been given.

LOCAL MINES.

In addition to the mines listed above there are several important local plants. Near Hilltown in the southeastern part of the county mining is quite extensively carried on for the country trade. The principal openings are the two Dickson mines (70), the Heim (71), and the Troublesome or Thompson mine (72). At Livingston in the southwestern part of the county the Parker mine (65), a shaft 110 feet deep, has been operated for some years. Northwest of Jerome is the Houser mine (64), near Plano is the Knight (77), and near Milledgeville are quite a number. Among the latter are the Fenton (66), Gurnsey (68), Mosby (69), and Young (67) mines. Northeast of Forbush there is a group of small mines along the Chariton, among which may be mentioned the Stevens (75) drift.

CLAYS.

There are two series of clays within the county which may be used in the manufacture of brick and other clay products. The first is the loess-silt and the second includes the shales of the coal measures.

The loess-silt is well adapted to manufacturing purposes. It is homogeneous, plastic, widely distributed, easily mixed and burns to a good color. In many important particulars it is resembled by the alluvium, though the loess-silt is usually a heavier clay. The alluvium itself is easily worked up into hand made brick, but is not at present used within the county.

The coal measure shales and fire clays are found throughout the county. They are readily obtained and adapted to a wide variety of treatment. Pavers, building brick, face brick and tile are among the products which may be made from these shales. Within the county the shales are interbedded with limestones and frequently contain a large lime content which greatly decreases their value. Where, as is usual, the lime occurs as separate nodules, it may be readily separated from the clay. Important beds may be found which are almost entirely free from lime.

In working the coal seams it is necessary to move a large amount of the underlying fire clay. This material is usually hoisted and dumped. It is quite probable that it could, to a large extent at least, be utilized. Mr. B. Parker, at Livingston, at one time experimented with the clay and found that it shrinks badly in burning. This could be remedied by proper admixture with the loess-silt or by changing the method of treatment. There is a good opening in the region for a combined brick plant and coal mine, and such plants will probably at no distant day, form an important industrial feature throughout the region.

Of the plants now in operation only one utilizes the coal measures shales. The remainder depend upon the loess-silt.

CENTERVILLE.

The Centerville Brick and Tile Co. have a plant in the southwestern portion of the city, located on the K. & W. railway. The brick works are on the territory worked by the Scandinavian mine, and a figure of the pit, showing the disturbed condition of the shales has already been given (see figure 65). The pit is located south of the Scandinavian shaft. The shale comes from above the fifty-foot limestone, and twenty or more feet of gray to greenish shale is exposed. The upper portion is weathered some and should be mixed with the loess.

Over the shale is about four to twelve feet of boulder clay, which must be stripped off. Formerly the loess-silt was used, being obtained nearer the kilns, but now the shale is taken alone. A combination of the two would probably be advantageous.

The clay is hauled by tail-rope from the pit to the plant, a distance of about 150 yards. It is run through a Frost dry-pan and a Fate and Freese Ohio machine. The product is in part dried in the open air and in part upon a furnace-heated floor. Three up draft kilns and one permanent open kiln are used in burning. It requires usually from five to seven days for the burning. Building brick and sidewalk blocks are made.

E. Ramsey has been making brick by hand in the northwestern part of Centerville for some years. The loess-silt from the crest of an upland ridge is used. The brick command a ready sale.

LIVINGSTON.

Brick have been made at Livingston by B. Parker, and later by Chivare and Lomberger, since 1880. The surface soil is used, being made up by hand and burned in a down draft kiln.

UNIONVILLE.

At Unionville there are two brickyards, both turning out a hand-made product, which is derived from the loess-silt and burned in cased kilns. The Miller & Calkins yard is about three-quarters of a mile west of town, and the Knight Brothers is nearly two miles northwest.

BUILDING STONES.

The limestones of the Appanoose beds furnish excellent material for the rougher grades of masonry. At many places along the streams of the area underlain by these beds are ledges which may be readily quarried. Near the Scandinavian mine, at Centerville, the fifty-foot rock is quarried. Near Milledgeville, Messrs. D. S. Fenton, R. I. Prenty, and N. J. Elam each operate small quarries to supply the local trade. The ledges occurring are nowhere of sufficient thickness to warrant the investment of capital in any extensive quarry enterprise. The rock is of good quality and stands the weather well. In the foundation of Mr. Elam's house, stone cut in 1866 shows the tool marks quite distinctly. The quality of rock available at any one quarry site is entirely too limited, however, to make the industry profitable.

The rock has been burned for lime at a few points and yields a good material; but the same factors which prevent the growth of a large quarry industry will be equally potent in discouraging any attempts towards lime burning on a large scale.

The Chariton conglomerate has been quarried a little on the farm of Mr. Wm. Duval, near Moravia, as also near Hilton, in Monroe county. The stone does well enough for rougher foundation work, though it is not usually as good as the limestone of the Appanoose beds. It is easily obtained and occurs in thick ledges, but will never support a large quarry industry.

WATER SUPPLIES.

The drainage system of Appanoose county is quite well developed. The streams have pushed out their lateral branches till the whole area is, as compared with regions in the northern portion of the state, covered with a network of waterways. These creeks and rivulets afford a generous supply of water for ordinary farm and stock purposes. Springs are rare, as is common in drift covered regions. The drift is made up of unconsolidated beds of boulder clays, sands and gravels. The latter are irregularly distributed in small patches, which form natural basins for the reception and storage of water. The larger number of wells throughout the county derive their water supply from these drift basins. The water is almost always of good quality and of sufficient quantity to meet ordinary demands.

At Centerville, water for the city supply is obtained from a deeper horizon. Two wells have been put down here. The first* was carried to a depth of 2,495 feet and encountered water at several horizons. This supply was not utilized. In 1895 a second well was put down and an abundant supply was struck at 1,439 feet. The water is of excellent quality and is pumped at the rate of 350 gallons per minute. It probably comes from the sandstone which Norton* has referred to the Upper Silurian.

ACKNOWLEDGMENTS.

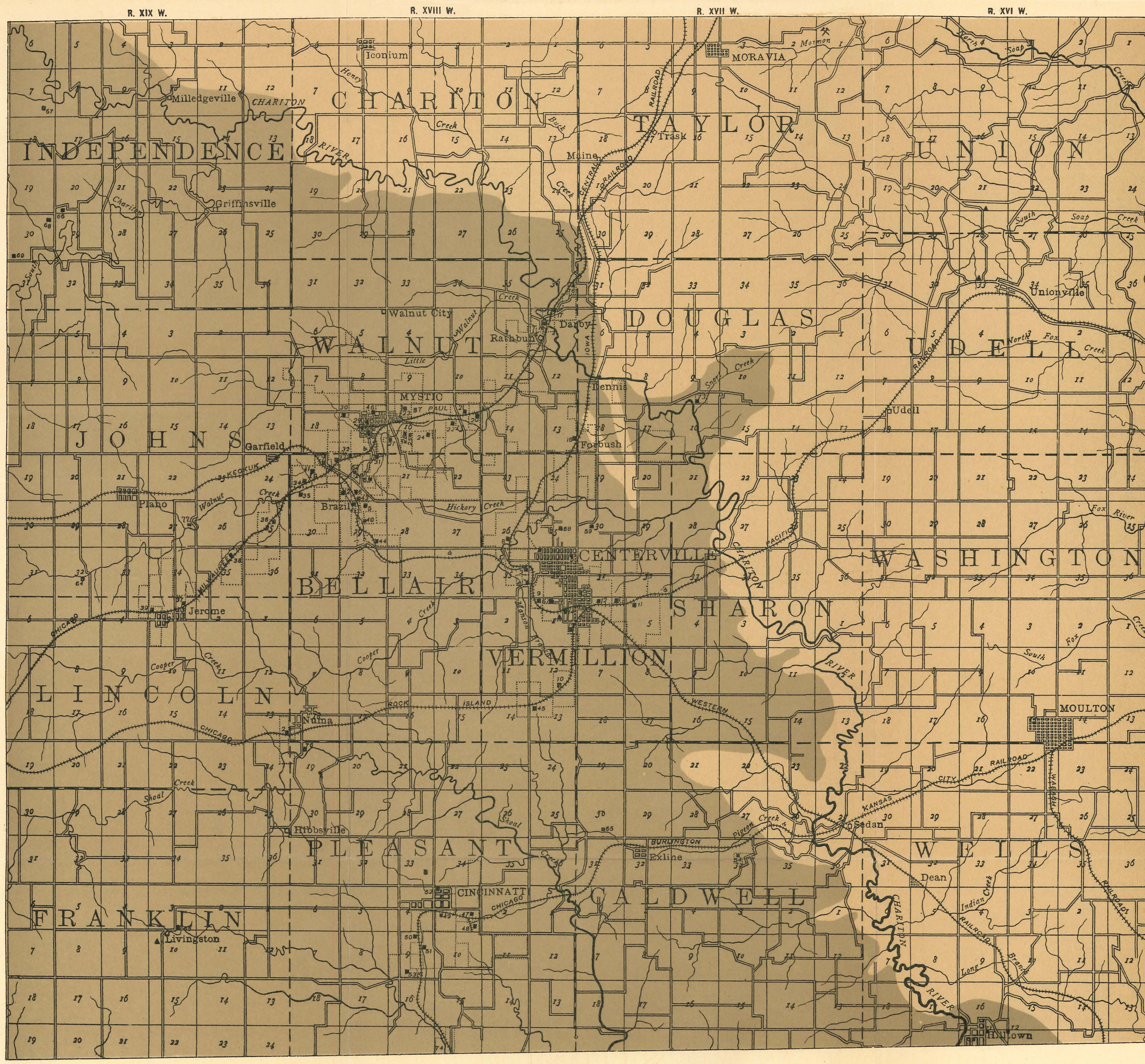
In the preparation of this report the writer has received important aid from very many people. It is impossible to name all, but among those who have been particularly helpful may be mentioned Messrs. Clarke & Peatman, Hon. J. T.

*See Norton: Iowa Geol. Surv., III, 205-210. Des Moines, 1895.

*Op. cit., 209.

Connor and Hon. D. W. Bryan, of Centerville, Hon. J. E. Gault, of Cincinnati, and the officers of the various coal companies. Among the latter, Messrs. Drake, Oliver and Dargavle of the Centerville Block Coal Co., Messrs. Lee of the Peerless, Merritt of the Standard; Johnson of the Scandinavian, Lodwick at Mystic and Denny at Cincinnati have been particularly helpful. To these and to many others not mentioned the larger portion of the facts presented in this report are due.

The field work upon which this report is based was carried on mainly in the summer of 1895. Since that time there have been numerous changes in the ownership and management of the various mines, so that the list as published is only correct up to August, 1895.



IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF APPANOOSE COUNTY, IOWA.

BY

H. FOSTER BAIN

1896.

LEGEND

GEOLOGICAL FORMATIONS

DES MOINES (Coal Measures)

APPANOOSE BEDS

INDUSTRIES

QUARRIES

COAL MINES

CLAY WORKS

IOWA PRINTING CO. DES MOINES, IA.

DRAWN BY F. C. TATE

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