IOWA

GEOLOGICAL SURVEY

VOLUME IX.

ANNUAL REPORT, 1898,

WITH

ACCOMPANYING PAPERS.

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

H. F. BAIN, Assistant State Geologist

DES MOINES:
PUBLISHED FOR THE IOWA GEOLOGICAL SURVEY
1899.

DES MOINES:
F. R. CONAWAY, STATE PRINTER.
1899.

Geological Board.

His Excellency, L. M. Shaw, - Governor of Iowa
Hon. F. F. Merriam, - - - Auditor of State
Dr. A. N. Currier, Acting Pres. State University of Iowa.
Dr. Wm. M. Beardshear, - Pres. Iowa State College
Prof. W. S. Hendrixson, Pres. Iowa Acad. of Sciences

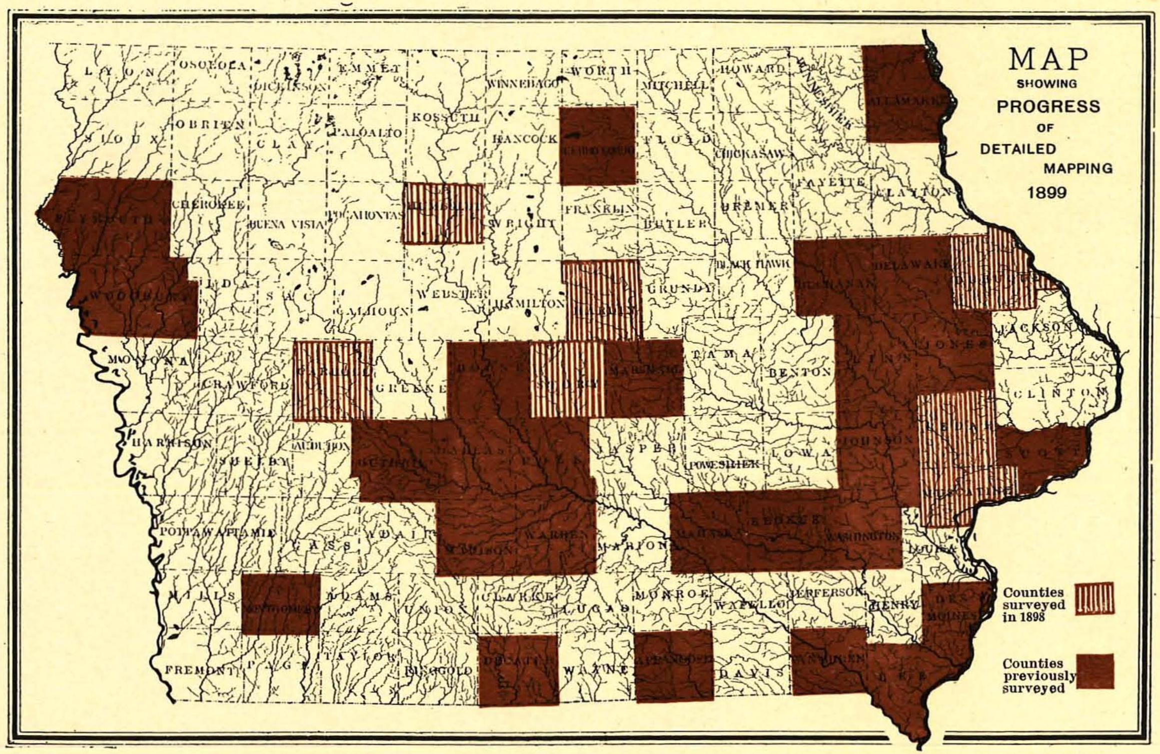
GEOLOGICAL CORPS.

SAMUEL CALVIN. ....STATE GEOLOGIST
H F. BAIN....................................ASSISTANT STATE GEOLOGIST
J. B. WEEMS..CHEMIST
S. W. BEYER.................. ....SPECIAL ASSISTANT
W. H. NORTON..SPECIAL ASSISTANT
J. A. UDDEN..SPECIAL ASSISTANT
NELLIE E. NEWMAN................................. ....SECRETARY

CONTENTS.

LIST OF ILLUSTRATIONS.

FIGURES.


MAP
SHOWING
PROGRESS
OF
DETAILED
MAPPING
1899
LYON
OSCEOLA
DICKINSON
EMMET
WINNEBAGO
WORTH
MITCHELL
HOWARD
WINNESHIEK
ALLAMAKEE
SIOUX
OBRIEN
CLAY
PALOALTO
KOSSUTH
HANCOCK
CERRO GORDO
FLOYD
CHICKASAW
FAYETTE
CLAYTON
PLYMOUTH
CHEROKEE
BUENA VISTA
POCAHONTAS
HUMBOLDT
WRIGHT
FRANKLIN
BUTLER
BREMER
BLACK HAWK
DELAWARE
DUBUQUE
WOODBURY
IDA
SAC
CALHOUN
WEBSTER
HAMILTON
HARDIN
GRUNDY
BUCHANAN
JACKSON
MONONA
CRAWFORD
CARROLL
GREENE
BOONE
STORY
MARSHALL
TAMA
BENTON
LINN
JONES
CLINTON
HARRISON
SHELBY
AUDUBON
GUTHRIE
DALLAS
POLK
JASPER
POWESHIEK
IOWA
JOHNSON
CEDAR
SCOTT
MUSCATINE
POTTAWATTAMIE
CASS
ADAIR
MADISON
WARREN
MARION
MAHASKA
KEOKUK
WASHINGTON
LOUISA
MILLS
MONTGOMERY
ADAMS
UNION
CLARKE
LUCAS
MONROE
WAPELLO
JEFFERSON
HENRY
DES MOINES
FREMONT
PAGE
TAYLOR
RINGGOLD
DECATUR
WAYNE
APPANOOSE
DAVIS
VAN BUREN
LEE
Counties surveyed in 1898
Counties previously surveyed

ADMINISTRATIVE REPORTS.

SEVENTH ANNUAL

Report of the State Geologist.

IOWA GEOLOGICAL SURVEY,
DES MOINES, December 31, 1898.

To Governor Leslie M. Shaw and Members of the Geological Board:

GENTLEMEN—As during preceding years, so during the past year, the work of the Survey has been mainly along the line of detailed mapping and the preparation of county reports. In all, six parties were in the field. The work in Dubuque county was under my immediate charge, the economic studies being carried on by Mr. Bain, assisted by Mr. W. H. Guilford. Mr. Bain also conducted the survey of Carroll county. Prof. W. H. Norton, after finishing the survey of Scott county, moved into Cedar and devoted the remainder of the field season to that area. Prof. T. H. Macbride undertook the work in Humboldt county, and carried it vigorously forward to an early completion. In Muscatine county we were fortunate in securing the services of Prof. J. A. Udden, of Agustana College, at Rock Island, Ill. Professor Udden had had experience in geological work in connection with the United States Survey and the Illinois Board of World's Fair Commissioners. His residence at Rock Island had led him to study the surrounding region, and he was accordingly exceptionally well qualified to take up the work in Muscatine. After a field conference with Professor Norton, in Scott county, he moved south and devoted his attention to the area assigned to him. His work here has been very thorough, and has led to the discovery of many new and interesting things.

Dr. S. W. Beyer devoted the field season to studies in Story and Hardin counties, and since the close of the season has been occupied in the Survey office at Des Moines. The survey of Story county has occupied his attention in the intervals of his work at the college at Ames, since the organization of this department. Since, however, Story is a prairie county with few outcrops, so that the most interesting problems of the region are those connected with the drift, it was thought better to defer the publication of a report upon it until the surrounding region had been studied. Accordingly, Boone, Polk and Marshall counties have been reported on, and the mapping of Hardin county is now complete. The report upon Story county, herewith submitted, fills an important gap in our scheme of mapping, and at the same time is of considerable intrinsic interest. Dr. Beyer's discovery of large bodies of loess below the drift of the region lends confirmation to some of the earlier results of the Survey, and at the same time may prove of considerable economic interest in affording a suitable brick clay in a region where such clay has not been previously known.

In Hardin county Dr. Beyer began the work with a field conference with Mr. Bain. He also had for a time the assistance of Mr. E. C. Hecker, as local assistant. The results of his work here are fully detailed in his report as appended.

The reports on Carroll, Humboldt, Story, Scott, and Muscatine counties are now well in hand, the maps are in the hands of the engraver and the illustrations are being prepared. The reports on Cedar and Hardin counties are being pushed and can probably be submitted within a few weeks. The Dubuque report will hardly be ready until after another field season, as the region is one of considerable interest and some difficulty, and it is expected that the report will be of more than usual detail.

The eastern part of the county lies in the driftless area, and the bold erosional topography developed in preglacial time has not been modified by the action of glaciers or the distribution of drift. On this account the mapping of the geological formations requires an amount of detailed field work greatly in excess of that necessary in the drift covered counties of the state. Furthermore, the economic problems are of unusual importance.

The field work of the past year has been carried forward along the same general lines as those heretofore followed. Scott county, mainly surveyed in 1897, was completed; and in addition, Cedar, Muscatine, Hardin, Story, Carroll, Dubuque and Humboldt counties, in all an area of 3,774 square miles, were mapped. In Cedar, Hardin and Dubuque counties certain details are yet unfinished, and the work is now being prosecuted so far as the weather permits. The mapping is, however, substantially complete. At the close of the present season the Survey has accordingly finished the mapping in thirty-three counties. These are indicated upon the accompanying map and are listed below. The total area surveyed up to date is 18,936 square miles, and includes much of the more difficult portion of the state.

COUNTIES SURVEYED AND MAPPED.

	Area sq. miles.		Area sq. miles.
Allamakee	658	Lee	512
Appanoose	576	Linn	720
Boone	576	Madison	576
Buchanan	576	Mahaska	576
Carroll	576	Marshall	576
Cedar	576	Montgomery	432
Cerro Gordo	576	Muscatine	437
Dallas	588	Plymouth	860
Decatur	576	Polk	585
Delaware	576	Scott	455
Des Moines	415	Story	576
Dubuque	601	Van Buren	484
Guthrie	593	Warren	569
Hardin	576	Washington	655
Humboldt	432	Woodbury	873
Johnson	618		
Jones	576	Total	18,936
Keokuk	576		

The work of mapping the Pleistocene formations has been continued, and numerous minor corrections have been made on the preliminary map compiled by Mr. Bain for the last report. The study of these surface deposits has its chief economic interest in the fact that they are the basis of the soil which has made Iowa famous among the agricultural states. The Survey has planned from the first a systematic study of the soils as one of the most important phases of its work. The mapping of the surface formations is a necessary preliminary. The latter having, however, progressed so satisfactorily, application was made in 1897 to the United States Department of Agriculture for aid in the study of the soils themselves. The Department found itself unable at this time to take up the Iowa work, but we were fortunate in enlisting the co-operation of the experiment station of the Iowa State College, and the work is now well under way.

A complete series of both mechanical and chemical analyses of the various soil types of the state is planned, and a thorough study of both the scientific and agricultural problems is to be made. The field work will be done by the regular Survey assistants, and the laboratory work will be done at the experiment station under the direction of Dr. J. B. Weems. The object of the work is to make a thorough study of the physical and chemical properties of the most important and typical soils in Iowa, adapted to the different staple crops, such as grass, wheat, corn, etc. Important features of the work will be a careful study of the texture of the soils, or the amount of sand, silt and clay, and the relation of the soils to moisture and heat. The soils selected for sampling for these investigations are to be typical, and each will represent fairly well a considerable area of land. They are expected to represent either the very best type of land for the staple crop or crops of the locality or the very poorest lands for these same crops. Both of these extremes are desired for contrast. For example, if the staple crop of the locality is wheat or corn the assistant is to select the best adapted to this staple crop and another soil if possible, in the same locality, representing a considerable area of land upon which this staple crop cannot successfully be grown on account of the small yield of inferior quality, or the time of ripening of the crop. It is desired to have the samples taken from fields which are now, or have recently been, under actual cultivation, in the crop or crops best adapted to it, so that the real agricultural value of the land can be accurately known.

The samples are taken inside the field, some distance away from houses, fences, roads, or trees. In fields planted to corn or similar large crops, the samples should be taken about midway in the open spaces. They should be taken where they will represent fairly well the average soil of the field and of the large area of land which they are to represent. They should not be taken where the soil has been washed, nor where the soil has accumulated to an unusual depth. In collecting the samples the assistants are instructed to remove all grass, leaves, or litter, from the surface, and then dig a hole like a post hole, twenty-four inches deep, scrape the sides clean and notice the depth at which the change of color occurs between the soil and the sub-soil. "Take a sample of the soil from above this, by cutting off a slice of soil three or four inches thick, down to the change in color, and mix this thoroughly together. Fill a cloth sack with this well-mixed soil, tie it securely, and fill out the label on the back of the tag. Then clean out the hole again, and scrape the sides so as to get rid of every particle of the soil, and take a sample of the sub-soil in like manner by cutting down a slice of the sub-soil and thoroughly mixing it together so that the samples shall contain particles of the sub-soil from immediately below the soil, to a depth of at least twenty-four inches. Put this sample of sub-soil into a separate sack, tie it securely, and fill out the label on the back of the shipping tag. If there is no apparent difference between the soil and the sub-soil, take a sample of soil, nevertheless, to a depth of six inches from the surface, and a sample of the sub-soil from below this to a depth of twenty-four inches, and put them into separate sacks as above. Fill out the form on the back of the shipping tag with the number of the sack, the name, locality, kind of soil, etc. Give as full information as possible as to what staple crop or crops are best adapted to this land and the reason why the staple crops, adapted to the locality, such as grass, wheat, corn, fruit, truck and the different types of tobacco cannot be successfully grown, so that we can compare the general agricultural value of the land with other samples. Give the geological formations, to which the soil belongs, if possible."

Samples have been collected, as directed above, in Dubuque, Carroll, Cedar, Scott, Muscatine, Story, Hardin and Humboldt counties, and are now in the hands of the chemist. It is hoped that the results of some at least of these analyses may be in in time to publish in connection with the papers accompanying this report.

Since the resignation of Prof. G. E. Patrick as chemist to the Survey we have had no regular chemist, and our investigations along that line have been somewhat limited. The work of the present year has, however, necessitated the making of numerous analyses and tests, and I have the pleasure of announcing that Dr. J. B. Weems, of the experiment station at Ames, has been employed to do this work.

The collection of statistics of production in the state was taken up last year, and the first tables were published in volume VIII. In order to have them ready for publication in that volume it was necessary to estimate the production in a few cases where unusual delay was met. These estimates were checked in every possible way, and the returns coming in later show that they were substantially correct, except that the total value of the clay output should have been slightly larger. In the collection of these statistics the Survey had the heartiest co-operation from the producers, and the letters of commendation received since indicate that the work met a real want. The total value of the mineral production of the state in 1897 was about $7,500,000, and important and encouraging advances along several lines were reported.

The statistics reported last year were obtained by personal letters or visits to each producer. This entailed a large amount of extra work, since the number of individual producers is large, and the operations are usually small. It also put upon each producer the burden of filling out a separate blank for this office, in addition to the one sent to the United States Geological Survey, and, in the case of the coal operators, to the mine inspectors. To avoid this duplication of work, and to insure as accurate results as possible, arrangements have been made whereby the work this year will be carried on in co-operation with the United States Geological Survey. In consultation with Messrs. E. W. Parker and Jefferson Middleton of that organization, who visited Des Moines for that purpose, terms mutually advantageous to both Surveys have been arranged, and the expense of the work will hereafter be divided. It is believed that this will meet with your hearty approval. The returns for the year 1898 are expected to be in hand in time to permit them to be appended to this report.

The law governing the Survey gives the director authority to investigate natural history subjects other than those directly relating to geology. So far it has not seemed possible to take up this work farther than the preparation of forestry notes on the various counties surveyed. For some time, however, Professor Pammel, of Ames, has had in preparation for the Survey a complete monograph on the grasses of Iowa, and it is a pleasure to be able to report the probable early completion of this valuable paper. At present it is being held awaiting the completion of a series of chemical analyses by Dr. J. B. Weems, which will add greatly to the value of the report, in the light which they will shed on the forage value of the various plants. Grasses, because of their intimate relation to the great stock raising and dairy interests of the state, are one of Iowa's most valuable products, and it has been thought better, for the sake of the greater value of the report, to allow this delay.

Other natural history monographs of economic value are promised or in contemplation, and will add greatly to the usefulness of the work which this organization is doing for the state. It is recommended that Professor Pammel's report be issued as a separate publication of the Survey.

Within the year volume VIII of the reports of the Survey was printed and distributed. Its table of contents will be found in the list below. As usual there has been a strong demand for the report and the edition is being rapidly exhausted. The original law governing the distribution of the reports of the Survey contemplated the sale of the bulk of the edition at a price sufficient to cover the cost of the printing and binding, and the proceeds of such sales have been from time to time covered into the state treasury. In the work of code revision the law was changed a little, so that the number which may be gratuitously distributed has been considerably increased. The volumes are now sent out upon the request of members of the general assembly, and at present copies of volumes VI to VIII, inclusive, may be obtained in this manner. A certain number of copies of each volume are reserved and are distributed only by sale, thus making it possible for any one, by the payment of a nominal sum, to complete his set. Some of the separate papers are now out of print and cloth bound copies of the earlier volumes cannot now be supplied. A price list of the publications on hand is appended.

The edition now published by the Survey consists of 3,000 copies. A portion of this edition, 2,000 copies of recent volumes, is bound in cloth, 500 are bound in paper, and the remaining 500 are cut up and bound in paper as separate pamphlets. Three hundred copies of each county report are placed at the disposal of the senator and representatives from the county, serving in the general assembly at the time the report is issued. The remaining copies are distributed by the Survey upon request. A very large number of these pamphlets have found their way into the schools and are being used as text-books. There is probably no place where they will be more useful, and so far as the supply at the disposal of the Survey permits we are glad to honor requests for them for such use.

VOLUME I. FIRST ANNUAL REPORT, 1892.

480 Pages, 10 Plates, 26 Figures.
Price, in paper, 70 cents; postage, 26 cents.

CONTENTS:

VOLUME II. COAL DEPOSITS.

BY CHARLES ROLLIN KEYES.

536 Pages, 18 Plates 251 Figures.
Price, in paper, 70 cents; postage, 31 cents.

CONTENTS:

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, 1892.

501 Pages, 37 Plates, 34 Figures.
Price, in cloth, $1.10; postage, 35 cents.
In paper, $1.00; postage, 30 cents.

Certain of the individual papers comprising this volume will be sent postpaid, bound in paper, upon receipt of the amount set opposite them.

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 Harry Foster Bain. 5 cents.
Certain Devonian and Carboniferous Outliers in Eastern Iowa; by William Harmon Norton. 10 cents.
Geological Section Along Middle River in Central Iowa; by J. L. Tilton. 5 cents.
Glacial Scorings in Iowa; by Charles Rollin Keyes. 10 cents.
Thickness of the Paleozoic Strata of Northeastern Iowa; by William Harmon Norton. 15 cents.
Composition and Origin of Iowa Chalk; by Samuel Calvin. 10 cents.
Buried River Channels in Southeastern Iowa; by C. H. Gordon. 10 cents.
Gypsum Deposits of Iowa; by Charles Rollin Keyes. 20 cents.
Geology of Lee County; by Charles Rollin Keyes. 30 cents.
Geology of Des Moines County; by Charles Rollin Keyes. 30 cents.

VOLUME IV. THIRD ANNUAL REPORT, 1894.

467 Pages, 11 Plates, 6 Maps, 54 Figures.
Price in cloth, $1.25; postage, 34 cents.
In paper, $1.00; postage, 28 cents.

The individual papers of this volume will be sent postpaid, bound in paper, upon receipt of the amount set opposite them.

CONTENTS:

Administrative Reports.
Geology of Allamakee County; by Samuel Calvin. Out of print.
Geology of Linn County; by W. H. Norton. 20 cents.
Geology of Van Buren County; by C. H. Gordon. 20 cents.

Geology of Keokuk County; by H. F. Bain. 20 cents.
Geology of Mahaska County; by H. F. Bain. 20 cents.
Geology of Montgomery County; by E. H. Lonsdale. 20 cents.

VOLUME V. ANNUAL REPORT, 1895.

452 Pages, 14 Plates, 7 Maps, 72 Figurss.
Price, in cloth, $1 00; postage, 34 cents.
In paper, 85 cents; postage, 28 cents

The individual papers of this volume will be sent postpaid, bound in paper, upon receipt of the amount set opposite them.

CONTENTS:

Administrative Reports.
Geology of Jones County; by S. Calvin 20 cents.
Geology of Boone County; by S. W. Beyer. Out of print.
Geology of Warren County; by J. L. Tilton. 20 cents.
Geology of Washington County; by H F. Bain. 20 cents.
Geology of Woodbury County; by H. F. Bain. 20 cents.
Geology of Appanoose County; by H. F. Bain. 20 cents.

VOLUME VI. LEAD AND ZINC, ARTESIAN WELLS, ETC.

487 Pages, 28 Plates, 57 Figures.
Price, in cloth, 85 cents; postage, 34 cents.
In paper, 70 cents; postage, 28 cents.

The individual papers of this volume will be sent postpaid, bound in paper, upon receipt of the amount set opposite them.

CONTENTS:

Lead and Zinc Deposits of Iowa; by A. G. Leonard. 10 cents.
The Sioux Quartzite and Certain Associated Rocks; by S. W Beyer. 10 cents.
Artesian Wells of Iowa; by W. H. Norton. 55 cents.
Relations of the Wisconsin and Kansan Drift Sheets in Central Iowa, and Related Phenomena; by H. F. Bain. 10 cents.

VOLUME VII. ANNUAL REPORT, 1896.

550 Pages, 11 Plates, 11 Maps, 81 Figures.
Price, in cloth, $1.30; postage, 34 cents.
In paper, $1.15; postage, 30 cents.

The individual papers of this volume will be sent postpaid, bound in paper, upon receipt of the amount set opposite them.

CONTENTS:

VOLUME VIII. ANNUAL REPORT, 1897.

427 Pages, 32 Plates, 6 Maps, 13 Figures.
Price, in cloth, $1.30; postage, 30 cents.
In paper, $1.15; postage, 26 cents.

The individual papers of this volume will be sent postpaid, bound in paper, upon receipt of the amount set opposite them.

CONTENTS:

The museum and library of the Survey have continued to grow and several valuable periodicals have been added to our exchange list. Among the more important are the following:

Trans. Australian Inst. Ming. Eng. (Melbourne.)
Technology Quarterly. (Boston.)
Proc. Philos. Soc. of Glasgow. (Glasgow.)
Jour. Western Soc. Eng. (Chicago.)

An important donation of fossils was received from McKeesport Scientific and Philosophical Society, representing the common fossils of the Pennsylvania coal measures.

In the office there has been the usual heavy correspondence relating to exchanges, distribution of reports, inquiries, etc. The copying and revising of manuscript, proof reading and the preparation of advance notes for the newspapers and the articles for the scientific and technical press, calling attention to Iowa's resources have also absorbed much time. This office work has been carried on as in previous years except that we have had the aid of Dr. Beyer during the winter months.

My personal work has involved the constant supervision of the operations of the Survey. The large amount of office work incident to the position, the revision of all manuscripts, the study of the fossil forms collected by all the parties in the field, together with the field work and study of structural problems which engaged my attention during the working season. The greater part of the field season was spent in Dubuque county. This is one of the most important counties, geologically speaking, in the state. A proper solution of all the problems presented by Dubuque county demands much more time and labor than will be necessary in many of the other counties of Iowa. In the driftless portion of the county, every square mile must be examined in detail. The borders of two of Iowa's drift sheets pass through Dubuque county; the county has long been noted as the seat of the lead and zinc industry of the state; and the building stones and lime-burning rocks are of especial importance. The work in this county was divided, Mr. Bain taking up the study of the economic problems, while my investigations were devoted to the geological structure—including both indurated rocks and superficial deposits—and to the detailed mapping of the several geological formations. Besides the time spent in Dubuque county, some time was spent with the several geologists having direct charge of the work in each of the following counties, namely, Scott, Cedar, Muscatine and Humboldt.

Mr. Roy Mosnat, of Belle Plaine, as volunteer assistant, has made a detailed study of the Belle Plaine Artesian Basin, has mapped the several wells, and has collected data of very great interest respecting the quality and volume of water supplied by this important hydrographic area.

Dr. Charles R. Eastman, of Harvard, is prosecuting studies on the interesting, and in some cases unique, collections of fossil fishes supplied by the geological formations of Iowa.

The United States Geological Survey extended its topographic work in Iowa, completing the sheet west of that which was surveyed last year. This work is of especial importance to the Iowa Survey, inasmuch as it will greatly reduce the expense of correct geological mapping in the Driftless Area. This area includes, so far as relates to Iowa, all or part of the counties of Jackson, Dubuque, Clayton, Fayette, Allamakee and Winneshiek. Of these important counties, Allamakee and Dubuque are the only ones so far studied. I have the honor to remain, gentlemen,

Your obedient servant,

SAMUEL CALVIN,
State Geologist.

REPORT OF ASSISTANT STATE GEOLOGIST.

IOWA GEOLOGICAL SURVEY,
DES MOINES, December 30, 1898.

MY DEAR SIR—I have the honor to submit the following report upon my work for the past year. The earlier months of the year were, as usual, taken up with office duties, including the supervision of the printing of volume VIII of the Survey reports. This required more or less attention throughout the first six months of the year. In April, when the weather became suitable, out-of-doors field work was taken up and was continued, so far as office duties would allow, until December 18th. My personal field work for the year was mainly in Carroll and Dubuque counties. Excursions were made in Hardin county, in company with Dr. Beyer; in Johnson and Tama counties, in your company, and in Pottawattamie and numerous other counties alone. In September a trip was made through the northwestern portion of the state, in company with Prof. J. E. Todd, state geologist of South Dakota, and Mr. Frank Leverett, of the United States Geological Survey. Carroll, Sac, Ida, Crawford, Woodbury, Plymouth, Sioux and Lyon counties, and adjacent portions of Minnesota and South Dakota were visited, attention being especially directed to a study of the drift formations. The discovery of fossiliferous clays of Buchanan age, at Sioux Falls, was one of the gratifying results of the trip. More extended studies of the interloessial till at Sioux City developed the fact that the beds found below the till are fine water-laid silts, and are probably different from the loess proper. Mr. Leverett traced the morainic hills of the Wisconsin drift into the northeast corner of Lyon county, and it seems probable that other changes in the mapping of the drift sheets of that region will be necessary.

In Carroll county one of the interesting results of the season's work has been the demonstration that much of the extra-morainic drift, heretofore believed to be young and provisionally correlated with the Iowan, belongs to an anomalous phase of the Kansan. What may be the correct age of the extra-morainic drift north and west of Carroll county can not yet be stated. A full report on the geology of Carroll county has been prepared, and is submitted herewith.

In Dubuque county my attention has been devoted mainly to a study of the economic features of the district. The excellent building and limestones of the region were studied, and the specimens collected for analyses are now in the hands of the chemist. The clays of Dubuque county have not heretofore received the attention which they deserve, and it is hoped that their development may be stimulated. A series of tests was carried on to determine the temperatures at which the brick now made were being burned. The major attention was necessarily devoted to a study of the lead and zinc mines, and a large scale map is now being prepared, showing the location of the various crevices and openings. In this work the Survey has had the aid of Mr. W. H. Guilford, whose long acquaintance with the region as a surveyor makes his assistance particularly valuable. The various miners and mine owners have also done all in their power to aid in the work.

While it is too soon to present conclusions, it may be stated that the outlook for the field seems very good. The area is limited and the operations are small, but several of the mines are yielding nicely, and there is a large amount of ore in sight. There are also considerable tracts of country wholly unexplored. It is believed that the future production of the region, particularly in zinc, will be large, and that the general impression that the region is worked out is wrong. Some facts which are believed to have an important bearing upon the genesis of the ores have been observed.

In June, a favorable opportunity occurring, a few days were spent in Joplin, Mo., studing the zinc mines of that region, and in December a similar visit was made to the lead region of southeastern Missouri to study the desseminated ores of that region. Points in Wisconsin have also been visited. The larger and often older mines of these regions show many facts which cannot be so readily observed at Dubuque, and many suggestions as to ore treatment were also obtained. A full report upon the subject is now being prepared. What the Dubuque mines need most at present is more buyers and a larger share in the rise in the price of zinc ores which has been so marked a feature of the year's markets. The prices paid for ore in the Dubuque region have not been such as would stimulate development. The result has been small, poorly developed mines and an uncertain supply of ore which has discouraged buyers and still further depressed the price. In the main the isolated position of the mines and the poor milling of the ores have been the reason of the low price. Recent developments have shown that considerable bodies of ore are present, and with proper organization of the industry the mines should receive considerable attention.

The usual routine work of the office has been carried on throughout the year. Specimens sent in from various parts of the state have been examined, investors have been advised, the preparation of manuscript, maps and illustrations has been supervised, etc. With the assistance of Doctor Beyer a dark room has been prepared, and hereafter the photographic work will not need to be sent out.

Respectfully yours,

H. F. BAIN,
Assistant State Geologist.

TO PROF. SAMUEL CALVIN,
State Geologist.

REPORT OF MR. SAMUEL W. BEYER.

IOWA GEOLOGICAL SURVEY,
DES MOINES, December 30, 1898.

SIR—I have the honor to submit to you the following report of work done by me during the year ending December 31st.

It was my good fortune to represent the Survey at the International congress which convened at St. Petersburg late in August, 1897. After traveling several thousand miles in Russia, and visiting many of the classic localities in that country, I spent some time at Freiberg, München and Berlin, and returned to the United States late in February of the present year.

During March, April and May, I put in as much time as I could spare from my college duties in pushing forward my field work in Story county, and made two, more extended trips. The first, in company with Mr. Bain, to investigate the "Marble Beds" reported to have been discovered between Iowa Falls and Alden, on the Iowa river. The second was made in company with yourself, Mr. Frank Leverett of the United States Geological Survey, Professors Chamberlain and Salisbury of the University of Chicago, and Messrs. Udden and Bain of this Survey; the object being to study the drift of Illinoian ice sheet as exhibited in the vicinity of Peoria in Illinois, and, if possible, to get some light in dealing with the multiplicity of ice sheets in Iowa.

The greater part of June and July was spent in the field in Hardin and the counties immediately adjoining. It was found that the Wisconsin drift extends much further east than was formerly supposed. Eldora hill marks the extreme advance in this direction and the North Fork of the Iowa river was born at the time the ice invaded this region. The marble quarries previously mentioned were examined more in detail and the results are somewhat disappointing. It was hoped that a further development of the quarries would show thicker ledges. But this is not the case. It is obvious that the power that caused the shattering of the beds was also the potent influence in effecting their marmorosis. The one varies directly as the other. While the marble takes an excellent polish and possesses a pleasing color and texture, the thinness and interrupted character of the beds precludes a more than local importance for them.

The "Honestone" and "Whetstone" quarries were also investigated and found of little significance save in showing detached basins of the coal measures.

Short field trips were made from August to November, inclusive, and the field work in Story county completed. Important deposits of loess were recognized in the west-central portion of the county. They afford an abundance of first-class material for pressed brick.

At the end of the field season, about December 1st, my headquarters were transferred to Des Moines, where my time has been employed in writing up Story county and relieving Mr. Bain of a portion of the routine work of the office.

Very respectfully yours,

SAMUEL W. BEYER.

TO PROF. SAMUEL CALVIN,

State Geologist.

MINERAL PRODUCTION OF IOWA IN 1898.

BY SAMUEL W. BEYER.

VALUE OF MINERAL PRODUCTION.

COAL	$5,123,187
CLAY	2,057,022
STONE	563,586
LEAD AND ZINC	43,784
TOTAL VALUE	$7,787,579

MINERAL PRODUCTION OF IOWA IN 1898

BY S. W. BEYER.

The kindly reception accorded the mineral statistics of Iowa for 1897 lead the Iowa Geological Survey to undertake their collection for 1898. It was the extreme good fortune of this department to secure the co-operation of the division of mineral statistics of the United States Geological Survey. All blanks, with return envelopes, were sent from Washington, and duplicates of all returns were forwarded promptly to the local office, thus saving the State a large amount of routine work, and the operators the annoyance of a confusing multiplicity of requests from two offices. The state organization assumed the responsibility of looking up the delinquents.

The very prompt and hearty co-operation shown by the producers deserves, and has, the fullest thanks of the Survey. They have, with almost no important exceptions, responded promptly and willingly. Many have asked for copies of the report when completed, thus expressing their appreciation of the work. Not a single important coal operator has failed to report, and it is believed that the coal output is correct within 3 per cent. The same is essentially true for clay and stone. One estimate is included with the totals for clay, but this plant was visited by the writer and the figures submitted are believed to be reliable.

The figures for the production of gypsum could not be obtained. The output for 1896 was $34,020. The steady improvement of trade conditions and great increase in building during the past two years has, probably more than doubled the output.

The increased production of lead and zinc, stimulated by the recent advance in the prices of those metals. is most gratifying.

Total Production.

Eighty-nine counties and nearly seven hundred producers were engaged in developing the mineral resources of the state in 1898.

The value of the total mineral production in 1898 was $7,787,579; distributed as follows:

	VALUE.	NO. OF PRODUCERS.
Coal	$ 5,123,187	188
Clay	2,057,022	349
Stone	563,586	161
Lead and zinc	43,784	10
Total	$ 7,787,579	708

According to the United States Geological Survey the output of the above products for 1897 were:

Coal	$ 5,219,503
Clay	1,821,247
Stone	495,343
Lead and zinc*	5,866
Total	$ 7,541,959

The production is shown by counties in Table I.

*Iowa Geological Survey.

TABLE I.

Total Value of Mineral Production by Counties.

COUNTIES.	Total clay.	Total coal.	Total stone.	Miscellaneous.	Total.
Adair	$ 2,220				$ 2,220
Adams	6,700	$ 18,108			24,808
Allamakee			$ 160		160
Appanoose	14,725	726,932	84		741,741
Audubon*					
Benton	14,040		3,556		17,596
Black Hawk	16,142		3,980		20,122
Boone	26,620	473,342			499,962
Bremer	1,596				1,596
Buchanan	1,988		118		2,106
Buena Vista	6,800				6,800
Calhoun	5,933				5,933
Carroll	9,100				9,100
Cass	11,800				11,800
Cedar	6,210		113,502		119,712
Cerro Gordo*					
Cherokee	10,560				10,560
Clarke*					
Clay*					
Clayton	8,391		4,820		13,211
Clinton	20,790		1,628		22,418
Crawford	12,500				12,500
Dallas	28,703	13,052			41,755
Davis*		490			490
Decatur	6,700		3,275		9,975
Delaware	6,175				6,175
Des Moines	26,912		12,135		39,047
Dubuque	35,110		23,183	$43,784	102,077
Fayette*					
Floyd*					
Franklin	1,656				1,656
Fremont	10,075				10,075
Greene*		21,318			21,318
Grundy	5,550		300		5,850
Guthrie	56.039	3,020			59,059
Hamilton	59,800				59,800
Hardin	16,875		7,400		24,275
Harrison	11,285				11,285
Henry	17,575		6,400		23,975
Howard	7,575		773		8,348
Humboldt*					
Ida*					
Iowa	38,600				38,600
Jackson	4,950		64,030		68,980
Jasper	22,700	219,481			242.181
Jefferson	11,832	1,386	1,000		14,218
Johnson	16,880		3,738		20,618
Jones	9,799		95,359		105,158
Keokuk	21,910	265,886	3,263		291,059

*Single producers of certain articles.

TABLE I—CONTINUED.

COUNTIES.	Total clay.	Total coal.	Total stone.	Miscellaneous.	Total.
Kossuth*					
Lee	20,425		28,724		49,149
Linn	32,359		18,560		20,919
Louisa	7,100		1,626		8,726
Lucas	2,000	12,000			14,000
Madison	3,850		11,647		15,497
Mahaska	56,580	1,304,727	503		1,361,810
Marion	16 275	113,329	2,481		132,085
Marshall	31,355		51,393		82,748
Mills	8,785				8 785
Mitchell			3,268		3,268
Monona*					
Monroe	1,476	594,980	130		596,586
Montgomery	27,397		1,830		29,227
Muscatine	25,811				25,811
Page	21,220	14,333			35,553
Plymouth*					
Pocahontas*					
Polk	347,257	787,940			1,135,197
Pottawattamie	52,837				52,837
Poweshiek	9,915				9,915
Ringgold	8,350				8,350
Sac*					
Scott	43,456		31,131		74,587
Shelby*					
Sioux	1,800				1,800
Story	16,220	11,554	1,125		28,899
Tama	41,195		350		41,545
Taylor	10,600	12,485			23,085
Union	8,050				8,050
Van Buren	8.800	9,610	9,541		27,951
Wapello	55,221	258,561	16,150		329,932
Warren	1,225	11,070			12,295
Washington	21,672		6,405		28,077
Wayne	7,505	68,633			76,138
Webster	78,158	180,750	3,487		262,395
Winnebago	2,874				2,874
Winneshiek	5,100		630		5,730
Woodbury	128,200				128,200
Wright	8,618				8,618
Single producers	97,981				97,981
Burnt clay ballast and unspecified	221,712				221,712
Total	$2,057,022	$5,123,187	$563,586	$43,784	$7,787,579

*Single producers of certain articles.

COAL.

The output of coal for 1898 shows a slight falling off as compared with the production for 1897, both in tonnage and in cash value. The open winter of 1897 and 1898, greatly affected the local demand and the opening of new fields in the southwest deprived Iowa of a portion of her railway clientage in that quarter. While the average price per ton ruled slightly higher, the total shrinkage in production was almost a hundred thousand tons. Of the great coal producing counties, Appanoose, Jasper, Keokuk, Mahaska, Marion and Webster, show a decrease, while Boone, Monroe, Polk and Wapello show a handsome increase. Of the total output 11 per cent was sold locally or consumed at the mine while 89 per cent was loaded on the cars and shipped to various points in and out of the state, chiefly to the west and south of the producing areas. Table II gives the total tonnage, average value, total value, number of mines producing, average number of days worked and number of men employed, arranged by counties.

TABLE II.

Coal Output by Counties.

COUNTIES.	Mines reporting	Tons.	Price per ton.	Value.	Average No. days worked.	Men employed.
Adams	11	9,822	$ 1.84	$ 18,108	169	83
Appanoose	41	608,165	1.19	726,932	175	2,008
Boone	14	331,543	1.43	473,342	209	1,110
Dallas	3	8,859	1.46	13,052	224	36
Davis	1	391	1.25	490	130	3
Greene	5	12,920	1.65	21,318	194	54
Guthrie	2	1,510	2.00	3,020	120	7
Jasper	6	151,816	1.45	219,481	238	267
Jefferson	2	1,025	1.35	1.386	120	7
Keokuk	7	251,145	1.06	265,886	186	558
Lucas	1	6,600	1 82	12,000	200	22
Mahaska	17	1,292,787	1.01	1,304,727	229	2,239
Marion	14	127.293	.89	113,329	217	487
Monroe	7	584,578	1.02	594,980	224	1,040
Page	2	6,370	2.25	14,333	200	23
Polk	15	635,606	1.22	787,940	219	1,340
Story	1	7,885	1.46	11,554	180	31
Taylor	2	6,555	1.91	12,485	193	27
Van Buren	2	6,605	1.45	9,610	258	14
Wapello	10	252,484	1.02	258,561	212	478
Warren	5	7,514	1.47	11,070	78	48
Wayne	7	51,550	1.33	68,633	164	253
Webster	13	137,787	1.31	180,750	212	379
Total	188	4,500,810	$ 1.14	$5,123,187	218	10,514

In the above table no attempt was made to keep separately the various sizes of coal put upon the market. Nut and slack are included and would tend to make the price per ton lower than for lump coal alone. This would not affect the results for the Centerville district, for the very persistent parting which is everywhere present in the principal vein worked, is mined with the coal, passes through the screen and renders the slack unmarketable.

Table III compares the output for 1898 with the most reliable figures for the preceding six years:

TABLE III.

YEARS.	SHORT TONS.	Price	VALUE.	AUTHORITY.
1892.............	3,918,491	$1.32	$5,175,060	United States Geological Survey.
1893.............	3,972,229	1.30	5,110,460	United States Geological Survey.
1894.............	3,967,253	1.26	4,999,939	United States Geological Survey.
1895.............	4,156,074	1.20	4,982,102	United States Geological Survey.
1896.............	3,954,028	1.17	4,628,022	Uni ed States Geological Survey.
1897.............	4,611,865	1.13	5,219,503	United States Geological Survey.
1898.............	4,500,810	1.14	5,123,187	Iowa Survey.

The number of men employed in the mines of Iowa for 1898 shows a falling off of nearly 200, while the average number of days worked was greater than for any year since 1892. The number of men employed and the average number of days worked during the past six years, according to the best information available, was as follows:

YEAR.	Av. number of active days.	Number of men employed.
1893........	204	8,863
1894........	170	9,995
1895........	189	10,066
1896........	178	9,672
1897........	201	10,703
1898........	218	10,514

According to the United States Geological Survey Iowa, in 1897, ranked sixth in bituminous coal tonnage, and fifth according to the market value of the product, and first in both tonnage and value of the states west of the Mississippi. The production of the ten leading states was as follows:

STATE.	TONS.	VALUE.
1. Pennsylvania	54,597.891	$37,636 347
2. Illinois	20,072,758	14,472,529
3. West Virginia	14 246.159	8,987,393
4. Ohio	12,196,942	9,535,409
5. Alabama	5,893,770	5.192,085
6. Iowa	4,611,865	5,219,503
7. Maryland	4.442,128	3,363.996
8. Indiana	4,151,169	3,472,348
9. Kentucky	3,602.097	2.828,326
10. Colorado	3,361,703	3,947,186

Clay.

The value of the clay products marketed during 1898, exceeded that of 1897 by nearly a quarter of a million dollars, and was the greatest since 1894. There was a sharp falling off in the output and sale of paving brick and draintile, but a marked increase in common brick. The greatest gain, however, was in the production of a burnt clay, which has gained great favor in the southern half of the state as a ballast. More than $200,000 worth of burnt clay, alone, was sold during the past year.

In 1896, nearly 35 per cent of the firms reporting were idle, in 1897 slightly more than 20 per cent, while in 1898 the percentage of firms not in operation was still less.

Of the great clay producing centers, Polk county alone shows a falling off, and that scarcely more than 3 per cent. The chief gain comes, however, from the large number of small firms which have been revived or brought into existence by the betterment of general trade conditions, especially in the building trade.

Fancy work and pottery show a slight decrease and it seems improbable that Iowa will ever become a dangerous competitor of the eastern Mississippi valley states in that line, unless new deposits of clay are discovered or new methods of working introduced.

The returns show 349 plants in active operation, a gain of 19 over 1897, and give the total value of brick produced at $1,415,165, and of all clay products, $2,057,022, showing a gain of $83,405 and $238,138, respectively. These amounts were distributed as follows:

	Thousands.	Price per thousand.	Value.
Common brick	181,331	$5 90	$ 1,069,947
Pressed brick	6,722	8.14	54,752
Vitrified brick	35,357	8 24	290,463
Fancy brick	....	....	993
Fire brick	....	....	5,525
Draintile	....	....	343,265
Sewer pipe	....	....	33,000
Terra cotta	....	....	350
Fire proofing	....	....	2,161
Floor tile, etc	....	....	429
Burnt clay	....	....	203,639
Pottery	....	....	34,425
Hollow brick, etc	....	....	18,073
Total	....	....	$ 2,057,022

According to the United States Geological Survey, the totals for 1895 to 1897, were as follows:

	1895.	1896.	1897.
Common brick	$1,095,074	$1,003,624	$ 850,834
Pressed brick	87,130	47,386	57,230
Vitrified brick	243,928	112,985	426,056
Fancy and ornamental brick	2,300	....	2,800
Fire brick	5,920	5,198	8,700
Draintile	290,5 5	225,650	372,070
Sewer pipe	55, 31	73,039	44,300
Ornamental terra cotta	2,800	800	500
Fire proofing	400	7,685	7,540
Tile—not drain	16,094	2,000	6,700
Pottery	25,600	42,710	38,641
Unclassified	45,400	173,000	5,501
Total	$1,870,292	$1,694,402	$1,821,247

Works in active operation reporting: 1896, 339; 1897, 330.

The production by counties is given in Table IV. Counties in which but one plant is reported as active in 1898, are mentioned in their proper order, but their production is not given separately.

TABLE IV.

Clay Production by Counties.

COUNTY.	Number of producers	THOUSANDS.		VALUE.		
		Common brick.	Total brick.	Common brick.	Total brick.	Total clay.
Adair	2	370	370	$ 2,220	$ 2,220	$ 2,220
Adams	3	1,200	1,200	6,200	6.200	6,700
Appanoose	3	1,650	2,750	8,925	15,725	15,725
Audubon	1	....	....	....	....	....
Benton	6	1,155	1,655	6,930	10,430	14,040
Black Hawk	3	2,432	2,432	14.992	14,992	16,142
Boone	10	1,615	2,465	9,600	15 600	26,620
Bremer	2	240	240	1 596	1,596	1,596
Buchanan	2	325	325	1,988	1,988	1,988
Buena Vista	2	300	300	2,200	2,200	6,800
Calhoun	3	55	55	405	405	5,933
Cass	3	1,700	1,700	11,800	11,800	11,800
Carroll	3	1,400	1,400	9,100	9,100	9,100
Cedar	2	487	487	3,310	3,310	6,210
Cerro Gordo	1	....	....	....	....	....
Cherokee	2	1,800	1,800	10,400	10,400	10,560
Clarke	1	....	....	....	....	....
Clay	1	....	....	....	....	....
Clayton	4	1,400	1,400	7,550	7,550	8,391
Clinton	4	3,795	3,795	16,740	16,740	20,790
Crawford	4	1,900	1,900	12,500	12,500	12,500
Dallas	9	1,912	2,086	11,351	13,189	28,703
Davis	1	....	....	....	....	....
Decatur	3	1,000	1,025	6,100	6,400	6,700
Delaware	3	800	875	4,450	4.975	6,175
Des Moines	6	900	2.485	4,900	18,612	26,912
Dubuque	7	7,045	7,045	35,110	35,110	35,110
Fayette	1	....	....	....	....	....
Floyd	1	....	....	....	....	....
Franklin	2	254	254	1,522	1,522	1,656
Fremont	5	1,870	1,870	10,075	10,075	10,075
Greene	1	....	....	....	....	....
Grundy	3	625	625	3,750	3,750	5,550
Guthrie	6	2,740	3,240	17.038	20,538	56,039
Hamilton	2	5,200	5,200	31,200	31,200	59,800
Hardin	3	280	280	1,800	1,800	16,875
Harrison	6	1,830	1,830	10,785	10,785	11,285
Henry	5	825	825	4,775	4,775	17,575
Howard	2	750	1,055	4,000	6,775	7,575
Humboldt	1	....	....	....	....	....
Ida	1	....	....	....	....	....
Iowa	6	3,700	3,700	21,200	21,200	38,600
Jackson	2	575	575	3,450	3,450	4,950
Jasper	7	3,500	3,500	19,850	19,850	22,700
Jefferson	2	580	580	4,740	4,740	11,832

TABLE IV—CONTINUED

COUNTY.	Number of producers.	THOUSANDS.		VALUE.		
		Common brick.	Total brick	Common brick.	Total brick.	Total clay.
Johnson	5	2,180	2,190	$ 10,900	$ 10,980	$ 16,880
Jones	4	605	680	3,847	4,447	9,799
Keokuk	8	1,955	1,955	12,230	12,230	21,910
Kossuth	1	....	....	....	....	....
Lee	6	3,310	3,410	19,525	20,425	20,425
Linn	11	5,029	5,069	27,287	27,607	32,359
Louisa	3	825	825	5,100	5,100	7,100
Lucas	2	340	340	2,000	2,000	2,000
Madison	3	625	625	3,850	3,850	3,850
Mahaska	5	2,070	6,070	13,230	51,230	56,580
Marion	2	940	950	6,050	6,125	16,275
Marshall	6	2,535	3,535	16,145	23,645	31,355
Mills	6	1,324	1,324	8,785	8,785	8,785
Monona	1	....	....	....	....	....
Monroe	3	286	286	1,476	1,476	1,476
Montgomery	3	3,694	3,719	20,571	20,759	27,397
Muscatine	10	3,089	3,089	16,211	16,211	25,811
Page	5	3,370	3,370	20,720	20,720	21,220
Pocahontas	1	....	....	....	....	....
Plymouth	1	....	....	....	....	....
Polk	20	24,087	21,621	147,116	288,857	347,257
Pottawattamie	9	7,890	8,390	48,837	52,837	52,837
Poweshiek	3	820	820	5,240	5,240	9,915
Ringgold	6	1,050	1,250	7,150	8,350	8,350
Sac	1	....	....	....	....	....
Scott	7	3,610	5,893	21,270	39,996	43,456
Shelby	1	....	....	....	....	....
Sioux	2	270	270	1,800	1,800	1,800
Story	5	1,090	1,140	7,920	8,320	16,220
Tama	8	4,417	5,343	25,037	32,995	41,195
Taylor	5	1,590	1,590	10,600	10,600	10,600
Union	2	1,180	1,180	7,360	7,360	8,050
Van Buren	4	900	900	5,400	5,400	8,800
Wapello	4	4,499	7,675	28,764	55,221	55,221
Warren	3	....	50	....	300	1,225
Washington	6	2,728	2,728	15,254	15,254	21,672
Wayne	3	1,181	1,181	7,505	7,505	7,505
Webster	8	7,583	8,454	40,534	50,095	78,158
Winnebago	2	410	412	2,700	2,724	2,874
Winneshiek	2	850	850	5,100	5,100	5,100
Woodbury	7	21,976	22,783	121,709	128,181	128,200
Wright	3	280	280	1,855	1,855	8,618
Single producers	16	6,883	7,412	42,417	46,180	97,981
Burnt clay ballast	4	....	....	....	....	203,639
Estimates. No. 2,455	1	100	100	700	700	6,700
Total	349	181,331	223,410	$1,069,947	$1,415,165	$2,057,022

The average prices ruled higher for all kinds of brick than since 1895 for common and 1894 for pavers. The total brick produced in thousands, their total values and their average selling price per thousand, are given in Table V.

TABLE V.

YEAR.	THOUSANDS.			VALUES.			AVERAGE. PRICE PER M.		
	COMMON.	PRESS'D.	VITRIFIED.	COMMON.	PRESS'D.	VITRIFIED.	Com.	Pressed.	Vitrif'd
1894	208.195	....	45,488	$ 1.317.473	....	$ 376.951	$ 6 33	......	$ 8.29
1895	180,664	11.159	31,704	1,095,074	$ 87.130	243.928	6.06	$ 7.81	7 69
1896	172,195	6.088	14,385	1,003,624	47,386	112,985	5.83	7.78	7 85
1897	152,446	7.823	56,315	850,834	57,230	426,056	5.58	7.31	7 56
1898	181.331	7,222	35,357	1,062,917	57,252	290,463	5.90	8.14	8.24

In 1897 Iowa ranked ninth in the total value of its clay goods, and third in the value of its paving brick. In 1896 it stood ninth and seventh in the value of total clay products and paving brick respectively. Table VI gives the ten leading clay producing states for 1897 according to rank, and is taken from the reports of the United States Geological Survey.

TABLE VI.

Total Clay 1897.

Rank.	STATE.	No of active firms reporting.	VALUE.	Per cent of total product.
1.	Ohio	842	$ 10,617,684	17.43
2.	Pennsylvania	435	7,874,695	12.93
3.	New York	231	5,615.504	9.22
4.	Illinois	570	5,398,574	8.86
5.	New Jersey	115	5,322,447	8.74
6.	Indiana	580	2,812,309	4.62
7.	Missouri	202	2,396,524	3.93
8.	Massachusetts	109	2,179,396	3.58
9.	Iowa	330	1,821,247	2.99
10.	Connecticut and Rhode Island	48	1,336,670	2.19

The ten leading states in the production of paving brick for 1897 are listed below:

TABLE VII.

Paving Brick in 1897.

STATES.	Thousands.	Value.	Price per thousand.
Illinois	87,169	$719,371	$8.25
Ohio	85,665	597,905	6.98
Iowa	56,315	426,056	7.57
Pennsylvania	41,620	336,413	8.08
New York	28,145	309,564	11.00
West Virginia	38,271	289,886	7.57
Indiana	27,239	266,638	9.78
Missouri	19,620	182,625	9.31
Kansas	17,463	127,600	7.31

Stone.

The stone trade for 1898 was indeed encouraging. The producers reported almost without exception the demand for stone to run from 10 to 20 and even in a few instances, 50 per cent better than 1897. The demand for lime shows very little improvement over the preceding year. The stone quarried includes limestone, dolomite and a small quantity of sandstone. Most of the quarries are small and improved machinery is to be found in but few. Returns have been received from 161 producers and show that a total of $563,586 worth of quarry products were marketed during the year. The production was distributed as follows:

Limestone—building and road making	$ 447,424
Lime	109,600
Sandstone	6,562
Total	$ 563,586

The production by counties is given in table VIII.

In 1898 the state ranked nineteenth among the stone producers and ninth in the value of its limestone.

TABLE VIII.

Value of Stone Produced in Iowa for 1898.

	COUNTIES.	No. of quarries represented.	Dimension.	Rough, rubble and concrete.	Lime.	Miscellaneous.	Total.
1	Allamakee............	1	....	....	....	......	....
2.	Appanoose............	3	$ 65	$ 19	....	......	$ 84
3.	Benton................	4	1,145	11	$ 2,400	......	3,556
4.	Black Hawk...........	9	3,730	250	....	......	3,980
5.	Buchanan.............	2	100	18	....	......	118
6.	Cedar..................	3	73,030	25,222	15,250	......	113,502
7.	Cerro Gordo..........	4	2,186	100	2,880	......	5,166
8.	Clarke.................	3	1,583	755	....	......	2,338
9.	Clayton	8	2,231	1,019	1,570	......	4,820
10.	Clinton................	5	750	578	300	$ 300	1,628
11.	Decatur...............	10	2,958	257	....	......	3,215
12.	Des Moines...........	8	8,100	3,785	250	......	12,135
13.	Dubuque...............	8	11,185	2,398	9,600	......	24,183
14.	Fayette...............	4	11,799	10	2,765	......	14,574
15.	Floyd..................	4	1,118	125	300	......	1,543
16.	Grundy................	1	....	....	....	......	....
17.	Hardin	2	6,500	900	....	......	7,400
18.	Henry	2	4,900	500	1,000	......	6,400
19.	Howard................	2	750	23	....	......	773
20.	Humboldt.............	2	2,240	100	....	......	2,340
21.	Jackson	5	1,480	600	61,950	......	64,030
22.	Jefferson..............	1	....	....	....	......	....
23.	Jones..................	7	91,393	3,966	....	......	95,359
24.	Johnson	5	1,947	1,491	300	......	3,738
25.	Keokuk................	12	3,162	101	....	......	3,263
26.	Lee.....................	7	13,294	14,430	1,000	......	28,724
27.	Linn....................	5	2 840	8,720	7,000	......	18,560
28	Louisa.................	3	8 0	826	....	......	1,626
29.	Madison	7	6,471	5,176	....	......	11,647
30.	Mahaska..............	2	503	....	....	......	503
31.	Marion	4	2,230	251	....	......	2,481
32.	Marshall	1	....	....	....	......	....
33	Mitchell..............	4	845	260	1,850	313	3,268
34.	Montgomery..........	3	1.130	600	100	......	1,830
35.	Monroe................	1	....	....	....	......	....
36.	Scott..................	8	9,591	21,365	175	......	31,131
37.	Story..................	4	1,100	25	....	......	1,125
38.	Tama..................	2	270	80	....	......	350
39.	Van Buren............	5	5,091	3,650	800	......	9,541
40.	Wapello...............	4	11,800	4,100	250	......	16,150
41.	Washington	4	6,080	325	....	......	6,405
42.	Webster...............	1	....	....	....	......	....
43.	Winneshiek...........	1	....	....	....	......	....
	Single producers.......	7	25,169	31,771	160	......	57,100
	Total...............	161	$319 566	$133,807	$109,600	613	$ 563,586

The value of the stone produced in Iowa during the five years preceding 1898, according to the United States Geological Survey, was as follows:

1893	$ 565,374
1894	673,269
1895	468,826
1896	462,128
1897	495,343

The decline in sandstone is more fanciful than real and was largely due to an erroneous classification. The Mason City and Iowa Falls dolomites were listed as sandstones in former reports.

Lead and Zinc.

The year 1898 was marked by more lead mining in Iowa than for some time past. The Halpin mine was a large producer, yielding nearly a million pounds of ore. Aside from this a considerable amount was taken out of the Kane Bros. mine and smaller sales were made from other diggings. In all 1,856,427 pounds of ore were sold for $37,128.54. The Allamakee and Clayton county mines were not producing in 1898 and all of the ore came from the Dubuque region. It was all reduced by the Watters Smelter, at which plant a certain amount of Illinois and Wisconsin ore were also run. There were no big ore discoveries during the year though a number of small bodies were located, and early in 1899 several promising prospects were being explored.

The zinc mines were not active in the early part of the season. Small amounts of the carbonate, or bone. were taken out at Buena Vista, Durango and Dubuque. Late in the summer some of the larger Dubuque mines which had lain idle for some years were opened up, and as prices advanced during the winter, mining became quite active. In all about 750 tons of the carbonate ore were sold at priees running from $5 to $9 per ton. The total value was $5,005.47. The year was marked by the first shipments of the sulphide, jack, made from this region in recent years. The ore was sold by the Alpine Mining Co., and brought from $18 to $22 per ton. The total shipments were 76.5 tons, which brought $1,550.40. Recapitulating, the output of the district was as follows:

Lead, 1,856,427 pounds	$ 37,128 54
Zinc carbonate, 750 tons	5,005.47
Zinc sulphide, 76 tons	1,550.40
Total	$ 43,784.41

GEOLOGY OF CARROLL COUNTY.

BY

H. F. BAIN.

GEOLOGY OF CARROLL COUNTY.

BY H. F. BAIN.

CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Carroll county is located in the western portion of the state, Crawford and Monona counties being between it and the Missouri river. It contains the usual sixteen townships, 576 square miles, and is rectangular in form. Sac and Calhoun counties border it on the north, Greene county lies to the east and Audubon and Guthrie are its neighbors on the south. It includes a portion of the high upland region which divides the waters of the Mississippi from the Missouri. The Altamont moraine crosses it from northwest to southeast just east of the divide. The older, Kansan, drift is well displayed in the southwestern portion of the county. In the northwestern townships the drift exhibits certain peculiarities which, attracting attention in the summer of 1897, seemed likely to throw considerable light upon the geology of the surface formations of the northwestern counties of Iowa. It was with this in view that the study of Carroll county was at this time taken up.

PREVIOUS GEOLOGICAL WORK.

The earlier geological surveys, conducted by Owen and Hall, did not extend into this region. The White survey, however, covered the county and in the report issued in 1870 there is an excellent though brief description of its geology.* This was previous to the general awakening of interest in the surface formations which has been so marked a feature of

*Geol. Iowa, Vol. II, pp. 138-146, 1870.

geologic work in recent years. Accordingly the drift deposits of the county did not receive the interpretation which is now given to them. Nevertheless the more important phenomena were accurately described and certain of the generalizations quite clearly foreshadowed. The term moraine was not used, but the presence of drift ridges was clearly recognized. Mr. Warren Upham seems to have been the first distinctly to recognize the moraine in this county. In 1880 he traced it through Iowa and gave a brief description* of it as developed from Coon Rapids to Breda.

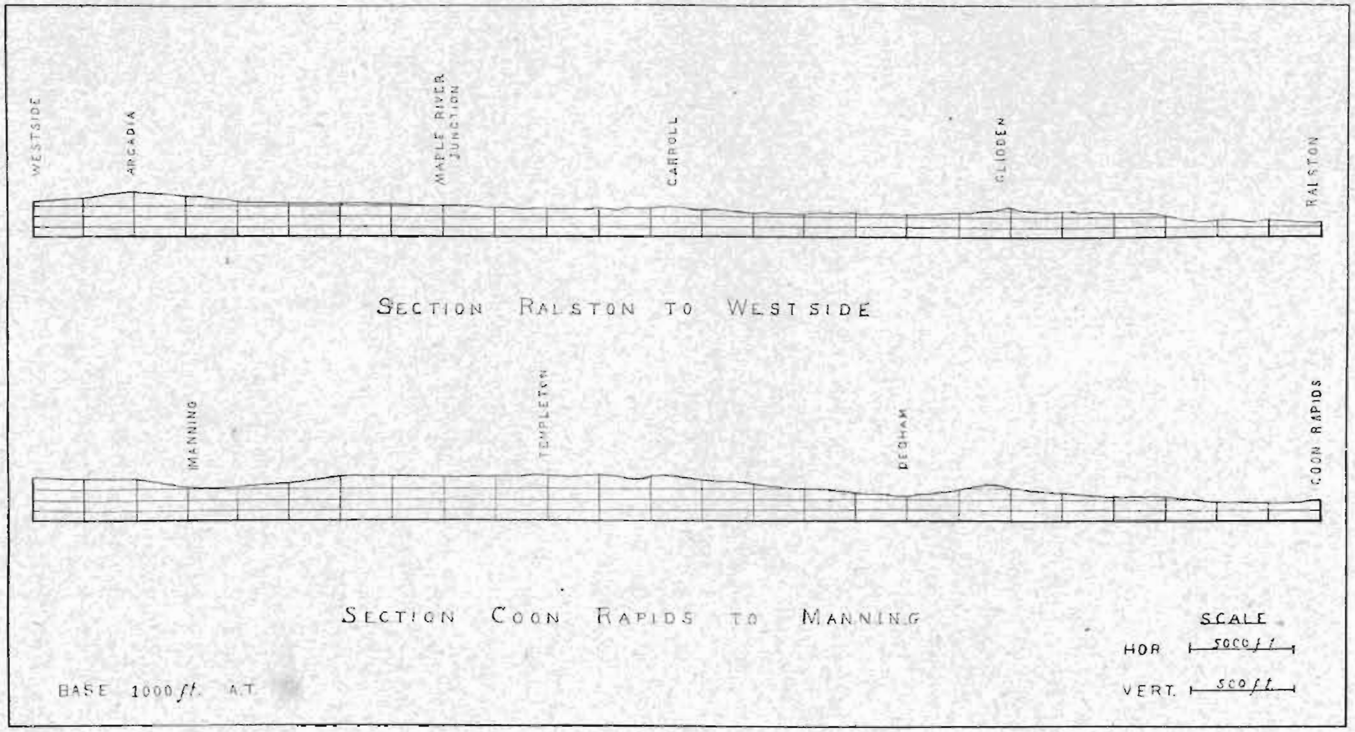
The present work has included certain brief reconnoissance trips in the fall of 1897 and more extended field work throughout the season just past. In the latter the Survey has had the benefit of field conferences with Mr. Frank Leverett, of the United States Geological Survey, who visited the most important exposures in company with the author.

PHYSIOGRAPHY.

TOPOGRAPHY.

Carroll county belongs to the great prairie plain of the middle west. It is not marked by any pronounced inequalities of surface. The maximum variation is about 360 feet, but individual slopes of more than 150 feet are exceptional. The general effect, away from the immediate neighborhood of the streams, is that of a gently undulating plain. This plain is, however, not quite level; neither is it tilted in a single direction. It has been warped so as to slope to the northeast and to the southwest, from a slightly sinuous line running approximately through Arcadia and Templeton. This line is the divide between the Mississippi and Missouri river systems. Plate ii shows two sections across the country, one following the line of the Chicago & Northwestern railway and accordingly running from east to west through the middle, and the other along the Chicago, Milwaukee & St. Paul rail-

*Geol. Nat. Hist. Surv., Minnesota, 1880, pp. 308-309.



CROSS-SECTIONS IN CARROLL COUNTY.

way, in the southern portion of the county. These cross-sections bring out fairly well the broad shield-like character of the divide, though this feature would be more pronounced if longer sections were taken. The fact that the major portion of the county lies on the eastern slope is shown, as well as the fact that the width of the area tributary to the Missouri increases to the south. The sections do not show the tabular character of the divide so well as one constructed regardless of drainage lines would. The railways have necessarily followed the latter for the sake of easy grades. Arcadia, Glidden and Templeton, however, stand practically on the upland. At Carroll the profile shows a considerable elevation, marking the Altamont moraine. This is, however, feeble, as compared with the actual profile, since the hills here rise 130 feet above the railway grade. The slope from Arcadia to Westside is too great, and gives an undue ridge-like aspect to the divide. At Arcadia the grade is but 45 feet below the general upland. At Westside it is considerably more. Coon Rapids is built on the out-wash plain of the moraine, and the hills, both north and south, rise 180 feet above the town.

The general flatness of the region is none the less shown by the profile, despite the fact that in the drawings the vertical scale is exaggerated to ten times the horizontal. The divide is not to be thought of as a narrow ridge, but as a broad, gentle swell. The opposing systems of streams lead up to it on opposite sides. They do not usually interlock to any notable extent. There is ordinarily a rather prominent belt of country between their headwaters, which is barely cut into. This debatable ground forms the real divide and is rather a bit of upland plain with imperceptible slopes than a narrow dividing ridge. It has itself a gentle slope to the south, from 1,476 feet on the higher flats north of Arcadia to 1,450 feet on similar flats west of Templeton. To the east the surface slopes off gently to the Mississippi, falling 850 feet in the 250 miles between Arcadia and Sabula, which lies approximately east of the latter place. The western slope is greater, as the fall between Arcadia and Onawa, which lies fifty miles almost due west, is 391 feet. As measured from Templeton to Lyons the fall is 856 feet in 245 miles, and the corresponding slope to the west is 398 feet in the fifty-eight miles to Blencoe. The major slope, however, is not directly east or west, but rather to the southeast and southwest. This is sufficiently indicated by the direction of the drainage lines, but is readily proven as well by comparisons of levels. The upland surface is very slightly convex. The slope per mile increases both from the west and east as the median line is approached, though the increment is very slight. The surface is not, however, even. It has been etched by the streams, which have cut great gashes into it, and it bears on its surface the unreduced accumulations of the later geological epochs. The latter are piled up so as to form minor rugosites on the shield surface.

The stream valleys, cutting in from the west and the east and acting according to the well known law of river profiles, have longitudinal sections which are of increasing concavity as the sources are approached. This concavity of the river profiles, while slight, as shown in instrumental surveys, is great as compared with the much slighter convexity of the upland surface. The result, of course, is that the stream valleys are relatively deep and sharp near the divide though the same valley is both broader and shallower nearer its mouth. This gives to the country near the divide a relatively fresh and uneroded appearance. There are broad, barely sloping divides bounded by narrow, deep-cut ravines. There are, however, many reasons for the belief that the region of the divide belongs with the more eroded region of southern Iowa in age, at least so far as the part found in Carroll county is concerned.

The erosion topography, while more noticeable near the headwaters of the streams, is characteristic of all the area south and west of the edge of the Wisconsin drift, as traced on the accompanying map. This line divides the county into two areas which are topographically quite distinct. The northeast part of the county has a typical drift-plain topography. The narrow median belt is morainic. The southwestern part is a region of typical erosion forms. Considering the morainic belt as belonging with the drift plain into which it merges, the area shows two sharply contrasted sets of topographic features. The one is almost wholly the result of ice action and the other is exclusively due to the long-continued work of rivers.

WISCONSIN DRIFT PLAIN.

The most striking topographic feature of the drift plain is the presence of undrained areas. While there are now no large lakes within the county there are numerous ponds and sloughs. Goose lake, in the western part of Richland township and a portion of Pleasant Valley, and Morris lake, in the northwestern part of Union township, are now drained but are reminders of a past but little removed. Goose lake was one and a half miles long by one-third as wide, and Morris lake covered nearly 200 acres. These are in the morainic belt near the edge of the drift. The smaller ponds and sloughs, however, are irregularly distributed from the very edge of the Wisconsin to the extreme northeastern corner of the county, and for that matter, for miles beyond. They vary considerably in size and depth but may all be fairly considered shallow and small. Many are now mere grassy swales, covered by water for only a portion of the year. In rainy seasons they expand and in prolonged wet weather a considerable area may be brought under water. Such a condition betokens extreme topographic youth and the increasing amount of land dry enough to cultivate regularly is due more to artificial ditching and drainage than to normal stream action. The whole country away from the immediate neighborhood of the major streams is one gently undulating plain of very slight relief, grass-covered where uncultivated, and dotted by the groves set out by the pioneers. The large valleys are marked by thin, straggling lines of native trees. The plain is made up of interlocking and disconnected shallow basins with intervening swells of reverse contour. It is the type of topography characteristic of the Wisconsin drift plain, throughout the state,* and called the saucer topography, from the likeness of the basins and swells to irregularly placed saucers. The basins are of various outline and usually without outlet. Some are connected by narrow ditch-like channels through which run the sluggish waters of a young stream. Storm creek is really a series of such basins so connected.

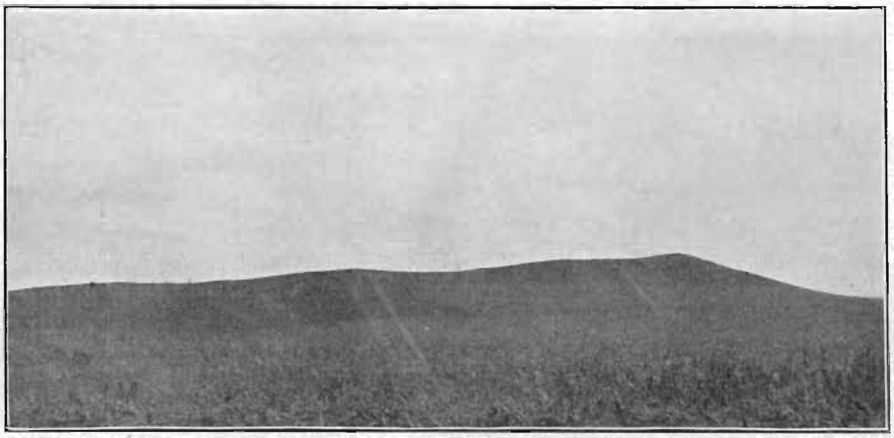


FIG. 1. Morainic knob in northwestern part of Carroll.

The swells rise normally but twenty to thirty feet above the adjacent low land. Southwest of Glidden there is a group rising quite sharply; one with three peaks forming a broken ridge. These are morainic in appearance, and are composed of drift. They seem to be detached, and do not apparently form a part of a connected series. Near Benan there is a small group of kames, which will be described later. Along the southwest border of the drift plain the swells become gradually more pronounced, the slopes steeper and the hills higher, until a well developed morainic topography is found. The morainic hills rise 60 to 70 feet above the drift plain proper, but do not stand up notably above the higher divides

*Geology of Polk County, Iowa Geol. Surv., Vol. VII, p. 270.

west of the Raccoon river. Near Carroll their tips rise to 1,400 A. T. At Breda, and in some portions of Carroll township, the outer slope of the morainic is well pronounced. In general, the inner border is not well defined. In Kneist township the country is slightly morainic as far east as Mt. Carmel. In Pleasant Valley township, where the moraine runs west of the Raccoon river, the border is much better defined, and from Carrollton to the southeast corner the bulk of the moraine is between the Raccoon river and a broad sag which seems to mark the former course of that stream. In general, the moraine covers a strip of country from one and a half to four miles in width. Upon the accompanying map its outer border is traced with some care. For the reason just given its inner border is generalized somewhat. The fading of the moraine into the drift plain is often so gradual as to make it a matter of opinion where the line should be drawn.

Mr. Upham's description of the moraine as found in the county may be quoted as being the first published, and also for its conciseness and clearness.*

"In Carroll county this belt, from one and one-half to three or four miles wide, continues northwestward by Coon Rapids, Carrollton, Carroll, and Maple Junction to Breda. From the southeast corner of the county to Gustine Grove, two miles beyond Carrollton, it consists of swelling hills of till, not so rough as to be typically morainic, which occupy a width of one and one-half to three miles along the northeast side of Middle Raccoon river, rising from 100 to 150 feet above it, and averaging seventy-five feet or more above the smooth sheet of till on the east. Between one and two miles northwest from Carrollton some of these hills, 100 feet above the river, consist of loess at the surface, free from pebbles to a depth of ten or twelve feet. This has the same yellowish color as the upper part of the till. Other hills near have many rock fragments, both large and small, being common till, but morainic in the abundance of bowlders. From Gustine Grove to Car-

* Geol. Nat. Hist. Surv. Minnesota, 1880, pp. 308-309, 1891.

roll the moraine holds its straight course northwestward, lying on the southwest side of the river, which here flows east and then south. Its height is from 100 to 125 feet above the river. A part of its mounds and hillocks through this distance are covered by loess, but mostly their surface is till, with numerous bowlders and pebbles. A lakelet two miles southeast of Carroll, and frequent sloughs, lie in the depressions of this formation. Beyond Carroll the Middle Raccoon river is again its southwest boundary, from which it reaches to Mount Carmel. It here consists of moderately rolling till, with crests thirty to fifty feet above its hollows; and this character continues to the north line of the county, where its course is through the northwest part of Wheatland township, with a width that reaches about a half-mile east and two miles west of Breda."

LOESS-KANSAN PLAIN.

South and west of the moraine a very different sort of topography prevails. There are no lakes, ponds or swales, except such as have been constructed by man, or an occasional bit of marshy ground on a river bottom land. The whole area is thoroughly drained by a well developed system of rivers. The valleys are cut deep into the drift and both they and the narrow, but usually flat, divides stand in obviously close relations to the present streams. There are no hills which rise above the general level and such hills as are present are but dissected portions of the inter-stream areas. The slopes are even and regular and usually are long and gentle. The peculiar hummocks of gravel and knob-on-knob hills which abound in the morainic area, and are occasionally found in the drift-plain area, are entirely absent. Everywhere it is the streams which are dominant and the topography has been carved by them out of the general upland plain already described. Standing on one divide one may look across a series of similar narrow tabular divides all rising to form this plain and together forming a skeleton net-work outlining its former extent. One hundred to 180 feet below this the streams are now cutting. The minor branches are working back into the hills and their headwaters reach up the slopes usually to the base of the loess which constitutes the most usual underground-water level. Above that the slopes are gentler and of different contour as resulting from occasional wet weather erosion and continued atmospheric weathering rather than continued erosion alone. In their lower courses the larger streams are developing bottom lands. The latter are, however, relatively slight and it is doubtful whether any considerable portion represents permanent filling. The flat areas found along the streams belong rather in the category of straths, as defined by McGee.* The region is one of very delicate adjustment of the streams. They are just approaching maturity and while the upland is almost gone, the lowland has hardly begun to form. The streams are actively eating away the inter-stream divides. Occasionally they cut so close together that narrow knife-like divides and unstable forms occur. An instance of this may be seen about three miles east of Dedham (Sec. 14, Newton Tp.) where a narrow divide has been broken up into a series of knobs closely simulating in appearance some of the morainic hills.

The southwestern area, as contrasted with the northeastern, presents everywhere evidence of topographic maturity rather than topographic youth, of erosion rather than deposition, of stream action rather than ice work. It is clearly older and the land forms present must have been almost wholly developed before the Wisconsin ice came into the region.

DRAINAGE.

The streams of the county reflect the same differences that are shown in the topography. The North Raccoon, Purgatory, Elk, Storm and Willow creeks are young, have few branches, and flow in anomalous valleys. The Middle Raccoon, Brushy Fork, the two Nishnabotnas, and their branches are older, have many secondaries and, except in the case of

*Pleistocene Hist. N. E. Iowa, Eleventh Ann. Rept. U. S. Geol. Survey, pp. 261-262.

the first mentioned, normal, unterraced valleys. The Nishnabotnas and their tributaries, with the headwaters of East Boyer river and Beaman creek, belong to the Missouri drainage system. The remaining streams flow into the Mississippi through the Raccoon and Des Moines.

The best developed stream in the northeastern portion of the county is the North Raccoon. This stream has its headwaters in Buena Vista county and unites with the Middle Raccoon near Van Meter in Dallas county. As found in Carroll county it is a narrow, shallow, recent stream. It receives Elk, Buck and Doe runs from the west, and Purgatory creek from the east. Its banks are mainly Wisconsin drift, though there are exposures of the Dakota sandstone on the main stream and on Purgatory creek. The system has done considerable cutting, and at Benan the river is eighty feet below the upland to the west. The divide between the main stream and Purgatory creek in the same region rises seventy feet. Where the North Raccoon crosses the east county line the valley has been cut to a depth of ninety-five feet. There are terraces on the main stream and gravels along Purgatory creek, which will later be discussed.

Storm creek is in many respects the youngest looking stream in the county. It has no real valley, but winds in and out between the low drift swells, expanding to form a swale and then contracting to a narrow ditch. Through much of its course it catches the drainage, such as it is, of the back slope of moraine. It has, though, no system of feeders nor any of the marks of age. It is a typical consequent stream. It joins the Middle Raccoon where the latter flows inside the moraine west of Glidden.

Willow creek is a name applied with more or less authority to three separate branches within the county. The largest is a stream starting about a mile southeast of Glidden and flowing across the southwestern corner of Greene county to the Middle Raccoon, about three miles south of Bayard in Guthrie county. In its upper portion this stream is a recent, consequent stream, similar in all respects to Storm creek. In its lower course it is an older, resurrected stream* occupying a part of a rock-cut valley out of which the Raccoon had been pushed by the ice. This valley is marked by a sag running across Union township and occupied in part by a tributary of Willow creek, to which the name of the parent stream is sometimes applied. The third Willow creek is a small tributary of Nishnabotna river joining that stream near Manning.

The most important river in the county is the Middle Raccoon, or Middle Coon as it is sometimes called. This stream has its headwaters within the county in the high upland region of Wheatland township. From Breda down to Maple River junction it is sometimes called Maple river. About half way between the two places it receives a rather important branch from the northwest, and near the junction it receives the stream followed from Arcadia by the main line of the Chicago & Northwestern railway. These three prairie streams together form what is usually considered as Middle river. From Carroll to Coon Rapids the river receives numerous branches from the west, each with well developed secondary and tertiary branches. A similar series of streams which doubtless once flowed into it from the east have been blotted out by the Wisconsin ice, and now Storm creek is the only important tributary from that direction. In general, Middle Coon flows just outside the altamont moraine, and usually in a valley older than the latter. In this it simulates the behavior of the older portions of the river in Guthrie,† Dallas‡ and Polk§ counties. In Carroll county the Coon has been more disturbed by ice than farther south. As far south as Carroll the valley is outside the theatre of action of the Wisconsin ice, and seems to have been uninfluenced by the latter. At Carroll it turns sharply to the east, cuts through the moraine, and reaches the broad low flat which lies just

*Bul. Geol. Soc. Am., vol. I, p. 549. Iowa Geol. Surv., vol. VI, p. 459.
†Iowa Geol. Surv., vol. VII, pp. 423-426.
‡Ibid, vol. VIII, pp. 60-62.
§Ibid, vol. VII, pp. 276-277.

inside the latter. There has been considerable filling in at this point, and it is not impossible that this portion of the river's course marks a temporary lake, obliterated by being filled up. After joining Storm creek the river runs south to Gustine's Grove where it cuts through the moraine in a narrow and impressive gap, and takes possession of the valley of an older but smaller stream coming from the west. It follows this valley to about a mile south of Carrollton, this portion of its course being beautifully terraced. At the last point mentioned it makes a loop into the moraine then out again, and finally, in Sec. 18 of Union township, it passes again into the moraine. From this point to Coon Rapids it has cut a deep, narrow trench among the morainic hills, and has all the marks of a very young stream. At Coon Rapids it has been pushed over into the valley of another small stream from the west, and it follows this valley to beyond the limits of the county to the mouth of Willow creek in Guthrie county.* In its

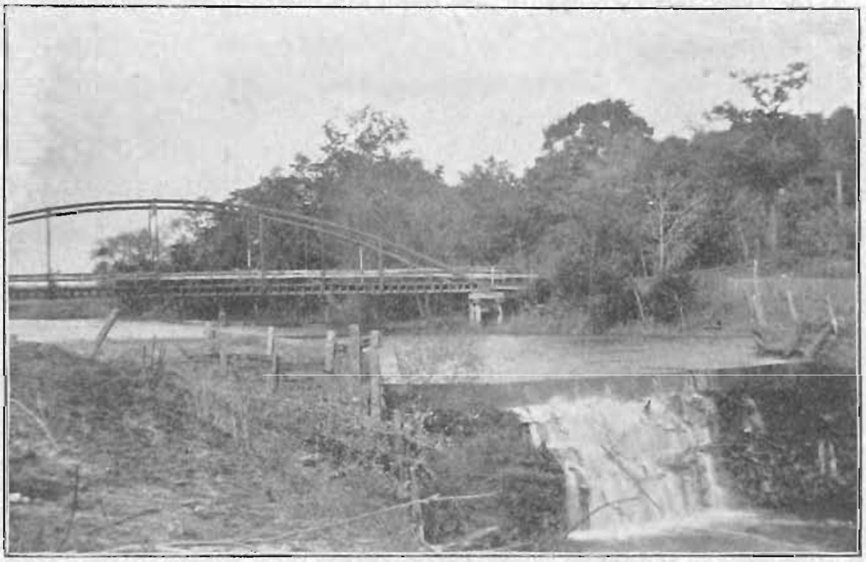


FIG. 2. The Middle Raccoon at Coon Rapids.

*See map of Superficial Deposits of Guthrie County, opp. p. 448, Iowa Geol. Surv., vol. VIII, 1897.

present form the stream is accordingly largely the result of the invasion of the Wisconsin ice sheet. Before the latter came into the region the streams were flowing to the southeast, and had, probably, symmetrically developed tributaries. Brushy Fork and Wichita creek in Guthrie county,* and portions of the Skunk river valley,† mark this old line of drainage. The southwestern front of the Wisconsin ice sheet met this direction of drainage at a slight angle, so that it crossed the successive streams in a north-south direction. Each stream, as it met the ice, was ponded till it found a gap into the next

FIG. 3. Middle Raccoon valley, southwest of Carrollton, with Altamont moraine in the background. Looking northeast. The trees mark the position of the river.

valley to the south. The latter would then be followed by the water till it in turn was blocked by the ice when a new outlet had to be found. As the ice retreated the waters occasionally followed the vanishing ice front until they were located on the low belt of land which in this region seems to be characteristically present just inside the moraine. Possibly in some cases they flowed temporarily under the edge of

*See map cited above.
†Geol. Polk County, Iowa Geol Surv., vol. VII, p. 284.

the ice when the volume of water to be so accommodated was not great. This may have been true for the present case from near Carroll to Gustine's Grove. At the latter point the waters were turned into a valley outside the ice. This same valley was crossed just south of Carrollton, and the water formerly flowing in it was carried along the ice front to Coon Rapids where, as already indicated, it was again turned into a small extra-morainic valley. The old valley proper runs from near Carrollton southeast to the mouth of Willow creek, and is occupied by the lower portion of that stream and the tributary already noted as sometimes called by the same name. The valley now shows as a prominent sag, marked by a line of artesian wells. The small stream flowing in it is wholly inadequate to its excavation, and is a resurrected stream. Coon river accordingly is made up of a series of bits of old captured valleys and new trenches which it has cut for itself. The lower portions of the older streams are cut off, and only in the case of the larger one have been resurrected.

Brushy Fork lies wholly outside the influence of the Wisconsin and shows accordingly what were probably the characteristics of the streams now united to form Coon river. It has a well developed valley cut at the south county line 220 feet below the upland, and has numerous tributaries. These are systematically developed, though those on the southwest are a trifle more abundant and vigorous. In the abundance of tributaries this portion of the stream differs a little from its lower course in Guthrie county.* It is, however, characteristic of the streams of the southwestern part of the county, which cover the area with a perfect net-work of branching and re-branching streams.

The Nishnabotna has two branches in the county, both having their sources within the limits. As developed here they are simple prairie streams of some age and in a heavily drift-covered country. They, with East Boyer river running from Arcadia west, and Beamans creek in the extreme north-

*Geol. Guthrie Co., Iowa Geol. Surv., vol. VII, pp. 424-425.

western part of the county, belong to the Missouri drainage system. Their lower courses have not yet been studied by the Survey.

Of the preglacial history of the streams of the county nothing is known. There are as yet too few facts relative to the rock surface to warrant any generalizations. In general, the streams of the southwestern part of the county are younger than the drift and older than the loess, in which they agree with the streams of most of southern Iowa.* There are minor branches which are younger than the loess and there are some even more recent changes, but the drainage as a whole is post-Kansan and pre-loessial. The streams east of the moraine are post-Wisconsin except the lower portion of Willow creek, already noted.

STRATIGRAPHY.

General Relations.

The surface formations of Carroll county belong entirely to the drift and associated deposits. These cover the entire county so completely that only a very few rock exposures are known. The later belong, with one exception, to the series of sandstones and clays which have been referred to the Cretaceous. Well borings in various parts of the county, as well as outcrops in the neighboring region, indicate that the Cretaceous covers almost the entire county immediately under the drift. At one point only, a different and probably older rock, which is provisionally referred to the coal measures, projects through the Cretaceous and is exposed at the surface. Quite possibly there are other cases of the coal measures running up through the Cretaceous, but if so, they are concealed by the drift.

In the subjoined tables the terrains found in the county are arranged in stratigraphic order.

*Geol. Washington county, Iowa. Geol. Surv., vol. V, p. 125; Geol. Appanoose county, Ibid, p. 374; Relations of Wis. and Kan. Drift Sheets, etc., Iowa Geol. Surv., vol. VI, p. 460; Geol. Johnson county, Ibid, vol. VII, p. 50; Geol. Polk county, Ibid, p. 277; Geol. Guthrie county, Ibid, p. 425; Geol. Dallas county, Ibid, vol. VIII, p. 61; Geol. Decatur county, Ibid, p. 265.

TABLE OF FORMATIONS.

GROUP.	SYSTEM.	SERIES.	STAGE
Cenozoic.	Pleistocene.	Recent.	Alluvial.
		Glacial.	Wisconsin. Iowan? (Loess.) Kansan.
Mesozoic.	Cretaceous.	Upper Cretaceous.	Dakota.
Paleozoic.	Carboniferous.	Des Moines.	

CARBONIFEROUS.

DES MOINES.

The rocks which are here referred to the Carboniferous are, so far as is now known, exposed at but one point; about one mile southwest of Carrollton (Ne. qr. of Sw. ¼, Sec. 1, Newton Tp.) The exposure is on the southwest side of the Middle Coon river, not far below the wagon bridge which spans the river in the same quarter section. The outcrop is small and is at present very largely covered up. The rocks found include both shale and limestone. The shale is gray, thinly laminated, sandy and micaceous. Its thickness could not be measured. It is covered by the limestone, which varies a little but is about three feet thick. The rock has been quarried some and quite a pile of fragments are present. A careful search through this pile of material failed to show any satisfactory fossils, though one obscure fragment, which may represent *Productus costatus*, was found. Nothing of certain value, however, could be collected. The rock itself is nodular and more or less fragmental. The matrix is a brown, fine grained limestone, such as usually breaks with a clean, conchoidal fracture. Here it is set with small, glistening particles, which at first sight may be taken for grains of sand. Nevertheless, many of them are soft enough to be calcite, and they are probably all or nearly all to be considered as small crystals of that mineral.

In general appearance the rock resembles closely certain limestones belonging to the middle coal measures or Raccoon river beds in Guthrie,* Dallas,† Madison,‡ and other counties to the south. In the latter region, however, the rock is usually fossiliferous. The fine grain of the Carrollton beds makes the material unfavorable for fossils and the limited outcrop makes it impossible to hope for another facies of the rock.

This exposure was first located and described by White,§ but no opinion was expressed as to its age. In considering the latter there are three hypotheses to be kept in mind. The rock may be (a) Carboniferous, (b) Cretaceous, or (c) Pleistocene. Considering the last first, it may be remarked that Pleistocene limestones are not uncommon in western Iowa. The loess and drift are very calcareous and the waters coming from them are heavily charged with lime. When, accordingly, such waters reach the surface through permeable sand or gravel beds, they quite frequently cement the latter into a hard ledge of rock. At Woodworth's Glen, in Monona county,‖ a ridge of this kind has led to the formation of a very pretty waterfall. Near Anthon, in Woodbury county,¶ there is a similar ledge. Near Fort Dodge a few years since, large masses of such limestone containing leaves of trees at present living in the vicinity, were collected by Mr. Frank Wilder. In Dubuque and Clayton counties the talus slopes along the Mississippi are cemented together so firmly as to be quite equal in hardness and strength to ordinary limestone of

*Iowa Geol Surv., vol. VII, p. 416.
†Ibid., vol. VIII, p 82.
‡Ibid, vol. VII, p. 509.
§Geol. Iowa, vol. II, p. 145, 1870.
‖Iowa Geol. Surv., vol. V, pp. 280-281.
¶Iowa Geol. Surv., vol. V, p. 281.

the region. In all these cases, however, the resulting rock would be classed rather as a conglomerate than a limestone. The calcareous matter has been deposited around and between particles of foreign matter and it seems not impossible that the presence of this foreign material may have had a certain amount of influence in inducing the deposition. It is known that deposition from super-saturated solutions is brought about by the introduction of foreign matter or by a change in the physical conditions of the solution. With favorable and uniform conditions, solutions may be overloaded to a notable degree without inducing deposition. It is something of a question, then, whether limestones would be deposited from simple fresh-water solutions except by the selective action of foreign material. On the other hand, it is easy to conceive that a conglomerate may be formed by the intense super-saturation induced by evaporation acting on a thin film of calcareous matter coating the pebbles or sand grains of the mass. The action would be similar to that in the case of the formation of stalactites. If, however, any such action took place it would be expected that the phenomena which Posepny has proposed to call "Crustification,"* would be present. There are, however, no signs of such phenomena in the rock in question. The limestone is largely a clean, brown to gray limestone, often almost wholly free from foreign matter, and with no pronounced banding. Furthermore the presence of the small films and grains of crystalline calcite seems to indicate an opportunity to crystalize out of a solution of considerable extent. The rock then does not have the structure or appearance of a spring deposit and is of such texture and composition as to make it difficult to conceive of its formation through the action of fresh-water solutions. It does, however, greatly resemble similar rock found not far away and known to belong to the marine Carboniferous. Other features of the case would be more favorable to the hypothesis of the Pleistocene age of the rock. Its

*Genesis of Ore Deposits, Trans. Amer. Inst., Ming. Eng., vol. XIII, p. 207.

apparently limited development, while it might be accounted for under either hypothesis, would be especially apt to be true if it were formed by spring action. The rock is covered by calcareous Wisconsin drift and rests on an impervious shale. The horizon is one of springs and seepage, and water is usually found seeping out of the bank along the top of the limestone. So far as was observed, however, this water was not more calcareous than elsewhere, where no limestone is present. No analyses were made, but a search for direct evidences of deposition such as are usually common in such cases, was fruitless.

Regarding the second hypothesis, that of the Cretaceous age of the rocks in question, but little need be said. The Cretaceous is the only indurated rock exposed within the immediate vicinity. It is, however, of a radically different lithological character and nowhere in the state has limestone of this type been found in the formation. The only limestones known are found in connection with the chalk beds of the Niobrara. These occur along the Big Sioux river,* the Floyd,† and on the North Raccoon, at Auburn,‡ in Sac county. They are always soft, fossiliferous and separated from the sandstone by a considerable body of fossiliferous shale. The beds at Auburn are of the same character as those on the Sioux, and if they should change so slightly in so great a distance it is hardly probable that in the distance between Auburn and Carrollton there would be an entire change in character. So far as the shales found with the limestone are concerned, they might readily be either Cretaceous or Carboniferous. It may be noted, however, that no such shales are known to occur in the Cretaceous of the region, though common enough elsewhere, while the type is one common in the Carboniferous.

There is, then, no good reason for referring the beds to the Cretaceous, though it can not be affirmed that such a refer-

*Iowa Geol. Surv., I, 147-161; III, 101-114; V, 273-275; VIII, 330.
†Iowa Geol. Surv , vol. VIII, p. 332.
‡Proc. Iowa Acad. Sci., II, 173.

ence would be wholly impossible. The reason for believing the beds are of coal measure age have been largely suggested in the foregoing. The resemblance of the material to the strata common to the coal measures of the region, the possible presence of *Productus costatus* and the apparent impossibility of referring them to any other series known to occur in the region, are the main reasons for the correlation. The limestone is about six feet above the river and the shales below it are largely covered by alluvium. The Cretaceous sandstone occurs at several points along the river, within sight of the exposure. The sandstone rises nearly twenty feet above the water and rests, according to White's observations*, upon some dark colored arenaceous clays, which were below water at the time of the present visits. Certain of the exposures nearest the limestone outcrop show cross-bedding dipping away from the later, which may, perhaps, be significant. The whole field evidence indicates unconformity and accords with the well known fact that there is a marked unconformity between the Carboniferous and Cretaceous.† Accordingly, while in the absence of good fossils the reference can only be provisional, it is best to consider the beds as belonging to the Carboniferous. More specifically, they may be referred to the upper part of the lower coal measures or Des Moines series. They represent, doubtless, some of the beds seen in Guthrie‡ and Dallas§ counties and which belong to the old middle coal measures. This particular facies is now known as the Raccoon river beds.‖ They represent the closing portion of the lower coal measures, the epoch immediately preceding the area of limestone formation represented by the quarry beds at Earlham and Winterset.¶

*Geol. Iowa, vol. II, p. 144.

†Geol. Guthrie Co., Iowa, Geol. Surv., vol. VII, p. 453, and map opp. p. 480.

‡Iowa Geol. Surv., vol. VII, p. 428.

§Ibid, vol. VIII, p. 63.

‖Jour. Geol., vol. VI, pp. 577-588.

¶Iowa Geol. Surv, vol. VIII, pp. 509-520, 524-531. Amer. Jour. Science (4), vol. V, pp. 433-439.

CRETACEOUS.

DAKOTA.

Along Middle Raccoon river near Carrollton and Coon Rapids, and on the North Raccoon and Purgatory creek near Benan, there are exposures of a soft sandstone with some associated clays and conglomerates which may be referred to the Cretaceous. As seen where the wagon road crosses a small stream coming into Raccoon river from the west, south of Coon Rapids (Se. qr., Sec. 34, Union Twp.), the rock is a soft orange colored sandstone, unfossiliferous, and much cross-bedded. It carries small, smooth and well rounded pebbles of white and pink quartz and black chert, such as is so abundant in the Guthrie county exposures. East of Coon Rapids, the railway at one point cuts into some bright red to orange sand, which doubtless represents the top of the formation. Southeast of the same place exposures of the sandstone are frequent, along both the Raccoon river and Willow creek.

At the mill in Coon Rapids the sandstone shows on both sides of the river, and probably originally formed a bar across the stream. It is the same soft yellow material, and carries the usual well rounded pebbles. Pink and white quartz, and black and white cherts were collected here. There are about four feet of sandstone exposed at the dam, the top being ten feet above the water. The stone shows some cross-bedding, and carries a thin band of clay. This band is not much more than an inch in thickness, but is remarkably clean and plastic, resembling putty in consistency. Similar material occurs near Rocky Bluff, southeast of Coon Rapids.* Near the dam there are several large blocks of this clay in the drift in such position as to indicate that they have not been carried far. The fact suggests that undisturbed beds of it may be found overlying the sandstone in the hill. Above the dam the sand-

*Iowa Geol. Surv., vol. VII, p. 452.

stone forms a pretty mural escarpment on the west side of the river, as shown in figure 4.

The Cretaceous exposures south of Carrollton are around the big bend in section 1 of Newton township. The stone shows at several points on both sides of the stream, forming

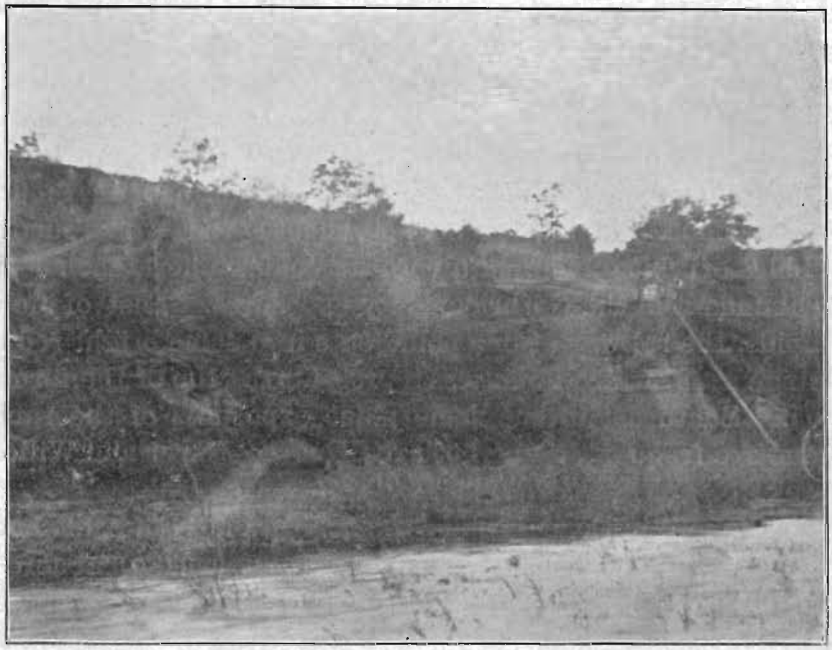


FIG. 4. Dakota Sandstone at Coon Rapids.

sharp bluffs twelve to fourteen feet high, with the tops rising to 1,165 feet above sea level. The stone is friable, lighter colored than at Coon Rapids, and not especially iron stained. It shows cross-bedding, and is cut by a system of great joints. In general appearance it closely resembles the Saint Peter sandstone as exposed along the Mississippi river.

The exposures on Purgatory creek and North Raccoon show similar material. The stone outcrops at the river's edge south of Benan, where a group of kames is cut through by the river. North of the town, at the ford where the old mill-dam was located, the rock is said to occur just below water level. While it is not now exposed the evidence is considered sufficiently good to warrant mapping an exposure at this point.

West of the exposures noted there are no outcrops in the county so far as can be discovered. At Arcadia and other points the sandstone is struck in deep wells. The altitude of the rock at Arcadia is about 1,100 feet, and the rock surface seems to be fairly level throughout the county.

Exposures of the sandstone are found in Sac county (sections 12 and 14, Sac township) and in Greene county,* and outcrops are very abundant in Guthrie county.† It is in the latter county that the rock has been mainly studied. The conglomeratic facies is more pronounced there, and, in addition to the quartz and chert pebbles, numerous silicified Niagara and Devonian fossils are found imbedded in the rock. A few Cretaceous fossils have been collected, and thin lignite seams occur. While neither the fossils nor the lignites are found in Carroll county the other resemblances are so close as to make the correlation quite secure. The exposures near Auburn offer the additional evidence of good outcrops of undoubted chalk rock of the Niobrara in connection with the sandstone. The chalk rock has all the characters common to the same formation as exposed along the Big Sioux,‡ and carries abundant *Inoceramus labiatus*.

PLEISTOCENE.

Carroll county lies within the area which was in recent geologic time covered by a series of great glaciers or ice sheets. These ice sheets, having their birth in the Canadian uplands, crept slowly southward as far as the Ohio and Missouri rivers. All of Iowa, except a small portion in the extreme northeast, was covered at the period of the maximum extent of the ice. Parts of Iowa were covered several times, for it seems that the ice more than once retreated and

*Geol. Iowa (White), vol. II, p. 133. 1870.
†Iowa Geol. Surv., vol. VII, pp. 451-459.
‡Iowa Geol. Surv., vol. III, pp. 99-114.

re-advanced. Some of the later ice sheets did not advance so far to the south as the earlier ones, and there were occasional differences in the deposits made. The drift series in Carroll county includes deposits made by two separate ice sheets. The one covered the whole county and indeed extended for miles beyond its limits. The bowlder clay left by this ice sheet is known as the Kansan, since it has been extensively studied in the state from which the name is derived. The other covers only the northeastern portion of the county. It is known as the Wisconsin, from its magnificent development in that state. These drift sheets, as now exposed, show certain very striking differences, though in many particulars they are closely alike. When the Kansan ice retreated from the region it probably left the country in much the same condition as that is now which was covered by the Wisconsin. The differences in the two areas are mainly differences which have resulted from the weathering of the drift and the erosion by the streams in the post-Kansan interval. One exception to this occurs in the uniform presence over the Kansan drift of the soft, pebbleless loam or loess. This is a comparatively late deposit, laid down over the Kansan after most of the erosion of the area had been accomplished.

KANSAN DRIFT.

As has been stated the Kansan, when first exposed by the melting of the overlying ice, probably resembled greatly the present Wisconsin drift. The great valleys of the Nishnabotna, Brushy Fork, Middle Raccoon and their numerous branches and sub branches, were not present. The whole country was a fairly even plain at a level a little above the present hill tops. This plain probably showed the same sort of swales, ponds and lakes which now dot the country to the north and east. There was the same absence of streams and irregular grouping of hills. Probably heavy morainic belts crossed the area but these have since been cut away beyond recognition, unless indeed the great Mississippi-Missouri divide be the much eroded remnant of such a master morainic belt. There is much evidence in favor of such a hypothesis since wells along this divide go down deep into drift and only occasionally strike rock at levels higher than the surrounding plain. At Arcadia the sandstone of the Cretaceous was struck at a depth of 130 feet in the creamery well, or at an altitude of 1,290 feet. This is about 150 feet above the level of the rock surface in the vicinity of Coon Rapids. At Odebolt wells are driven more than 350 feet in the drift, which would place the rock surface at about 1,100 feet, or a little below that, at Coon Rapids. At Adair the wells are very deep and in the drift. In southern Madison and northern Union county the divide represents an accumulation of drift 250 to 300 feet thick over a fairly uniform surface of rock. All these facts points to the hypothesis that the divide did not exist, at least as at present outlined, in pre-Kansan times, and probably originated as a great morainic belt. There is, however, nothing morainic in its present appearance, nor indeed in the surface of the Kansan, anywhere in the region.

The Kansan drift is a typical bowlder clay. It shows all the marks which are so characteristic of ice deposition as contrasted with water work. Material of all sizes is heterogeneously mixed together. The sorting out of fine and coarse, which everywhere marks water work, is altogether lacking. Fine clay, sand, pebbles and large bowlders are all kneaded together in one mass. The heterogeneity in size is matched by a similar heterogeneity of material. Amid abundant bits of rock derived from the formations of the immediate vicinity are pieces of clear quartz, of pink quartzite, gray and red granites, diorites, traps, and other greenstones, whose nearest outcrops are miles to the north. This northern material, picked up and frozen into the ice, has been shoved to the south and mixed with bits of chalk rock, sandstone, conglomerate and shale derived from the Cretaceous. A matrix for coarser material has been formed from finely ground rock dust, rubbed off the surface rocks by the rock-studded ice. In its original condition this bowlder clay is drab to blue in color. Such a color is occasionally seen in the deeper railway cuts or in wells or in excavations. As ordinarily exposed this blue has given place to various tones of yellow, or even red and brown. The change is due to the oxidation of the iron disseminated through the clay, whereby it is changed from the blue carbonate and ferrus salts to the yellow or brown or red oxides. Frequently an exposure of the blue bowlder clay will show a series of interesting joints and cracks stained yellow to a distance of half or three-quarters of an inch from their walls. This change is the same as that noted on a larger scale where the upper portion of the drift is yellow and the lower is blue. Both phenomena point to an exposure to atmospheric agencies for a considerable time. As has already been stated, the large erosion and the complete development of the drainage system point in the same direction. In southern Iowa, where the Kansan is more characteristically displayed, there are certain other phenomena which mark this drift and which aid in its recognition. For reasons to be discussed later, some of these phenomena are but imperfectly developed in Carroll county, and their absence has caused some confusion to creep into the subject.

The exposures in southern Iowa usually show, in addition to the erosion and general change of color toward the surface, a corresponding decrease in lime and increase in rotted bowlders with the almost invariable development of what is called the ferretto* and the occasional presence of a forest bed or series of water-laid deposits between the drift and the loess. Of these phenomena the absence of lime and presence of ferretto are most widespread and most easily recognized.

The drift is very largely made up of mechanically prepared material. The finer parts consist of broken and finely ground rock. Inasmuch as the glaciers passed over vast areas of limestone, a fresh drift normally carries large quantities of

*Proc. Iowa Acad. Sci., vol. V, p. 90

crushed limestone. This, when touched by any of the commoner acids, has the property of effervescing. When limestone is exposed to weathering agencies the soluble material is carried off and that which remains is unacted on by ordinary acids. When a fresh drift containing small bits of limestone is exposed for a long time to weathering agencies, the same process takes place. After a time all the soluble part of the limestone particles is carried away, and the drift shows no reaction to the acid. It is thus possible, normally, to distirguish between an old, long exposed drift and a fresh one, and in southern Iowa it has been found that before the loess was laid down the Kansan drift was so long exposed to the agencies of solution that there is no reaction to the acid at its upper surface and only a feeble reaction to depths of five to nine feet below. On the other hand the younger drift sheets, with the rarest exception, show an effervescence up to the very grass roots.

Practically all rocks carry a greater or less percentage of iron. The amount while small, is usually the determining factor in the matter of color. As commonly found in the rocks, iron exists in four forms; the carbonate ($Fe\,CO_3$ = Fe 48.27%), which affects various shades of blue; limonite ($Fe_2\,O_3\,H_2\,O$ = Fe 59.89%) and the various earthy ochres which vary in shade from yellow to brown; hematite ($Fe_2\,O_3$ = Fe 70%) which, in the pulverized form, is red, and magnetite ($Fe_3\,O_4$ = Fe 72%), which is black. Magnetite is rarely an important constituent of sedimentary, though common in the igneous and metamorphic rocks. As will be seen from the chemical formulas the carbonate contains no oxide proper. If a rock whose color is determined by the iron content be subjected to oxidation, the color will pass progressively from drab or blue through yellow and brown to red. The latter color is the indicating mark of a high stage of oxidation.

Oxygen is one of the most active chemicals in the air and oxidation is one of the most widespread and prevalent processes to which rocks are subjected in weathering. In driftless areas, where the soil has been formed by the slow weathering away of the rocks, red soils are common. In the driftless area of Iowa and adjacent states the hard, blue limestones and dolomites of the Paleozoic have been leached and oxidized till a sticky, red clay called geest, alone remains. In many of the southern states, beyond the limits of glacial action, red soils of this genesis are common.

When drift is exposed to atmospheric agencies the processes of weathering are closely akin to those which take place in the weathering of ordinary rocks. The chemical activities are relatively more intense, as the material is already broken up, and there is no need to wait for the slow processes of frost action to shatter the rock. The finely comminuted rock flour is at once attacked by chemical agents, and decalcification, oxidation and ferrugination at once set in. Old drifts accordingly soon became highly oxidized. The iron assumes a deep brown to red color. This color is less and less intense from the surface downward. The iron segregates and, to a certain extent, sometimes cements the soil. This dark, iron-stained and highly oxidized band at the surface of the drift is what is called the ferretto. In southern Iowa it is widespread below the loess and at the surface of the drift, and can only be interpreted as indicating a considerable period of weathering between the deposition of the two.

The oxidation which produces the ferretto leads also to the breaking down of the bowlders at the old drift surface. It is a very usual thing to find the granites and other crystalline rocks, which at some depth in the drift are fresh and hard, thoroughly disintegrated at the contact between the Kansan and the loess. Often they may be crushed between the fingers. It is not very unusual to find rotted bowlders in any portion of the older drift, as would be expected from the fact that the older drift sheets had much rotted material to work with. But it is frequently possible to prove that the disintegration of the bowlders at the surface of the drift took place after they had been shaped by the ice, and furthermore the number of rotted bowlders usually increases with the nearness to the surface. Accordingly this phenomenon accords with the decalcification and the development of ferretto in indicating a period of considerable exposure to weathering agencies.

In the study of Polk,* Dallas and Guthrie counties, it was found that the Wisconsin drift rested not on the next younger, Iowan, drift,† but upon the Kansan. In the northwestern part of Iowa there is, outside the limits of the Wisconsin, a drift sheet which has been provisionally correlated with the Iowan.‡ As the exact southern limit of this younger drift is as yet unknown it was necessary in taking up the work in Carroll county to keep in mind the hypothesis that the drift outside the moraine might be either Kansan, Iowan, or both. In the preliminary work some of it was assigned to the Iowan. The later studies have failed to confirm this correlation.

There are excellent exposures of the extra-morainic drift in the railway cuts along the Chicago, Milwaukee & St. Paul railway and the Chicago & North-Western line from Carroll to Manning. There is also a cut of interest at Arcadia, on the main line of the latter road. Along the streams the exposures show the drift in two facies, one, the normal Kansan exposure, showing ferretto, leaching, rotted bowlders, etc., and the other an abnormal type in which these phenomena are lacking. Selected outcrops of these two types are noted on the map in order to indicate their distribution. No attempt has been made to map every outcrop. The universal presence of the loess, often in great thickness, and the fact that the bulk of the erosion was earlier than that deposit, makes exposures relatively rare. This is especially true in the northwestern portion of the county where the streams are small and scattered, and there are no deep railway cuts.

*Iowa Geol. Surv., vol. VI, pp 433-476.

†See paper just cited with Geol. Johnson County; Ibid, vol. VII, 86-91; Cerro Gordo County, 174-176; Proc. Iowa Acad. Sci, vol. V, pp. 64-104.

‡Iowa Geol. Surv., vol. VII, p. 20; Ibid, vol. VIII, p. 28, pp. 335-351.

South and west of Coon Rapids exposures of the ordinary type of Kansan are frequent. The ferretto, rotten bowlders, and leached drift appear immediately below the loess at numerous points, both in Guthrie and Carroll counties. In the first deep railway cut east of Dedham (Sec. 16, Newton Tp.) the leaching has been carried to a depth of five feet and the ferretto is sixteen to eighteen inches in thickness. West of this point to Manning the exposures show only the abnormal facies or imperfectly developed ferretto, except in a small exposure near milepost 413 (Se. qr., Sec. 11, Warren Tp.). This exposure is well up on the divide, back a little from its edge (144 A. T.). It is near exposures of the unleached till. The section shown is sketched below.

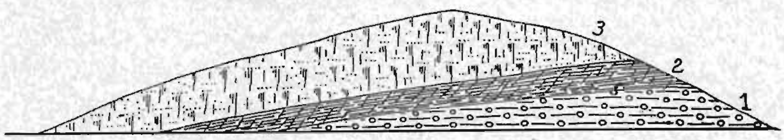


FIG. 5. Old soil east of Manning. Loess, 3, over soil, 2, which in turn lies on drift, 1.

The loess is quite the usual type, mantles the hill in ordinary fashion, and is about six feet thick at the crest. The old soil is a sandy, black material, resembling in some particulars certain phases of the white clays, but with abundant humus mixed with the rock material. It is about eighteen inches to ten feet thick. Below it the drift is only shown to a corresponding depth, but it is thoroughly leached and iron stained, a typical ferretto zone. West of Manning, between that place and Manilla, the drift is deeply stained, and near Aspinwall there are exposures showing a good ferretto. In the southwestern part of Manning and in the hills south of town the Kansan shows the high color indicative of iron staining.

From Dedham north to Carroll exposures of leached till are frequent and ferretto is found widely. In the northwest quarter of section 36, Carroll township, for example, the drift is leached to a depth of five feet, and the ferretto is fairly well developed. Along the main road west from Carroll ferretto is seen at several points. In the railway cut immediately east of Arcadia, a little over one foot of ferretto is developed at the contact between the loess and the drift. In the southeast corner of Wheatland township the drift shows below the loess. It is reddish-yellow and has been leached. No great thickness of the drift is exposed here, but that present seems sufficient to fix the age of the deposit. The exposure is the more interesting because it is the farthest north of any in the county where the ferretto has been recognized.

The abnormal phase of the Kansan is not exposed in the extreme southeastern part of the county. In the northwest and southwest, however, the exposures of unleached till probably outnumber those that are leached. An excellent example of this drift may be seen in a group of exposures in some railway cuts about two miles southwest of Carroll (Sw. qr., Sec. 22; Nw. ¼, Sec. 27; Ne. ¼, Sec. 28; Se. ¼, same; Sw. ¼, Sec. 33, Carroll Tp.). The exposures extend from where the railway first cuts into the hills to within about a mile of Halbur. The ordinary exposure is as sketched below. The

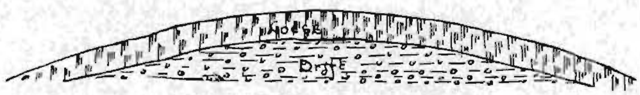


FIG. 6. Loess over Kansan drift.

drift is a yellow bowlder clay rising fifteen to twenty feet above the railway track. It is full of pebbles and bowlders up to a foot in diameter. Granites are common and there are a good many rotted bowlders, though the latter do not seem much more abundant at the top than the bottom. There are joint cracks in the clay, which are stained a deep orange color and yet react to the acid. There is no ferretto and the drift usually effervesces up to the contact with the loess. In no case is the drift leached to a depth of more than six inches, except in the southwest quarter of section 33, where, in between two exposures of the type described, is one showing leached drift and a ferretto zone. In section 27 the loess does not show lime concretions and gives usually but a feeble reaction to the acid. It rarely extends over the crests of the drift exposures in any thickness, being usually less than three feet deep at such points, though there may be as much as eight feet on the flanks of the hills. Further south the loess thickens and becomes calcareous.

The non-calcareous, fresh looking drift is exposed at intervals along the railway to Manning, and from there east to Dedham. In the southeast quarter of section 15, Warren township, a cut shows ten feet of unleached and unstained drift below six feet of loess. In the southeast quarter of section 11, near the exposure of old soil already mentioned, twelve to fifteen feet of the unleached till, covered as usual by the loess, is exposed. On the township line (Se. qr. Sec. 12) the calcareous drift again shows and there are more exposures between Templeton and Dedham.

In the northwestern part of the county there are several good exposures of the calcareous drift. In the northwest quarter of section 36 of Wheatland township, about forty feet of the drift is exposed. It is very light colored and shows no staining at all. The erosion here is very active and the stream gorges quite sharp. About two miles south of Breda (Ne. of Se. Sec. 24, Wheatland) about twenty to thirty feet of fresh looking calcareous drift shows below loess of the usual aspect. The drift is light buff, carries many granites, shows no ferretto and reacts to the acid up to the loess contact. At one point in the drift there is a considerable patch of orange-colored sand, but not much of the material is seen. In the northwest quarter of section 9, of the same township, there is a small drift exposure on Beaman creek. The drift is yellow, effervesces freely and shows no ferretto, though the exposure is poor and it can not be certain that the original upper surface of the drift is exposed.

The exposures specifically noted, and others located upon the map, indicate sufficiently how intimately the two phases of the drift are inter-related. Excepting these in Wheatland township as possible examples of Wisconsin buried beneath wind-drifted loess, though this is not believed to be their explanation, the whole series belongs together. The most careful search in the field has so far failed to reveal any dividing line either vertical or horizontal. If there were two drift sheets in the region, one fresh and unleached and the other old and ferretto-covered, the younger drift could hardly have the patchy geographical distribution necessitated by the facts in the present case, except upon the hypothesis of its being thin and much eroded. Single exposures of more than thirty feet are, however, known and there is no evidence whatever that it has been eroded. No cases of super-position have been detected nor are there forest beds, buried loess sheets or other evidences of an interglacial period. Both sorts of drift have exactly the same relations to the loess, which in turn shows no evidence of being anything except a homogeneous deposit. Except that Wheatland township seems less eroded than the others, a fact explained by its position far from large streams, there is no apparent evidence in the topography of difference in the age of the various parts of the region. Accordingly, the two sorts of drift are believed to represent but differing phases of the Kansan. The unleached drift resembles closely the Kansan usually found five to ten feet below the base of the ferretto. It is as if a portion of the Kansan had been in places eroded, and that, in short, is believed to be the correct explanation of the phenomena.

It is obvious that the presence of the lime in the drift depends upon its original abundance and the degree to which it has been carried away. The former is wholly independent of the time the drift has been exposed, and the latter may or may not vary with the time, but, in the absence of specific evidence to the contrary, it may be fairly assumed to be dependent on that factor. All the drift sheets of Iowa carry, when unaltered, enough lime to make the acid test a valuable one. The presence or absence of lime, then, in the upper portion may, unless good evidence of its exceptional nature be offered, be considered to indicate the amount of exposure which the drift has suffered. The amount of lime leached from a calcareous drift will depend upon the strength of the solvent and the amount passing through the drift in a given time. It will also depend upon the direction which the percolating waters take. In an arid region the excessive evaporation may locally cause the flow of ground water upward and lead to the deposition of soluble salts in the upper portion of the soil. This factor can, however, hardly be important in the present case. There is no reason to believe that the water soaking into the ground in one part of Iowa varies greatly in solvent power as compared with that in any other part, when considerable districts are considered. There are, of course, wide differences in detailed areas, but in general the rain water, which is the original source of the underground circulation, seems as likely to become charged with humus and other acids at one point as another. It is true, however, that the amount of water entering the ground varies widely. There are considerable differences in the rainfall in different part of the state, the variation in 1894 being from 15.65 inches to 27.57. In the northwest it ran from 15 to 20 inches, and in the southeast from 20 to 25, with areas running from 25 to 30.* The run-off also varies widely. There are no data relative to Iowa streams, but it is well known that the run-off is proportional to the character of the surface, the slope and the time distribution of the rainfall. It is greater in an area with a non-absorbent surface, on greater slopes, and when the rainfall is bunched. In the present case the surface of the Kansan drift seems not to vary in any systematic way with relation to its capacity to absorb water. The rainfall in Carroll county is probably as evenly distributed

*Rept. Iowa Weather and Crop Service, 1894, p. 52.

as in other parts of the state. There are, however, considerable differences in slope. It is to be remembered that the region represents the high upland between the Mississippi and the Missouri. The railway grades across the country are heavy and the stream grades are even greater. The drainage consists of the headwater portions of the streams only, and the water reaches them by running over the steep surface slopes rather than through the ground. Springs in the southwestern part of the county are almost unknown and seepage is rare. The whole series of evidences indicate that the water passes over, rather than through, the drift, and hence that solution is relatively slight. This seems to be one of the important factors in the failure of the leaching tests.

When the grades are high and the amount of surface water notably in excess, it must be obvious that erosion will be very active. This will be as true of the slower and less easily noticed surface erosion of the interstream areas as of the direct corrasion of the streams. It has already been suggested that stream action in the region is intense. It is also true that the erosion of the general surface is much greater than on the low, wide divides further south. The relations of the loess to the river valleys indicate that the latter occupied approximately the same position in the interval between the Kansan and the loess that they do now, so that erosion was probably, at least, as active then as now. This is probably the main explanation of the absence of the ferretto and leached drift in the region under discussion. Aside from the fact that there may have been less leaching here than in lower lying regions, the active erosion by which the stained and leached material has been carried away as fast as formed, is probably the main factor in the explanation. In very many instances where the more weathered portion of the Kansan is absent, the field evidence shows that its absence is probably due to the local intensity of erosion. The fact that erosion over a general surface presents the widest variation in intensity and effect from point to point, is not perhaps always appreciated as thoroughly as it should be. A difference of five to ten feet in the amount of erosion on neighboring swells and divides is not unusual, but where the uppermost stratum happens to be so strongly marked as is the ferretto zone, the effects of this difference become very striking. On high land much cut up by streams, erosion is very active, and it seems reasonable to believe that these minor differences from point to point would be correspondingly magnified. These very conditions prevail now over most of the territory in question, and the stream history of the region, so far as it can be read, indicates that conditions were not greatly different before the loess was laid down.

The high divide in Madison and Union counties between Clanteen creek and Grand river shows a corresponding local variation in the amount of erosion. At numerous points the yellow, unleached drift of the Kansan is exposed at the surface in the heart of a region where leached drift and ferretto are widespread. In this case the erosion, since the exposures are loess covered, seems to be recent. In the case of the Carroll county outcrops the ercsion would be mainly preloessial.

No attempt can be made here to fix the age of the extramorainic and fresh looking drift found in the counties to the north. The work of the present field season has shown that the reference of this drift to the Iowan is probably wrong. The work in Carroll county has shown that there is no danger of confusing certain phases of the Kansan with the later drifts. It is possible that a limited extent of the northwestern part of Carroll county is covered by the later drift. The exposures are few, and such as are found are of the equivocal type. There are, however, no marked border phenomena, such as elsewhere denote the limits of a drift sheet, and the possibility of a later extra-morainic drift within the limits of the county is believed to be remote. Until, however, the counties to the north be studied in more detail than has so far been possible the absence of such later drift cannot be positively affirmed. It may be said, however, that so far no extra-morainic drift is known in Carroll county which is not known to be Kansan, or which might not readily be assigned to that formation.

It is interesting to note that up to the present no traces have been found in this county of any drift older than the Kansan. The pre-Kansan, which is occasionally found in other parts of the state,* is not known to occur here, though it probably at one time covered the county. A fuller study of well records than has yet been possible would not unlikely show its presence.

THE LOESS.

Outside the area covered by the Wisconsin drift, and to a limited extent along the border of the latter, the surface formation is the loess. This is, as developed here, a buff, pebbleless clay, friable, and of limited plasticity. It is intermediate in character between the dust-like and highly absorbent type of loess developed along the Missouri river and formerly known as the Bluff deposit† and the very plastic, argillaceous, gray to white surface clay common in southern Iowa, northern Missouri and parts of Illinois, Indiana, and Ohio, and called by Leverett the White Clay.‡ The loess in Carroll county takes the usual sheet form, spreading over the drift as an irregular but usually thin mantle. It is not sufficiently thick to develop its own peculiar type of topography. It conforms everywhere to the inequalities in the surface of the Kansan drift, and exposures of the latter occur only when it has been cut through by recent erosion.

The relations to the Wisconsin drift are at first glance a little confusing. Near Coon Rapids the loess passes directly under the latter. There are two exposures near town which show this feature. One of these exposures is in a deep rail-

*Proc. Iowa Acad. Sci., vol. IV, pp. 54-66; vol. V, pp. 86-101.

†Swallow: Geol. Surv., Missouri, 1855, pp. 59-76. White: Geol. Iowa, vol. I, pp. 103-109. 1870.

‡Leverett: Amer. Geol., vol. X, pp. 18-24.

way cut about one mile east of the station. The surface around the cut shows the usual saucer topography characteristic of the Wisconsin drift plain, and the sides of the cut show the usual Wisconsin drift with a buff color, numerous pebbles and occasional lime balls. Below the drift and rising about two feet above the track is the loess. It is of the same type as is found west of town, and is unfossiliferous. In general appearance it closely resembles the matrix of the Wisconsin drift, but prolonged digging failed to show any pebbles in it. The Wisconsin is in this region made up largely of worked-over loess, but the loess seen in the cut is believed to be undisturbed. The exposure is about a half mile back from the edge of the Wisconsin drift.

The second exposure is about a mile south of town, near where the main wagon road crosses the river. The hills on the east side of the river are capped by a series of little gravelly knolls, such as form part of the gravel apron fronting the Wisconsin. Back of these knolls is the moraine and the regular bowlder clay. The slope toward the river shows the usual loess overlying the Kansan drift, so that the ice itself evidently failed here to reach the valley, though the outwash spread over the flanking hills.

In the northwestern part of the city of Carroll the same relations may be observed, though the exposures are not so satisfactory. The hill upon which the hospital stands is made up of ordinary Wisconsin drift and shows the usual surface bowlders. The next hill west is heavily coated with loess, which was at one time used for brick making. Traveling north on the road, in the northwest quarter of section 24, Carroll township, the loess is seen passing up the slope to the north line of the section. Soon a few pebbles are discovered on the slope. These become more common until a well exposed bowlder clay is found, from which the pebbles have evidently washed and rolled down over the loess. A good contact could not be found here, but the whole of the evidence seemed to indicate that this exposure falls in with those observed near Coon Rapids, and that the relations are the same as those observed in Polk*, Guthrie† and Dallas‡ counties, where the loess passes well under the edge of the Wisconsin. Doctor Beyer's observations in Story county, detailed in this volume, greatly strengthen this hypothesis; so much, in fact, that the general matter may fairly be considered to have passed out of the realm of hypothesis into that of demonstrated fact.

North and west of Carroll the loess occasionally laps up over the edge of the Wisconsin for a short distance. This is true about the middle of the west line of section 29, Kniest township. At this point about twelve inches of loess covers the outer face of the moraine. In the southern part of section 29 of the same township, loess two feet thick is found overlying drift which can hardly be anything but Wisconsin. Upham mentions cases where as much as ten to twelve feet of loess is found mantling the morainic hills.§ No such thickness was observed in the present work, though hills of loess-covered Kansan were found among the morainic knobs. In every case examined by the writer where undoubted Wisconsin is covered by loess the latter is very thin and the situation is such as to invite the hypothesis that the wind has blown the loess from the west up onto the outer slopes of the morainic hills. It is believed that in Carroll county, as farther south, the loess is distinctly older than the Wisconsin and usually runs under the latter.

The age of the loess can not be positively fixed. In eastern Iowa,‖ and the same is true in Illinois, the bulk of the loess seems to have been deposited contemporaneously with the maximum advance of the Iowan ice. The loess in Polk, Dallas and Guthrie counties has been considered to fall in the same category. There is no observable break between the loess of Guthrie and Carroll counties, and the natural refer-

*Iowa Geol. Surv., vol. VII, 340-343.
†Ibid, 463-466.
‡Ibid, vol. VI, 433-476.
§Iowa Geol. Surv., vol. VII, pp. 88-90.
‖Geol. Nat. Hist. Surv., Minnesota, 1880, p. 309.

ence for the latter would likewise be to the Iowan. It is known, however, that loess in northwestern Iowa probably belongs to more than one geological epoch,* and Professor Macbride's observations in Humboldt county† make it conclusive that the Iowan did not cover the region immediately north of Carroll county as has heretofore been believed. The correlation of this loess with the Iowan drift is accordingly open to considerable doubt. While it remains true that its most probable age is Iowan it can be assigned only to that period tentatively.

THE WISCONSIN DRIFT.

The northeastern portion of Carroll county lies within the limits of the Des Moines lobe of the Wisconsin drift. This lobe marks out the territory occupied by a long tongue of ice which crossed the north state line between Clear Lake and Spirit Lake, and covered all the territory south to its apex at Des Moines. This was the last ice sheet which entered Iowa.

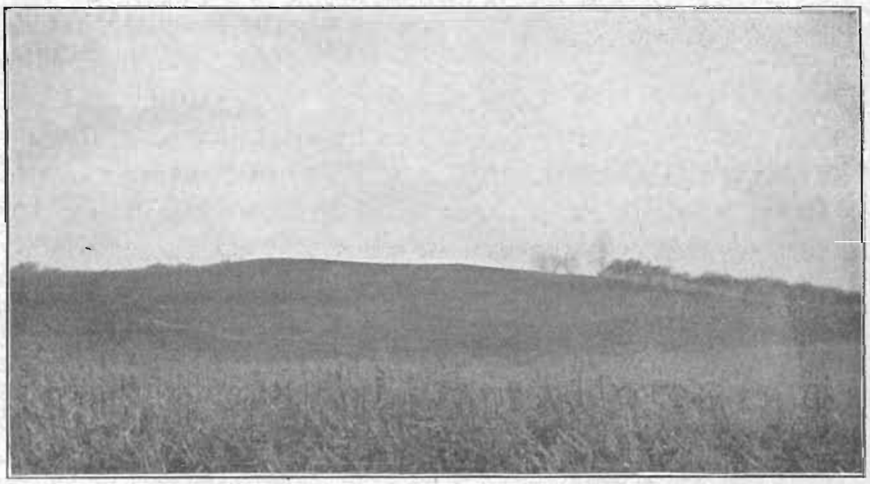


FIG. 7. Morainic hill in northwestern part of Carroll.

It occupied the territory at a time geologically very recent; measured, probably, by a few thousand years. The evidences

*Geol. Plymouth County, Iowa Geol. Surv., vol. VIII, pp 339-340.
†In this volume.

of the recency of this invasion are mainly to be found in the topographic peculiarities of the region already discussed. The drift itself is also of the fresh type. It has a gray to light buff color, and does not show the deep orange, brown and red

FIG. 8. Cretaceous clays in Wisconsin drift above the dam at Coon Rapids.

colors, which have been shown to be characteristic of the older drift sheets. It is wholly unleached, and the pebbles and bowlders found in it are usually hard and unweathered. The surface of the country is plentifully sprinkled with the large surface bowlders commonly referred to as niggerheads. These are so widespread as to be everywhere observable, and so frequent as to be an occasional hindrance to agriculture. The farmers gather them up in great ridges along the fences, or bury them where they lie in the field. These surface bowlders are mainly granite, and several types are found. Limestones also contribute a notable percentage to the lot, and in early days the surface limestone bowlders were occasionally burned to lime.

The matrix of the till consists mainly of loess which has been picked up by the glacier and reworked. Pebbles, bowlders, sand and clay have been kneaded into it. Figure 8 illustrates how great masses of Cretaceous clay and other materials have been mixed together. The preponderance of the loess material, however, is sufficient to give the bowlder clay a buff color, and it is believed that the latter is due more to this cause than to any alteration in the iron content since the drift was laid down. The Wisconsin drift is usually associated with gravel and coarse sand deposits,* and this characteristic is well developed in the area under discussion. Surface knolls of gravel are common throughout the intermorainic area. They are especially characteristic features of the broad bottom land followed by the Middle Raccoon river for some five miles east of Carroll, and can be easily recognized by passengers on the railway. Near Glidden and at various points throughout the region they occur.

South of Benan (Se. qr., Sec. 3, Glidden Tp.) there is a group of gravel hills cut through by the river. These hills rise 130 feet above the river and project forty feet above the surrounding country. They are clearly constructional in form and may be referred to the type known as kames.†

*Geol. Wisconsin, vol. I, 284, 1883; Iowa Geol. Surv., vol. VI, pp. 442-443. 1897.

†Chamberlin: Third Ann Rept. U. S Geol. Surv., p. 300.

On the river here, there are a series of terraces as sketched below. These are gravel terraces of aggradation and seem

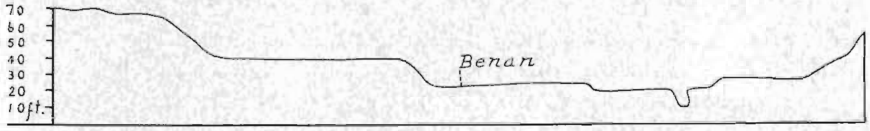


FIG. 9. Terraces on the North Raccoon at Benan.

to be gravel trains. They are probably to be correlated with some temporary halt of the ice in retreat, at some point a few miles above Benan. They do not extend down the river as far as the east county line, as the valley at that point shows no sign of them. Their regular form differentiates them from the gravel patches found throughout the vicinity and to which category the gravel on Purgatory creek belongs.

Along the Middle Raccoon river gravels are developed wherever the valley has been influenced by the ice. The river cuts through the moraine in section 26 of Pleasant Valley township and runs outside to section 1 of Newton township. This portion of the valley seems to have been ponded by the ice and formed a temporary lake. While in this condition it was filled up with gravel to a level sixteen feet above the present stream. Into this gravel the river has since cut till the old filling is represented now by remnants of a fringing terrace. At Coon Rapids, where the drainage of the ice was turned into the valley of the small stream coming from the west, a gravel terrace was formed, and the main part of the town is located on this terrace. Patches of the same terrace can be found along the river valley for some miles south of town. The terrace at its upper end rises fifty feet above the river, but to the south it declines until it eventually reaches the level of the flood-plain. This indicates that the terrace was produced by material supplied from an ice front above, rather than by ice damming it below. Most of the material of the gravels is hard and fresh, but some is rotted, and occasionally there are streaks which are iron-stained. A section taken on the north side of the railway pit at Coon Rapids showed the following beds:

		INCHES.
4.	Stripping-loam, brown to black, with a few scattered pebbles	6-30
3.	Gravel, stained, much rotted material, sharply limited below	12
2.	Gravel, coarse, irregularly colored and bedded	60
1.	Gravel, fine, worked further south in the pit	12+

The layer of iron-stained and rotted gravel (No. 3) suggests a weathered zone akin to the ferretto, but the fact that it is so sharply limited below sets it off from this class of phenomena. It is probably a local accident of bedding. The weathered material is almost exclusively a coarse grained, micaceous granite or some other micaceous rock. One enumeration of weathered bowlders gave the following results: granite, 15; mica schist, 1; greenstones, 2; limestone, 1. It seems that the weathering is due more to the presence of easily decomposed minerals than to the position of the materials.

At first glance the gravels seem to contain a great preponderance of granitic material, and this is true if attention is directed to the larger sizes. An enumeration, however, of all the pebbles more than a half inch in diameter in a certain surface gave the following results:

	Limestone.	Granite.	Greenstone.	Quartzite.	Miscel.
Fresh	75	13	38	5	4
Weathered	0	8	4	0	0

The granitic appearance of the gravels is accordingly due to the fact that the basic rocks and the limestones have been more broken up. Altogether, some seventeen varieties of pebbles are fairly common in the gravel. These varieties include diorite, slate, greenstone, amygaloid, fine grained trap, mica schist, white quartzite, pink and clear quartz, black and white chert, limestone, Cretaceous conglomerate, limonite and a bit of taconyte, the rock associated with the iron ores of the Lake Superior region.

The gravel shows east of the river, where the railway cut crosses the little side lobes of the hills. It soon gives place to the unassorted material of the bowlder clay. The latter contains much the same pebbles which are common in the gravel. The bowlder clay, except where patches of gravel occur, forms the surface material throughout the northeastern portion of the county. The stream cuts into it, and in the morainic area it is heaped up into the irregular hills and knobs characteristic of moraines. Elsewhere it spreads out into the gently swelling drift plains.

ECONOMIC PRODUCTS.

COAL.

Carroll county lies within the limits of the Western Interior coal field, though it is west of the portion which in Iowa has been shown to be productive. The nearest mines have been located near Grand Junction and Rippey in Greene county, and along the Middle Raccoon in Guthrie county. The coal mined at Grand Junction lies at an altitude of about 1,000 feet. The coal mined near Fanslers would be at about the same altitude. If there were no dip to the west, and a slight one must be allowed for, this would still be a considerable distance below the lowest point in the county.

As has already been stated, the coal measures in Carroll county are covered not only by the drift but by the Cretaceous beds. The full thickness of the latter is not exposed at any point in the county and may be expected to be somewhat irregular since the Cretaceous is uncomformable, not only with the drift above, but with the coal measures below. As shown southeast of Coon Rapids, on the Middle Raccoon, the beds have a thickness of about one hundred feet. This may be assumed to represent the average thickness for the eastern portion of the county. In the western portion the sandstone rises, in points at least, to 1,300 feet above tide, and probably is accordingly, 100 feet or more thicker. The drift in the region varies from nothing to as much as 516 feet. The maximum thickness of drift is not, however, found at the same point with the maximum thickness of Cretaceous, and in general, the drift may be assumed to be from 100 to 200 feet in thickness. It will vary between wider limits but the larger portion of the area would probably show rock at that depth. It is obvious that in any prospecting for coal in this region it is desirable to stick to the lowlands so as to avoid, as much as possible, drilling through the drift. Coon Rapids, in the southeastern portion of the county, lies on a terrace at 1,173 feet above tide. The river itself has cut to about 1,118 feet. This is believed to be about the lowest point in the county. Allowing fifty feet for the dip, the horizons which carry coal to the east should occur at a depth of about 170 feet below water level at Coon Rapids, or 200 to 225 below the bottom land of the Coon river.

As has already been stated, the Cretaceous sandstone rests uncomformably upon the coal measures. The latter were exposed to erosion and their surface was cut up by streams before the later beds were laid down over them. The thickness of sandstone to be penetrated will accordingly vary from point to point. At the one outcrop already described the drill would at once go into the coal measures. The upper portion of the coal measures is, however, but sparingly productive, and it would in all probability be necessary to go at least to the horizon already mentioned as productive at Grand Junction and Dawson, in order to obtain coal. Coal may be encountered at any point in the coal measures, but the chances of thick beds increase toward the bottom. The base of the coal measures here would probably lie at from 550 to 600 feet above sea level, so that there is, in Carroll county, a considerable thickness of strata suitable for exploration with the drill.

The question whether or not the coal horizons which run under Carroll couuty would prove productive, is a difficult one, and one that can only finally be settled by the drill. There are in this region no surface indications of value whatever. With the exception of the outcrop of presumably Carboniferous limestone, all the rock exposed in the county is much later than the coal measures and wholly unrelated to them. The sandstone outcrops afford no basis whatever for the local belief that they indicate coal. The whole question is one which can be answered by systematic drilling, and by that alone. There are, however, certain indications of interest.

It is well known that with certain rare exception, the individual coal beds of Iowa do not have any great lateral extent. They pinch out from point to point, thicken and thin, pass over low rolls and are cut out by sandstone and shale. It has so far been impossible to construct a detailed vertical section of the measures that could lay claim to be of more than local value. While, however, the coal beds are not usually persistent, there are certain horizons which have usually proven productive, and which may be recognized over a considerable area. For example, the coal mainly worked in Keokuk, Mahaska, Wapello, Monroe and Lucas counties occurs at about the same stratigraphic horizon. The coal is not continuous from point to point and only perhaps 12 to 15 per cent of the entire area carries coal in workable thickness. Yet the horizon shows more or less coal for a distance of at least sixty miles back from its outcrop, and it is about as rich at its western known limits as at its eastern. How far under cover of the upper coal measures it will prove productive cannot yet be stated, but there is reason to believe that at least some of the area will show coal of merchantable thickness. This Wapello horizon, as it has been called, is the best known coal horizon in Iowa. It has furnished more coal and has been more extensively prospected than any other. It is probable that it is more extensive than many of the other horizons, but, none the less, its richness for a distance of at least sixty miles down the dip is of suggestive interest in connection with the probabilities of coal in Carroll county. Coal has been mined and is, in fact, now being mined within twenty-five miles east of the county line. The presence within the county of an exposure of the Raccoon river beds of the coal measures shows that the latter have not been cut out by the erosion which intervened between the Carboniferous and the Cretaceous. It is, accordingly, altogether probable that workable coal beds underlie at least the eastern part of Carroll county. The commercial question resolves itself, accordingly, into a matter of the value of the coal and the probable cost of locating, opening and mining it.

It has already been stated that any prospecting in this region should be carried on with the drill. The experience of large mine operators in the southern part of the state indicates that for this work the core or diamond drill is better. The depths to which it would be necessary to go, and the fact that so little is known of the beds underlying the county, make it more than ever necessary that there should be no mistakes in the determination of the thickness and character of each stratum penetrated. The increased cost of diamond drill work is more than repaid by the increased certainty of the result. The cost of diamond drill work varies greatly with the depths, nature of the strata, skill of the manipulator, amount of work done, proximity to water, and the number of diamonds or other tools lost or injured. Several large contracts have been carried out in this state, where the depths were mainly from 100 to 400 feet, at an average cost of 75 cents to $1 per foot. Single holes will, of course, average very much higher, and the figures quoted cannot be attained except under favorable circumstances, and where 5,000 to 10,000 feet of drilling are to be done. It would probably require at least that much work here to locate coal with sufficient accuracy to warrant the further outlay incident to sinking a shaft and putting up top works. A single drill hole or even a dozen drill holes would probably not answer the purpose. The amount of money necessary to open up a mine here would be large, and the cost of prospecting would necessarily be considerably higher than in the counties to the east, where the coal lies nearer the surface and more is already known as to the region. A mine in this region, of course, would have important advantage in reaching the western markets, and in the local trade. It is quite unlikely, too, that mines will be opened west of Coon Rapids and Dedham, as, in the region beyond, the drift is so thick as greatly to increase the cost of prospecting, and the distance from the outcrops of the coal so great as to make it very uncertain as to whether the beds have not altogether thinned out. The lower portion of the valleys of Brushy Fork and the Coon river, especially the latter, are the most favorable points in the county in which to prospect. Whether or not the chances are sufficiently favorable to warrant investment at present is something of a question. It certainly would not pay unless the company undertaking the work has sufficient capital to prospect thoroughly a considerable area.

CLAYS.

The Pleistocene series is the only one which yields workable clay in the county The Cretaceous clays are of excellent quality, but so far they have not been found in quantity sufficient to be valuable. As has been suggested, the large amount of Cretaceous clay in the drift at Coon Rapids indicates that a good bed of it occurs at some point in the vicinity, under the drift. It is possible that this may at some time prove workable. The only clay now used is the loess. This is widely distributed throughout the southwestern portion of the county, and is excellently adapted to the manufacture of several grades of brick. It may be worked by hand, as a soft-mud, or on the dry-press. It is especially well adapted to the latter treatment, and yields a good face brick of excellent color. While much of the loess is so filled with lime concretions as to be nearly useless for brick work, there are large bodies almost entirely free from lime. At present brick is made at but two points in the county, though brick plants have been in operation at other points, and the material is at hand over most of the county. The facts that coal must be shipped in, and that there is only a moderate demand for brick, has so far prevented the growth of a large industry. The brick now marketed are of the cheaper grades. Dry-press work has not been attempted, the initial expense more than balancing the increased return on the probably limited output. With the growth of the towns and cities of the county, and the decreasing use of wood in building, these conditions will undoubtedly change in future. The plants now in operation are located at Carroll and Manning.

Carroll.—In the southwestern part of the town the firm of O'Neil & Kellenberg have the most important brick works in the county. The plant was started a little more than fifteen years ago by Mr. C. P. O'Neil, and has been enlarged from time to time. At present it includes one soft-mud Eagle machine, a Freese brick machine, 30 horse-power engine, 40 horse-power boiler, pump, drying-sheds, etc. The kilns are two in number, one a large cased kiln, and one smaller round, down-draft. The main portion of the output is burned in the former. In burning, about four days are allowed for water-smoking, and the whole burn is made in seven to nine days. About half the burning is done with wood. The drying is done on pallets, under open sheds with movable roof, and there is but little trouble with checking The brick are a good building brick, of salmon color and fair strength. The clay is taken from a hillside pit on the grounds, and is of two varieties, which are suitably mixed. A sketch of the pit is shown below.

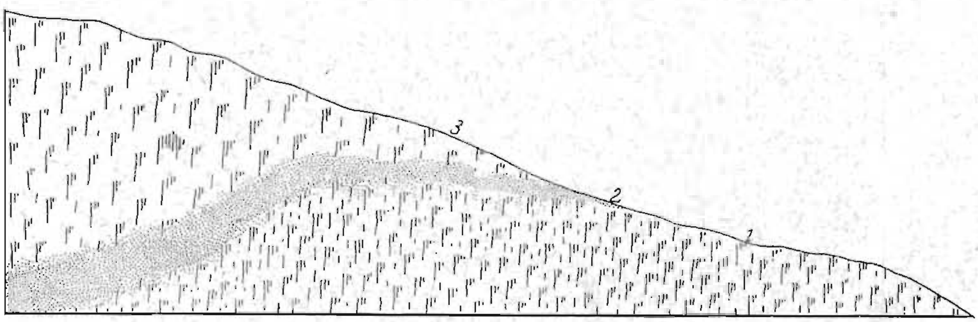


FIG. 10. Clays of the O'Neil Brick Yard, Carroll, Iowa.

The figures refer to the following beds:

		FEET.
3.	Loess, vertical jointing, considerable humus, buff color, ordinary character of the loess of the region	3-7
2.	Sand with clay streaks thickening to the left, horizontally bedded	1-3
1.	Fine grained blue, silt-like loess with horizontal bedding	5

In the northwestern part of Carroll, at a locality already mentioned, brick were for some years made by W. M. Boom. The loess was used to make a hard brick, but the work stopped in 1892.

Manning.—On the slope north of the Chicago & North-Western railway station is the brick yard of Mr. F. H. Long. The plant includes a New Quaker machine, the usual sheds and a cased kiln. The loess is used to make an ordinary building brick. Near this plant brick were formerly made by hand from the alluvium of the bottom land.

At Coon Rapids, between the station and the southern boundary of the county, Mr. E. Gibbons formerly ran a small hand brick yard. A short-grained brick of rather light color was made.

WATER SUPPLIES.

SURFACE WATERS.

The rainfall of Carroll county is abundant. The annual precipitation in 1897 was 28.80 inches at Carroll.* The immature drainage of the Wisconsin drift plain allows a considerable amount of this water to stand on the surface, and occasional small lakes and ponds afford convenient storage reservoirs. Outside of this area ponds can only be made by artificially damming some small stream or draw. The streams themselves, where they have cut below water level, carry abundant water for stock purposes. Many large stock farms, however, are supplied by means of wells and windmills. Dug wells are usually shallow and draw their supply from the base

*Rept. Iowa Weather Service, 1897.

of the loess or from the upper part of the drift. The stock wells are, however, usually drilled and reach deeper horizons. There seems to be no very general water horizon, but at varying depths, from 100 to 300 feet, beds of gravel are found in the drift. These are of irregular distribution but are good water horizons. A few of the wells in the western part of the county pass entirely through the drift and into the Cretaceous. The creamery well at Arcadia is an example. This well is 430 feet deep, the well head being at 1,430 A. T., and the sandstone being found at 130 feet. An abundant supply of excellent water is found. The creamery well at Mt. Carmel is said to be 260 feet deep and to end in gravel. South of Mt. Carmel there are several wells from 200 to 300 feet in depth. In the northwest of the northwest of section 11 is a well reported to be 305 feet deep, and in the southwest of the southeast, section 3, is one of 250 feet.

ARTESIAN WELLS.

There are no deep artesian wells in the county, but there are several shallow flowing wells which may perhaps be included under the title artesian. There is an area showing such wells east of Coon Rapids. The old drift-filled valley, previously noted as running through Union township, includes most of these. They are located on the accompanying map. The Hoffman well has been running for eleven years. It throws a vigorous stream from a two-inch pipe, and a small artificial lake has been made by the overflow. The well is at the foot of the slope into the old valley, and the well head is at 1,115 A. T. The Tom Campbell, John Glenn, and Henry George wells are in the neighborhood. In Coon Rapids itself is the Robertson & Martin well. Some of these wells go down to the level of the Dakota sandstone, but they do not seem actually to penetrate it. The hypothesis that they draw their supplies from the source is negatived by this and the further fact that the upper portion of the sandstone is not known to be especially aqueous in this region. Apparently

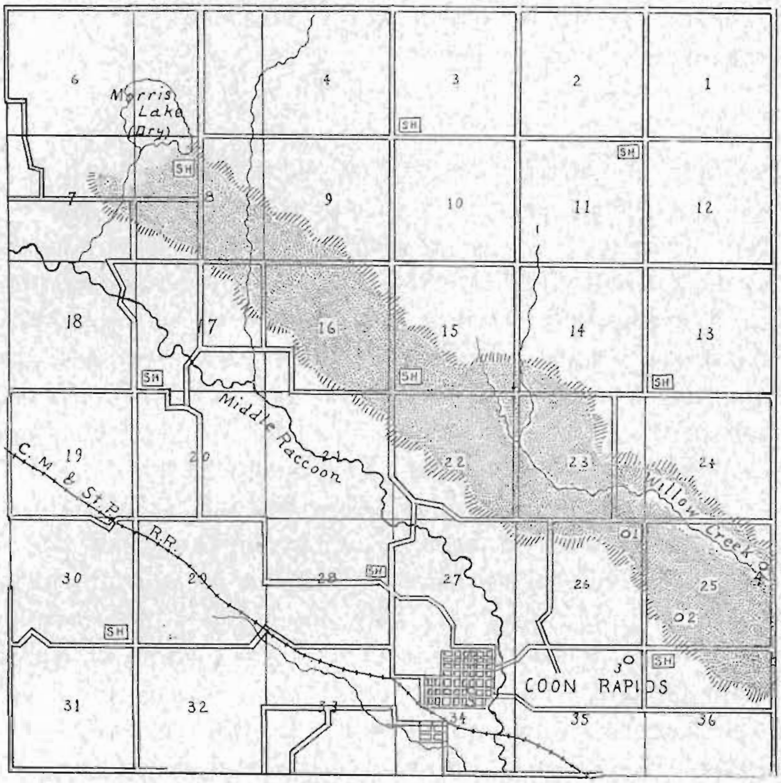


FIG. 11. Sketch map, locating old river valley and artesian wells near Coon Rapids; 1, Hoffman well; 2, Campbell well; 3, Glenn well; 4, George well; 5, Robertson & Martin well.

the wells are entirely similar to the local flowing wells common in Greene, Story and Guthrie counties.* These draw their supplies from the drift. Local gravel beds, or in the latter case, a buried loess forms the aquifer. The latter is probably the source of water in some of the Coon Rapids wells, while others are doubtless supplied by the old river gravels now buried beneath the drift. It is to be expected that more flowing wells will be found in the area covered by the Wisconsin drift, particularly near the moraine. The wells will, however, all be shallow. The deeper horizons, the various Paleozoic sandstones which supply the wells of northeastern Iowa,†

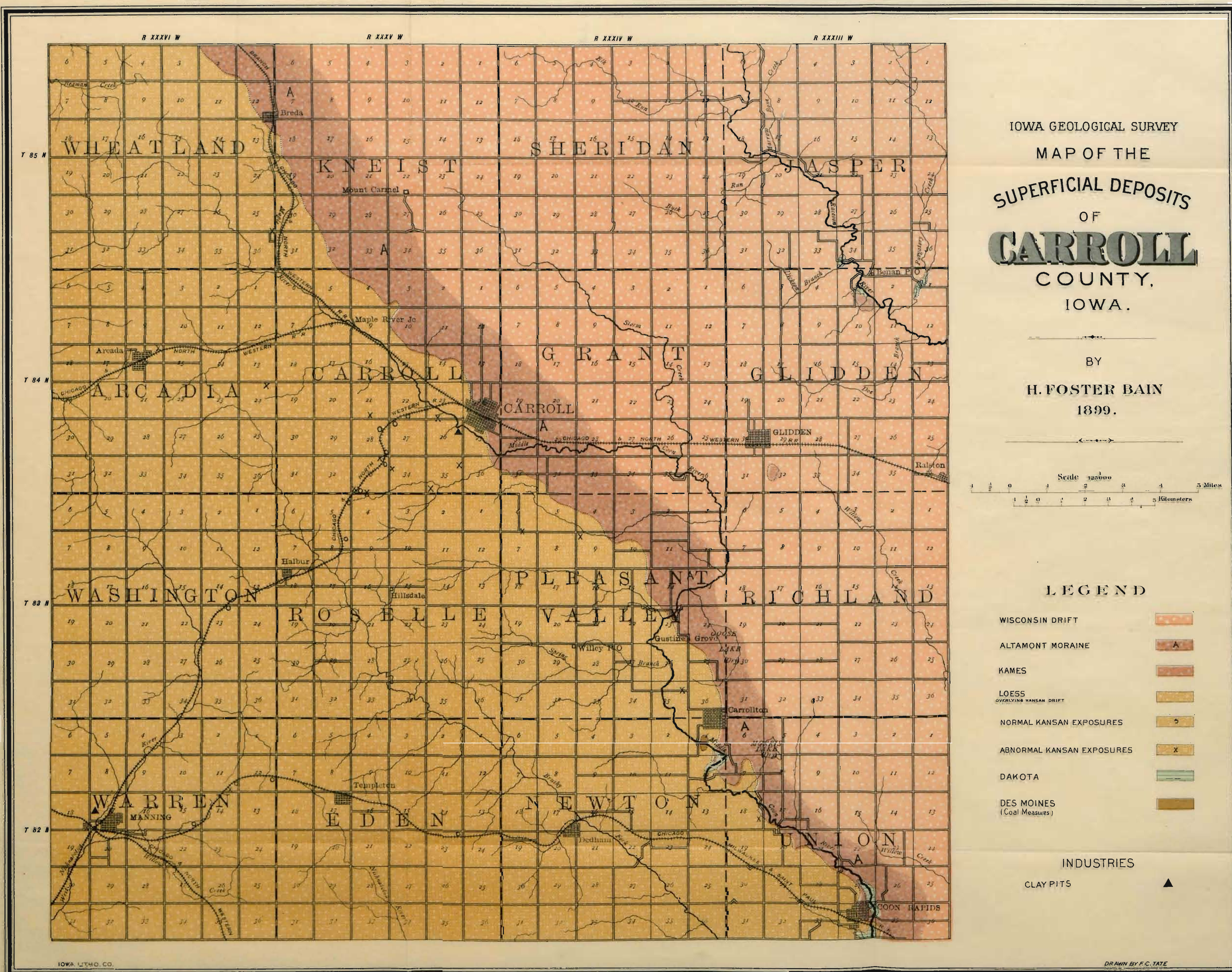
*Iowa Geol. Surv., vol. VII, pp. 483-486.
†Norton: Artesian wells, Iowa Geol. Surv., vol. VI, 113-428.

may in time be drawn on for water, but they will not afford flowing wells in this county.

SOILS.

The soils of Carroll county are of two general types, corresponding to the two drift sheets that occur in the area. In the northeast, in the region covered by the Wisconsin drift, is a typical drift soil. The upper six to twelve inches is usually composed of a fine black loam or sandy material. This material is usually coarser in texture than the loess of the southwestern portion of the county, and is accordingly often spoken of as the sandy soil, as distinguished from a loam, which term is locally more usually applied to the loess. The latter covers all the region south and west of the Altamont moraine, as marked on the accompanying map. It is a buff to yellow, fine pebbleless material, and is usually mixed with humus in its upper portion. The black soil is not ordinarily as deep over the loess as over the drift, except in cases of secondary wash. The loess found here is intermediate in type between the fine, pulvurent, dust-like material found along the Missouri and the stiff clays found in southern Iowa and northern Missouri. It stands dry seasons excellently and does not bake. The homogeneous texture of the loess gives it important advantages as a soil. The air spaces in it are so evenly divided that the tension of the water is equalized throughout the mass and the plants accordingly receive an even, regular supply of moisture.

Both the drift and the loess soils of the county are rich and largely productive. The drift-covered farms have the advantage of a more level surface, but face the difficulties of numerous surface bowlders and the common necessity for artificial drainage. The farms in the loess region have no difficulty in the matter of drainage or bowlders, but, on the other hand, the erosion of the region has been so vigorous that steep slopes interfere to some extent with easy cultivation of the ground.


IOWA GEOLOGICAL SURVEY
MAP OF THE
SUPERFICIAL DEPOSITS
OF
CARROLL
COUNTY,
IOWA.
BY
H. FOSTER BAIN
1899.
Scale 1/125000
Miles
Kilometers
LEGEND
WISCONSIN DRIFT
ALTAMONT MORAINE
KAMES
LOESS
OVERLYING KANSAN DRIFT
NORMAL KANSAN EXPOSURES
ABNORMAL KANSAN EXPOSURES
DAKOTA
DES MOINES
(Coal Measures)
INDUSTRIES
CLAY PITS
R XXXVI W
R XXXV W
R XXXIV W
R XXXIII W
T 85 N
T 84 N
T 83 N
T 82 N
WHEATLAND
KNEIST
SHERIDAN
JASPER
ARCADIA
CARROLL
GRANT
GLIDDEN
WASHINGTON
ROSELLE
PLEASANT VALLEY
RICHLAND
WARREN
EDEN
NEWTON
UNION
Breda
Mount Carmel
Maple River Jc.
Arcadia
CARROLL
GLIDDEN
Ralston
Halbur
Hillsdale
Gustine's Grove
Willey P.O.
Carrollton
Templeton
MANNING
Dedham
COON RAPIDS
Benan P.O.
IOWA LITHO. CO.
DRAWN BY F.C. TATE

Samples of the various soils as found in the county have been taken and are now in the hands of the chemist for analysis. It was hoped that at least the preliminary results might be included in this report, but that has proven impossible, so that the matter must wait for the fuller discussion of the soils of the state now in preparation.

GEOLOGY OF HUMBOLDT COUNTY.

BY

T. H. MACBRIDE.

GEOLOGY OF HUMBOLDT COUNTY.

BY T. H. MACBRIDE.

CONTENTS:

INTRODUCTION.

Humboldt county belongs to that group of Iowa counties known in the various publications of the state as north-central. It lies in the third tier of counties south of the Minnesota line and is almost equally distant from the Missouri and Mississippi rivers, some twenty-five or thirty miles nearer the former stream. The surface is an almost perfect plain; the highest elevation within its limits rises not more than thirty or forty feet above the general level. Nevertheless the west side of the county, as at Gilmore, is higher by about 100 feet than the eastern, and the north side is likewise higher than the south, so that the general drainage, as effected by streams, is from the north and the west. The only streams of any importance are the forks of the Des Moines river with their tributaries. These occupy comparatively narrow channels, cut down from twenty to seventy feet below the level of the general plateau. To the early pioneer the whole county must have appeared an absolute plain—a prairie, covered with grass and flowers, dotted everywhere by unnumbered lakes, or marshes, darkened by their sombre-tinted vegetation, varied with woodland only within the narrow limits of the flood-plains of the streams. Now the whole landscape is that of a cultivated field, adorned on every side with grove and orchard; the ponds and lakes have vanished, or show as mere depressions, where waving harvests of wheat and corn attest the marvelous fertility of the prairie soil. The native woods have been, in large measure, still preserved, at least in area, and, thickened by a growth unchecked by fire, they border the river channel in many localities much as of yore, contributing wonderfully to the general beauty and attractiveness of this fortunate county. Owing to causes to be set forth by some future student of the political history of the state, the county is among the smallest, includes but twelve congressional townships, while most counties of the state have sixteen and many, twenty. Kossuth, to the north, has twenty-eight, Webster, to the south, twenty, and Wright and Pocahontas, to the east and west respectively, have each sixteen. Nevertheless, within these narrow limits Humboldt county does not lack biologic, geologic and topographic problems of peculiar interest. These will come out as occasion offers, in the pages to follow. The lack of coal in the county and the scantiness of rock exposure have combined to make this county hitherto less attractive to those sent by the state to report on her resources. Prof. James Hall, whose name will be forever associated with all the geologic science of his country, studied Iowa, it is true, but never saw the northwest counties. Worthen, in 1856, under Hall's direction, followed the Des Moines river and proceeded as far as Fort Dodge.* Dr. White, who, as state geologist, succeeded Hall, visited Humboldt county in 1867, remained for a few days only and made a hasty examination of its rocks and soils. His report, published in 1869–70, is still the only account we have been able to find of the problem before us.† Dr. White visited the exposures in the town of Humboldt along the bank of the river, the oolitic beds, the point known since as Dr. Welch's quarry, of which he gives a section, the exposures at Rutland, and certain exposures just west of the Humboldt county line, in Pocahontas county, on Lizard creek. From a mere cursory examination, Dr. White recognized in general, the true stratigraphy of the rocks he saw, and pointed out the fact that their character did not lend much encourage-

*Hall, Geology of Iowa, vol. I. p. 147.

†Rept. on the Geol. Surv. of the State of Iowa, by Charles A. White, M. D., vol. I, pp. 198 199; vol. II, pp. 243-245.

ment to those who even then were seeking coal within the limits of the county.

PHYSIOGRAPHY.

TOPOGRAPHY.

The topography or surface character of Humboldt county is, as already stated, for the most part extremely simple. Nevertheless, its very simplicity must be explained, and for thorough explanation, as men look at such problems to-day, it requires the consideration and study of not less than three determining factors; these are the Kansan drift, the succeeding Wisconsin drift, and the erosion effected by the Des Moines river and its branches and tributaries.

The Wisconsin drift,—for so we name the latest surface deposit by which the entire north-central portion of Iowa has been more or less completely covered,—has been so thoroughly described elsewhere in these reports* that simple mention would seem perhaps sufficient here. To the Wisconsin drift we owe the peculiarly level upland so characteristic of the county. To the same deposit belong, as a distinguishing character, the thousand diminutive, circular lakes or pools which mark everywhere the open prairie; nor less in the southern and eastern townships the undrained swamps and peat-beds, until recently, so uninviting to the farmer; as, also, the larger lakes that once lent their sheen to the beauty of the landscape. Indeed, almost the entire topography is typical Wisconsin, recognizable from the car windows by the intelligent passing tourist.

Not only is the surface drainage of the county thus imperfect, incomplete, but the erosion effected by the smaller streams is in many places likewise peculiar, indicating in unexpected places the comparative newness of the process. For instance, the banks of the Des Moines in Beaver township and elsewhere show, instead of the usual tributary valleys, singular precipitous ravines cut almost perpendicularly

*See, of the present series, Iowa Geol. Surv., vol. VI, pp. 431-476.

into the body of the drift. These extend back from the river only the shortest distance, sometimes failing to reach the margin of a marsh or lakelet lying only a few rods distant. The processes of erosion here, as such things go, are plainly new and recent.

But, however striking such features of Humboldt topography may thus appear, there are some others that are still more remarkable. A moving glacier is nothing if not a gigantic plane which tends to obliterate completely all surface irregularities and to leave just such a landscape as has been described. But to do its work completely the amount of drift carried by the glacier must be large; enough, practically, to fill up the depressions of the topography pre-existing. In the case before us that condition failed. The amount of detritus carried down was small. In Humboldt county the Wisconsin drift-sheet is remarkable for its thinness. Notwithstanding the fact, therefore, that for the county as a whole the Wisconsin determines the dominant landscape type, there are, nevertheless, numerous special localities in which the deposit is either entirely wanting or so thin, so very thin, as hardly to affect the topography upon which it came. It is but a veil, through which an earlier, older sculpture exhibits still its ancient features. This older topography is that of the Kansan drift, carved by all the erosion which everywhere mark that time-worn stratum. The hills in Humboldt county in general, except as otherwise noted, may be said to represent the pre-Wisconsin or Kansan surface. Those near the mouth of Bloody creek may be taken as example, stretching back northwesterly, with long, low valleys between them. The steep river banks everywhere, such as that near the bridge on the east side of the East Fork, in section 10 of Grove township, or that immediately south of the railway tracks in section 24, Corinth township, are Kansan, and have, in all probability, suffered little change in all the years since floods from retreating Kansan ice-fields passed down the valleys. The ridge north of "Owl lake" is Kansan with a veneer of Wisconsin on its steep northern declivity. There are even a few scattered hills (or kames?) in the western part of the county probably referable to the same formation. The highest noted is in Corinth township, Nw. qr., Nw. ¼, Sec. 4. This is a gravel knoll, capped by Wisconsin bowlders. It seems to bear no relation to the local drainage system, but the gravel, though not freshly exposed, may be put down as Kansan, judging from what is observed elsewhere. Further details will be given later, when we come to discuss the Kansan drift as such.

As referable to glacial action it remains to mention one further topographic feature marking the surface of Humboldt county. This is a low ridge, generally breaking off rather abruptly on the south, extending east and west across the northern half of the county. To be more explicit the highland referred to is traceable from Wacousta through Delana and across Grove and Humboldt townships; it forms the divide between Bloody and Trullinger creeks; rises abruptly just north of Hardy and forms the plateau on which stands the town of Renwick. This highland carries up the general level of this part of the county some twenty or thirty feet and seems to be morainic in character; referable probably to the retreat of the Wisconsin ice.

The third factor to be considered in discussing the topography of Humboldt county, is erosion, as effected by the principal streams.

The two principal branches or forks of the Des Moines river meet to form the main stream near the southern boundary of the county. The East Fork enters almost exactly at the center of the north line of the county, bends slightly to the east, and flowing southwardly turns west at length to meet the West Fork at a point almost directly south of the point of entrance first mentioned· so that the East Fork divides the county from north to south into two almost equal sections. For nearly its entire course through the county the East Fork flows above sandy bottoms. There are no rock exposures until we reach the south line of Grove township where the stream cuts into the St. Louis limestone, as will be hereafter noted. The valley of the East Fork is narrow, its banks often low and wooded, the erosion of its flood-plains referable in some places at least to waters from the Kansan ice. A good illustration is seen near the town of Livermore. The flat land on the west side of the river is the old Kansan flood-plain, while the hill east of the bridge is a steep bank of Kansan gravel covered by a veneer of Wisconsin drift. The situation is much like that often observed in the loess-covered regions farther south, with the exception that the Wisconsin here takes the place of the loess.

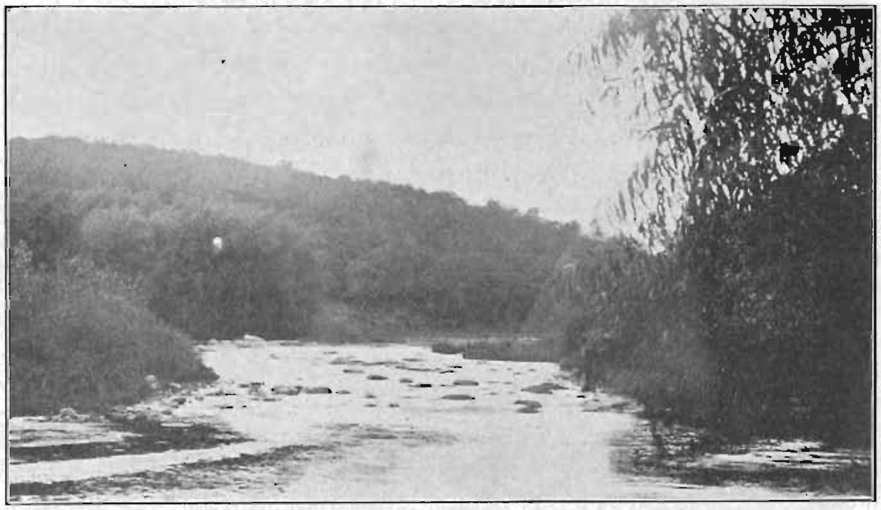


FIG. 12. View of the West Fork Des Moines river, near Humboldt, showing bowlders in river channel.

The West Fork enters the county near its northwest corner, follows the county line southwardly for about one mile, then turns west into Pocahontas county, only to reappear and re-enter Humboldt county five or six miles further south, at Bradgate. The course of this stream, unlike that of the East Fork, is everywhere marked by rock-exposures; the channel is almost uniformly rock-paved and strewn with granite bowlders from the drift, so abundant as to suggest some New

England mountain channel, rather than the quiet, creeping river of the level prairie (Fig. 12). The sides of the stream are limited by rocky walls which become more and more picturesque, more and more prominent topographic characters, as we pass east and south. The banks are, therefore, generally well defined; floods seldom rise above them, and the valley across which the present channel passes, now to this side, now to the other, seems old and long unflooded. In fact, the flood plain, nowhere wide, perhaps less than a mile at its widest point, southwest of Rutland, shows everywhere a shallow deposit of sand and gravel referable again to the Kansan drift, with only here and there a scattered bowlder or group of bowlders, to indicate that ever the Wisconsin had come and gone. It is difficult to reconcile the situation thus described with our pre-conceived notions of glacial activity. It may be, however, suggested, that the on-coming of the Wisconsin ice was slcw; the valleys in question were slowly filled, while later accumulations, moving southwards, passed over the valleys entirely. At any rate, the later ice-sheet in many parts of the Humboldt county valleys, seems hardly to have moved at all, and in such places the deposits of drift are insignificant.

The secondary streams of the county present few topographic features of special interest. They are in general typical prairie streams, with shallow channels, low gradient, and accordingly show erosive characters only as they near the flood-plain of the receiving rivers, as already mentioned in the case of Beaver creek and Bloody run. The principal secondary stream of the county is Lott's creek, which, with its tributary Trullinger, drains the northern part of Delana township, and is reported to be a perennial stream, especially below its junction with Trullinger. Lott's creek empties into the East Fork just north of the town of Livermore, and its banks, especially west of that village, exhibit the characteristics already described as forming a Kansan landscape.

DRAINAGE.

As already intimated the drainage of the county, as effected by natural channels, is quite imperfect. The general slope of the west half of the county is from west to east. Gilmore is more than a hundred feet higher than Dakota City; the east half shows little variation, is almost level, with only a slight fall toward the Des Moines river to the southwest, and toward the Boone river to the southeast. The early settlers occupied the higher ground to the north and west, leaving the great swamps of the east and south as a problem for later comers. It is hardly necessary to say that the problem has been quite effectively solved. Ditches and tile drains have worked marvels, and will no doubt eventually bring almost the entire prairie under the plow. Even considerable lakes, respected of the United States surveyor, which might have remained to lend charm and attractiveness to the otherwise monotonous landscape, have yielded to the spirit of conquest which would bring every foot of nature's domain under man's control. Owl lake seems to have been a beautiful and permanent sheet of water, covering several hundred acres, ten or fifteen feet deep, bordered by beautiful groves of native trees. In draining a great marsh which lay to the south, and which, if reports are true, might better have found outlet by Beaver creek, Owl lake was put in the line of the ditch, and the waters from both regions carried into Boone river. The fact illustrates well the topography of this part of the county; the drainage canal might have gone at least equally well east or west, and there is not in either direction sufficient fall to have brought about natural drainage. The drift is, in the neighborhood, very deep. A well, wholly in the drift, near the south margin of the lake-bed, is 118 feet deep. The water rises from beneath a bed of organic matter, which doubtless represents here the pre-Kansan surface forest-bed. A well in the middle of the former bed of Owl lake is said to be sixty feet deep.

Drainage by ditches is, however, characteristic rather of the eastern and southern portion of the county. The western, and especially the central townships, exhibit a very different system, in some of its features unique. The limestone which underlies the region now in question appears to be full of fissures, and as a result we have subterranean drainage. In numerous places, instead of the ordinary lakelet or pond characteristic of the Wisconsin drift, we have a sinkhole. The lakelets ("kettle-holes") are not wanting; but the great majority of them leak, and drain effectively the contiguous lands. Within the past few years the farmers, taking their cue from the natural state of affairs, have begun boring holes in the bottoms of the marshes or lakes not having such outlets by nature. It is found that a well deep enough to furnish an inexhaustible supply of water will also, on the other hand, receive any amount of water that may be poured into it, and deep-well drainage has become a singular characteristic of the agriculture of Humboldt county. Once a well is sunk in some particular slough, other wet acres in the neighborhood are, by tiling, brought into connection, so that sometimes a single well will drain a very large area, several hundred acres. In every case, of course, the well must reach an aquifer, or water-bearing stratum. The depth to which such wells are sunk varies but little in a given area; the average depth of a large number sunk by Mr. Charles De Groote is about 100 feet. On the other hand a well sunk in the town of Humboldt, to drain the stone quarry operated there, is 185 feet deep, and inefficient. Drainage wells are five inches in diameter, cased from the surface to the rock, and often without so much as a screen at the top. Soil, sand, clay, and detritus of all sorts seem to be received with impunity. The propriety of sending the discharge of unfiltered surface waters into the water couches that must supply at the same time the wells and springs of the county, is, perhaps, a matter that will one day merit consideration at the hands of the sanitary engineer.

STRATIGRAPHY.

Formations Represented.

The geological formations represented in Humboldt county are not numerous, and yet more so than one might at first suppose. Here and there within the county appear the edges (outlying traces) of several of the paleozoic formations that are well developed, and well exposed further to the south. In general, however, vast beds of drift cover all the older formations of Humboldt county, removing them entirely from ordinary exploration, leaving us to guess the extent of their presence from the few exposures along the rivers, where recent erosion has uncovered for a little way these ancient layers. Sometimes, also, the comminuted drill-chips, preserved by an intelligent well-digger, are brought to our assistance, but the data so obtained are not very helpful in identification, and can do no more than confirm conclusions elsewhere more happily formulated. In any event the distance between exposures is, in the case before us, so great that the identification of strata, on grounds lithological only, becomes a matter of some uncertainty. Added to this there is every indication that in the intervals of deposition the succeeding paleozoic strata suffered enormous erosion; everywhere is want of conformity, continuity, offering to the student a problem of no little complexity. So far as at present appears, the geological formations of Humboldt county may be tabulated as follows:

Synoptical Table of Geological Formations.

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Glacial.	Wisconsin.
			Buchanan gravels.
			Kansan.
			Aftonian?
			Pre-Kansan?
Paleozoic.	Carboniferous.	Upper Carboniferous.	Des Moines.
		Lower Carboniferous or Mississippian.	Saint Louis.
			Kinderhook.

GEOLOGICAL FORMATIONS.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

KINDERHOOK LIMESTONE.

The Kinderhook limestone was recognized in Humboldt county by Dr. White.* This observer, however, included under the name all the stratified limestones of the region. Facts now patent to every student, but inaccessible at the time of Dr. White's visit to the county, make it plain that the Kinderhook is really much more narrowly limited than was at first supposed, and is in fact represented by the lowest strata only of the Humboldt county limestones. For its identification we must depend upon lithological characters chiefly; organic remains being few and poorly preserved. But the beds in question are oolitic, and in this respect resemble beds of recognized Kinderhook age in Des Moines and Marshall counties. Besides, the organic remains, such as they are, are undoubtedly such as characterize the Kinderhook strata of Illinois, where these were first described. In the University geological collections may be seen *Loxonema yandellana* Hall?, *Straparollus macromphalus* Winchell, *S. obtusus* Hall, *S. planispira* Hall?, *Omphalotrochus springvalensis* White, *Bellerophon sublaevis* Hall, a small Allorisma and some other undetermined species. These specimens are from the Humboldt beds of oolite, and were deposited at the University by Dr. Clark, of Humboldt, who collected them.

Oolite limestone, as the name suggests, is composed in large part of minute ovate, or egg-shaped calcareous grains or granules, held together by a cement or matrix of similar material. The granules show a concentric structure, and seem to have been formed from what may be termed calcareous sand, each grain first rounded by attrition, then coated by successive layers of lime precipitated from solution.

*Geology of Iowa, by Dr. Charles A. White, vol II, pp. 244-245. 1870.

Oolite is forming to-day along many tropical shores. The process takes place chiefly in the littoral zone, between high and low tide, wherever the beach is covered with fine calcareous sand. Such sands originate along the beaches of low islands, or other land areas that send no gross products of mechanical erosion to the sea, provided the adjacent sea bottoms support coral reefs or other profuse growth of lime-secreting organisms. Waves pound to pieces the structures reared by living forms; and the fine calcareous grains to which these structures are evidently reduced, are strewn over the sea bottom up to the limits of high tide. Winds may carry them inland and pile them up in heaps and wreaths, far beyond the limits of tidal movements; but between tide-marks the grains are alternately moistened and dried, a pellicle of lime carbonate is left upon each calcareous sand grain as a result of evaporation of the saturated sea water, the grains grow by accretion after each retreating tide, and are at length converted into the perfectly rounded ooliths that give character to this particular type of limestone. The very processes, however, which produce calcareous sand, would destroy as well the remains of all forms of living things, and the paucity of fossils is, perhaps, in this way explained.

Exposures of Kinderhook limestone occur at intervals along the banks of the west fork of the Des Moines river, from Humboldt city to Rutland. Within these limits the rock varies in character, very often and very much. These variations depend upon the relative amounts of cement and oolitic material present in the several cases. Thus the rocks by the river at Humboldt, near the abandoned limekiln, show the following section:

	FEET.
6. Drift, with gravel and rotten bowlders	1-2
5. Traces of ferruginous sandstone	1
4. Oolite; the ooliths fewer, irregular, uneven; the rock crystalline	2
3. Oolite; the ooliths of great uniformity, comprising nearly the whole mass of the stone	8-10
2. Oolite; the granules of uneven size, irregular	2
1. Fine-grained "lithographic" limestone, of unknown thickness, at the water's edge.	

The term lithographic, as here used, was employed by Worthen* in describing what is deemed a similar rock in the Kinderhook of Missouri and Illinois. The rock is an exceedingly hard, fine-grained limestone, of a pale drab or bluish-gray color, breaking with irregular, angular or conchoidal fracture and remarkably smooth surface. It appears to have been laid down in deep water, is only rarely fossiliferous, and is composed entirely of only the finest sort of calcareous detritus. In its pure form this kind of rock occurs again and

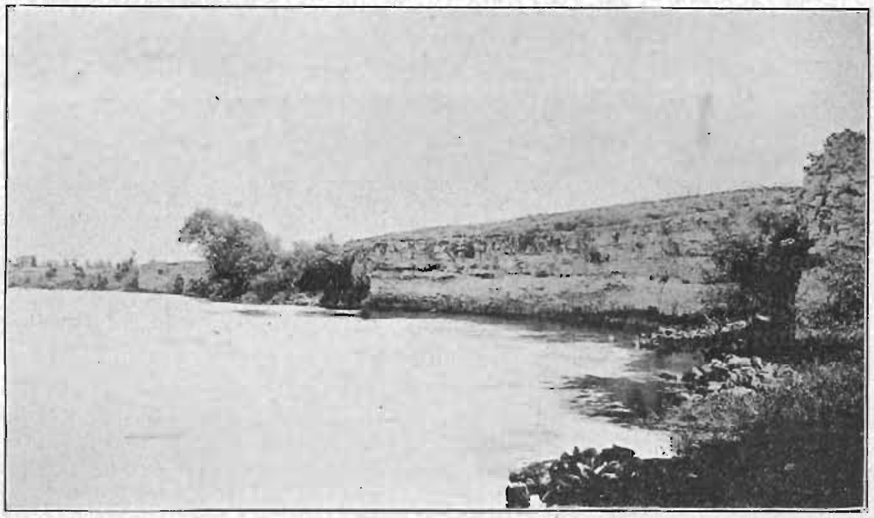


FIG 13. Exposure of Limestone near Rutland—probably Kinderhook.

again in the Saint Louis beds, as we shall presently show; in the Kinderhook it seems to be affected generally with oolitic concretions.

The oolite in the vicinity of Humboldt affords beautiful illustrations of rock of its type, but the beds exposed are of very limited extent. Along the river front they are traceable for a short distance only, within the city limits, and are well seen where the rock has been extensively used for lime-burning. North of the town, in a field adjoining, on the east, the city cemetery, is a small quarry of oolitic stone, but here the

*Geol of Illinois, vol. I, p. 114

oolites are much larger, and the rock of coarser texture. In fact as we go north and west from Humboldt the oolites become larger. At the same time they become fewer in proportion to amount of cement material present, until they cease to be a conspicuous feature of the rock at all. The conditions of rock formation seem to have varied everywhere within a short distance.

At Rutland, along the south bank of the river, is one of the most conspicuous rock exposures in the county (see figure 13). The strata here are also believed to be Kinderhook, and probably correspond to the lower beds in the Humboldt section. The beds are nearly horizontal, dip perhaps a little to the east, may be followed for about half a mile eastward where they disappear, probably having been removed by pre-Carboniferous erosion. Westward the same beds may be traced for some distance along the stream, but are replaced by Saint Louis at the water's edge in section 23 of Avery township. South of Rutland there are outcrops of the same rock here and there on the old flood-plain of the river, especially in the northeast quarter of section 30, in Rutland township. The

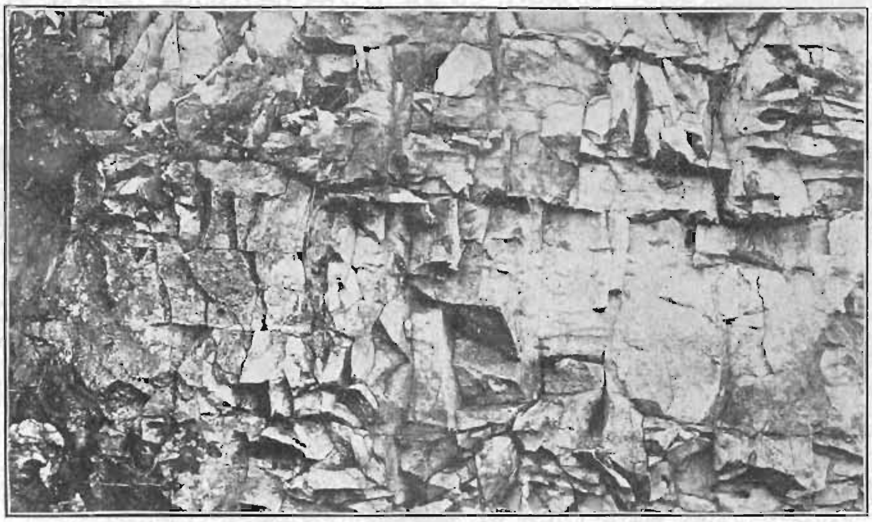


FIG. 14 Kinderhook opposite Rutland—to show mode of weathering.

Rutland limestone is not bedded, at least not evidently, it checks and cracks in all directions on exposure to the weather (see figure 14). The rock is, nevertheless, very hard, and erosion proceeds but slowly. Under the lens very large ooliths, or pisoliths, appear, from a quarter of an inch to half an inch in diameter, but no traces of organic remains were discovered. The total thickness of these rocks, as exposed at Rutland bridge, is about twenty feet.

SAINT LOUIS LIMESTONE.

Exposures of rock provisionally referred to the Saint Louis age occur in Humboldt county from the mouth of Beaver creek, near the south line of the county, north to Humboldt, and west to Bradgate. All the exposures visited are situated in the valley of the Des Moines river, and have been uncovered by erosion effected by that stream or its tributaries. For determinations of the horizon of these exposures we must again be guided by characters lithological, and by stratigraphical position; no fossils are discoverable to guide us in our researches. Unfortunately, too, the rocks in question occupy a position which everywhere marks a period of transition, between the two great series of the Carboniferous system; they are accordingly mixed in character. In the same quarry we have sandstones, or arenaceous limestones, evenly bedded limestones, lithographic limestone, generally in thin, hard seams, pockets of shale and clay. Nor is lacking the peculiar brecciated limestone which, in all other western localities, is held to be a sign of the Saint Louis stage.

Notwithstanding all this diversity the various exposures visited are in general consistent with each other; their strata are, in the main, comparable and lie all above the oolite, and where contact can be observed are plainly unconformable with it.

An exposure along the east bank of the river, near the south line of the county, shows the section following:

		FEET.
10.	Drift, probably Kansan covered by Wisconsin; several feet.	
9.	Traces of Des Moines sandstone	6-7
8.	Thin layers of arenaceous-calcareous rock	6-10
7.	Irregular, heavy-bedded limestone, containing angular fragments of lithographic rock	5-7
6.	Shale, with pockets of clay; of variable thickness.	
5.	A thin parting layer, very hard, dense limestone.	4
4.	Regularly bedded limestones, more or less arenaceous; about	2
3.	Regularly bedded limestones, some lithographic; about	2
2.	Talus covering the layers to the water's edge, say	4
1.	Soft, whitish or bluish limestone in the bed of the river. On exposure turns brown or yellow, and washes readily under the rain. Occurs in layers six or eight inches thick, and is said to overlie blue shales.	

Bed number 1, in the above section, has been extensively quarried from the river channel, and used in construction of dwellings in the vicinity. It is said to be white when fresh, and is easily worked. On exposure to the weather it assumes a yellow color and a chalky surface. The succeeding layers up to number 5 are, as far as observed, alternating beds of lithographic stone and rock of softer texture. That called lithographic corresponds with rock so named in other exposures, is exceedingly hard, fine-grained, breaking with angular, somewhat conchoidal fracture. Number 6 is shale passing into clay, and varies in thickness from two to eighteen inches. Number 7 is the most characteristic and clearly defined member of the whole series. It occurs in layers three to four feet thick, unevenly bedded, more or less brecciated, and breaks off in large blocks as undermined by the erosion of the thinner beds below. On the east side of the river this particular layer may be traced to near the mouth of Beaver creek; it is probably represented by the heavy upper rocks exposed east of the bridge over Beaver creek, in section 32 of Beaver township, and again appears in connection with exposures along the east fork, in section 31 of Grove township. The same rock appears also at one or two points on the west bank of the Des Moines, as in section 31, Beaver township.

From the point last mentioned, northward, the lime rocks in question are seen no more until we reach the south limits of the town of Humboldt. Any limestones that may have occupied the interval have been completely removed by erosion, and their place supplied by drift or deposits of sandstones and shales representing the Des Moines stage.

On the river bank, near the fair grounds, a quarry has been opened which shows an unevenly-bedded blue limestone affording abundant evidence of flexure, and dipping rapidly southward under the black shales of the coal measures. Near the mill on the east fork, east of Dakota, is another exposure of similar limestone, associated with beds of shale and clays. Both these exposures represent beds below number 7 of the section on page 128.

A very much more satisfactory view of these particular strata is obtained at Dr. Welch's quarry in section 31 of Grove township, above referred to. Here we have an exposure of some sixteen or eighteen feet. Heavy, rather evenly-bedded limestone at the bottom, yields a superior quality of quarry stone. It is impossible at present to determine the thickness of these beds; the exposure at present reveals no more than two or three feet. Above comes a course of shale followed by other courses of thin-bedded limestone, the first of which, about seven feet up, is lithographic. The courses above the lithographic seam show traces of oolite. At length appear sandy fragments, probably of the Des Moines, capped by Kansan drift, one or two feet in thickness. The eastern end of the exposure, only a short distance east, demonstrates the unreliable nature of these strata, and the instability of the earth's crust during the period in which they were laid down. Here the strata of limestone pass into beds of twisted, contorted shale, mingled with blocks of sandstone, loose pieces of limestone, angular fragments, imbedded in clay. Even the best defined strata are traceable for a short distance only.

Similar rock underlies nearly all of the western part of the city of Humboldt. An exposure is seen in Mr. Bull's quarry near the center of the town. Here we have the section following:

		FEET.
3.	Kansan drift, with bowlders, soil, etc.	1-2
2.	Thin-bedded, flinty layers of limestone, passing into beds of clay	2
1.	Evenly-bedded, blue limestone, of variable texture	6

Number 1 rests unconformably upon subjacent limestone rock, and is evidently here, if our conclusions are right, the lowest member of the Saint Louis stage. The uneven floor of the Humboldt quarry is the eroded upper surface of the Kinderhook. The limestone is in some places shaly, but at its best is of good quality, dark blue in color, weathering to buff or pale yellow. It is in many places much seamed by vertical fissures of greater or less extent. In some instances these are packed with crystalline calcite; in other cases the rock is simply oxidized and discolored for the depth of an inch or two on each side of the fissure. Number 2 is variable in the extreme, and apparently valueless.

Other exposures, which we refer to the Saint Louis horizon, are found in the so-called "sandstone quarry" in Rutland, and in Mr. Finch's quarry, at the river's edge, in the Sw. qr. of Ne. ¼, Sec. 23, Avery township. The same rock crops out at the water's edge for the last time on the west fork, just below the bridge, in the Ne. qr. of Nw. ¼, Sec. 17, Avery township. Loose rocks of the same character cover the bottom of the present river channel, from the point last named eastward, nearly to the town of Rutland. Some of the exposures mentioned show, in more or less abundance, the curious structure called, by Worthen,* crystallites. There is probably nothing of crystalline nature about these formations. They resemble crystals in form only, are like the casts of crystals,

*Geology of Illinois, vol. I, pp. 115-116.

but more probably represent slight faults in the material of the rock, faults formed while the material was as yet plastic. The axis of the crystallite is always perpendicular, or nearly so, to the plane of bedding. These forms are now known as Stylolites.

At various points in Weaver township, as in the Ne. qr. of Sec. 9, there are exposures of limestone rock which must be considered here. These are mostly in the form of quarries, originally sink-holes, which have been developed to meet the local demand for rubble stone. From the exposure in section 9, just mentioned, a large amount of rock has been taken. The quality seems to be excellent, and the bedding is such as to make comparatively light the labor of the quarryman. The rock is a rather coarse-grained, crystalline, encrinital limestone, reminding one of rocks elsewhere referred to the Augusta stage, unlike any seen anywhere in the river exposures. Open sink-holes in this neighborhood show almost everywhere rock of the same character, so that it is probable that all the southwestern part of the county is underlain by similar strata, except where removed by pre-glacial erosion. In the town of Gilmore, for instance, a similar rock in the northeast part of the village comes to the surface of the ground, while a few rods west, the town well goes down sixty feet before encountering rock at all. Nevertheless, we may consider this peculiar encrinital limestone as the surface rock for all that part of Humboldt county lying south of the west fork, except the flood plains immediately adjacent to the stream. The same rock extends far into Pocahontas county, and is there exposed in precisely the same way. Thus in Clinton township, in Pocahontas county, one mile west of Gilmore, and one and one-half miles north, is a sink-hole quarry, which for years has been very extensively worked. The Gilmore quarry presents the following section:

		FEET.
10.	Alluvium, surface soil, etc.	6
9.	Coarse sand and gravels, Buchanan gravel	3
8.	Red clay and rotten bowlders of various sizes, representing the Kansan drift	2-4
7.	Heavy-bedded, coarse-grained limestone, crystalline, encrinital	20
6.	Blue shales, limestone and clay; very fossiliferous	2
5.	Lithographic limestone, much inclined to angular fracture	1½
4.	Heavy-bedded, fine-grained limestone, no fossils	3
3.	Shaly, thin-bedded limestones, with few fossils	1
2.	Coarse-grained, fossiliferous limestone, containing fragments of No. 1, but separated from it by a parting of shale	1
1.	Lithographic limestone, fine-grained, and very hard	2

If we may judge from characters lithological chiefly, and from comparative position, the surface rock of the southwest part of Humboldt county is identical with number 7 in the above table. The strata exposed in the Gilmore quarry are the only beds above the oolite which contain fossils sufficiently well preserved to give the student any assistance in determining the geologic horizon. But the fossils in this, our only locality, are poor; those of the limestone imbedded so firmly as to be difficult of extraction, those of the shale fragmentary, flattened and generally imperfect, though very abundant. Long and patient search will be required to secure anything like a satisfactory series. The specimens collected were sent to Mr. Stuart Weller, of Chicago, and identified in part as follows: *Eumetria verneuilana*, *Athyris subquadrata* (?), *Spirifer increbrescens* (?), *Rhynchonella*—Sp. Concerning their horizon or geologic age, Mr. Weller says: "All these forms indicate a younger age than the Osage, or Augusta, as some prefer to call it, and I think they can safely be referred to the Saint Louis."

This accords entirely with the view we have expressed as to the age of the upper formations in the southern part of the county, as at Humboldt and Beaver creek. The strata exposed in Dr. Welch's quarry, for instance, are the equivalent of the very lowest beds in the Gilmore quarry, or, more likely, of beds still lower down. This conclusion accords likewise with the topographic evidence. The difference in level between the river channel at Bradgate and the Gilmore quarry is at least twenty-five feet; *i. e.*, the last exposure at the river, supposing the strata level, is still thirty or more feet below the bottom of the Gilmore quarry. The encrinital limestones of the Gilmore quarry, and of Weaver township, resemble very much in texture the limestones long known in Iowa geology as Burlington, but the reference of the Gilmore shales to the Saint Louis in so far excludes the Burlington from our problem.

Upper Carboniferous.

DES MOINES.

There is every reason to believe that the Saint Louis strata were no sooner deposited than they became forthwith subject to long continued and enormous erosion. The scant deposits which we have been tracing along the rivers, from the county line north to Humboldt, Rutland and Bradgate, are doubtless but remnants of beds once continuous over the entire region, and possessed of thickness possibly only partially indicated by the piled up strata of the Gilmore quarry. The valleys and irregularities, left as a result of erosion, are now in general buried beneath various sheets of drift; some of them, however, were filled long ages before by the sand and shales of Carboniferous waters. One such erosion valley lies immediately south of the town of Humboldt, and extends nearly to the county line. In the southwest corner of the Nw. qr. of the Se. ¼ of Sec. 12, in Corinth township, is a limestone quarry, as already stated, page 129. Within a few rods south occur beds of black shale, and no more limestone appears until near the mouth of Beaver creek, as heretofore described. Along the east fork the situation is exactly the same, and we have here an interval more than four miles in extent occupied, so far as indurated rocks are concerned, wholly by sandstones and shales. These represent the upper Carboniferous, and are apparently to be correlated with beds of the Des Moines stage, abundantly exposed immediately above the limestone along the river, south of the county line. Here, again, our decision rests upon relative position and characters purely lithological. Most of the material representing the coal measures has also been carried off by long erosion, so that the outcrops are nowhere important or extensive. We may, however, trace them quite continuously along both forks of the river, especially within the limits above described.

Beginning at the south, the first coal measure exposure within the county is found on the west side of the river, in the southwest quarter of section 29, in Beaver township. The outcrop here is sufficiently remarkable to have long attracted general attention. It is known as the "ore bed" or "lava bed." Contrary, however, to the generally received opinion, the "ore beds" have probably never known heat more intense than that of the Humboldt August sun. The ore, however, is real; it is a form of hematite, iron ore containing aluminum, traces of arsenic, zinc and other impurities. The following analysis made by Mr. T. E. Savage, at the University laboratories, shows the content of our "lava":

	PER CENT.
Iron	50.256
Silica, approximately	15
Aluminum, approximately	4
Zinc	Trace
Arsenic	Trace
Other substances, oxygen, etc., estimated	30
	99.256

A similar ore is not uncommon in rocks of this horizon throughout the world. In the particular case before us the iron was doubtless brought down and deposited with the sand, obtained from the waste and decomposition of older rocks not far away. The sandstone so formed later became checked and cracked in every direction, by slight local disturbances, flexures, etc., while the contained iron was in part leached out in the presence of decomposing organic matter, only to be redeposited as hematite where oxygen was abundant, as in the cracks and fissures just referred to. Subsequent erosion and washing of the sandstone left the hardier ore behind in angular blocks and plates, box-like cavities, etc., the shape determined by the fissures in which concentration originally took place. The ore contains impurities of such character and amount as to make it intractable, and these, together with the small extent of the ore body, render it of little or no value.

A characteristic exposure of Des Moines sandstone may be seen on the east fork, in the southwest quarter of section 19, Beaver township. Here the Minneapolis & St. Louis railway crosses the stream, and the sandstone outcrop is sufficient in extent and solidity to warrant its use to form the abutment for the west end of the railway bridge. The rock is coarse, heavy-bedded, hard, ferruginous, yellow, and furnishes the best illustration seen in the county of the formation now considered. The same rock crops out along the river, on the west bank, in the southeast quarter of section 18, Beaver township, at the upper end of Riverside park, in the town of Humboldt, and on the opposite side of the river, at various points; also in the northeast quarter of section 34, Rutland township. At the point last mentioned the very ferruginous coal measure sandstones are succeeded on the north by a bed of remarkably clean, sharp, white sand, of unknown depth and extent. This, though closely associated here with the coal measure outcrop, represents evidently an entirely different period of deposition. It is probably referable to the overlying Kansan, and is a most noteworthy deposit.

On the east side of the east fork, in the southeast quarter of section 18, Beaver township, the Des Moines is represented low down along the water edge, and for some distance up and down the stream, by the characteristic black shale of the coal measures. This on the land of Mr. Hermanus Ketman was explored some years ago for coal. A drift was run in some distance from the river, and some imperfect shaly coal seems to have been taken out, but the prospect was on the whole unsatisfactory, and the work was soon abandoned. On the west fork, in the southwest quarter of section 12, Corinth township, within the limits of the incorporated town of Humboldt, a similar exposure of shale occurs along the river. This, also, was at one time the subject of experiment, and several tons of coal are reported to have been taken out. But the vein seems to have been fragmentary, the coal was soon exhausted, and the enterprise was abandoned. At present there are no exposures by which one can judge as to the real character of this particular member of the coal bearing series. The black shales seem to be capped by soft, sandy material, which speedily weathers to rounded slopes, and the whole surface in the localities mentioned is now grown over with grass and shrubs, down to the water's edge. In fact the sandstones and shales of Humboldt county, so far as studied, seem simply to fill up the erosion valleys of the older strata. They are nowhere continuous for any great distance. They are a part only of the northernmost edge of the productive fields of Iowa, and it seems probable that any coal that may once have found place here was swept away by erosive agencies, acting prior to and during the invasion of the Kansan or pre-Kansan ice.

From none of the exposures of coal-measure rocks and shales were fossils collected. Fragmentary plant-remains are said to have been encountered by those who explored for coal, but no trace of these can now be found.

PLEISTOCENE SYSTEM.

The Pleistocene deposits in Humboldt county, as elsewhere generally in Iowa, consist of sheets of drift, beds of gravel, clay, sand, soil, alluvium, etc. Two distinct formations of such deposits may everywhere be easily discovered, an upper and a lower, or, as sometimes described, a younger and an older. The younger, newer, deposits in Humboldt county belong to what has been already called in this report the Wisconsin drift, the older to the Kansan.

KANSAN DRIFT.

The vast body of all the soils, sands and clays, which almost entirely bury the indurated rocks of Humboldt county, belong to the Kansan age. Even where the soil is thinnest, and underlying limestones come nearest to the surface, even there, remains of the work of the old Kansan ice sheet are not lacking. From the reports of well diggers we may gather that, in some parts of the county at least, a deposit older still intervenes between the Kansan and the limestone rocks below. Such deposits doubtless represent the famous pre-Kansan formations revealed, with more or less clearness in various parts of the state, elsewhere. Our data for Humboldt county, however, are insufficient to justify more than this simple mention, and in what follows we may consider all the drift underlying the Wisconsin as Kansan.

In Humboldt, as elsewhere, the Kansan drift takes on different aspects, according as it has or has not been exposed to the action of the elements. Originally in large part a blue clay, where long exposed to the weather it becomes brown or ferruginous. In many localities the upper portion of the Kansan consists of beds of sands and gravels, and such deposits are always reddish-brown in color, very unlike the pale yellow of the overlying Wisconsin clay. It follows from this that the natural exposures of the Kansan are brown, while the same formation may and does furnish the blue clay of the well digger. In the particular case before us the only natural outcrops of the Kansan occur along the river valleys, as already intimated, and here they seem to represent the drainage deposits left by the abundant south-flowing waters of the retreating glacier; they are the Buchanan gravels and alluvial sands. The sandy plains about Bradgate, the flat valley opposite Rutland, the town site of Humboldt, the sandy fields south of the mouth of Indian creek, all represent the old Kansan alluvium, over which the later drift passed like a shadow, leaving only here and there the slightest impress. On the other hand there are no finer exposures of Buchanan gravel than may be seen in the gravel pits of the Minneapolis & St. Louis railway, near the west end of the railroad bridge across the east fork, or one half a mile further west, where the gravel is excavated for road material to improve the public highways. Similar exposures occur at several places along the river valley in Beaver township, as near the center of section 17, on the north side of Coon creek, near the mouth, in the northwest quarter of section 20, and even on the top of the hill in the northwest quarter of section 30. In all these cases we find the peculiar orange-brown, ferruginous, coarse sand and gravel formed from decomposing pebbles, which are to-day so near disintegration that they crumble in the fingers of the collector.

The extent of these deposits is very difficult to estimate. They probably underlie in considerable depth all the upland south of Dakota City and between the two forks of the Des Moines, south to their union. Reports of deep wells indicate the presence of the gravels all over the western portion of the county. At the Gilmore quarry there is an exposure of the same deposits, about three or four feet in thickness, and along the road running east and west immediately north of the quarry there is a prominent ridge of sand and gravel, referable to the same origin. The ridge north of what was once Owl lake is also chiefly Buchanan gravels and wind-driven sand.

Elsewhere our knowledge of the Kansan is limited to reports of wells; but these uniformly report blue clay, in greater or less thickness, below the Wisconsin or "gravel dirt," so that we may reasonably infer the presence of the Kansan drift over the whole county.

WISCONSIN DRIFT.

Except as noted, this is the surface deposit over the whole county. It is generally pale yellow, almost white in color when dry, contains abundant calcareous pebbles, generally small, but sometimes of considerable size, when they often show to perfection the evidence of glacial planing. The granite bowlders are also fresh, untouched by decomposition or decay, generally of medium size, those of reddish color predominating. The deposit is not only remarkable for uniformity of composition, but of distribution also. Nowhere very thick, yet it covers the surface nearly everywhere, conforming generally very closely to the eroded features of the underlying Kansan. Hillsides are often as well and evenly covered as hilltops, showing that erosion since the Wisconsin has been slight. For these reasons natural exposures of contact between the two drift sheets are seldom to be observed. One such, however, is at present shown near the mouth of Coon creek, and one east of Rutland, just north of the ford on the west fork. Railway cuttings and road gradings sometimes here serve the purpose of the student, but unhappily in Humboldt county there is little grading of any kind necessary, and artificial exposures are not numerous. The railroad cuts immediately north of Humboldt show fine exposures of Wisconsin, here probably twenty feet in thickness. When fresh these excavations probably revealed the contact in question, but at present, in consequence of erosion from rains, all such features are obliterated. An exposure of typical Wisconsin may be seen immediately south of Rutland, where the road leading south has recently been graded, directly up the face of the hill. Similar exposures are thus in evidence in various parts of the county. From what may be observed in cuttings, and from well records, the thickness of the Wisconsin probably nowhere in this county exceeds fifteen or twenty feet, and is often very much less. It is but a thin veneer, as said before, everywhere immediately capping the Kansan. At Livermore, at the site of the town well, the surface clay does not exceed two feet in thickness; near the mouth of Beaver creek it is about sixteen feet in thickness, where the underlying Kansan is some seventy feet in depth; an exposure in

Weaver township showed for the same deposit a thickness of perhaps eight feet, humus and all, while along the alluvial plains by the river, as already remarked, and sometimes on the upland, there is no trace of the pale deposit at all, only here and there a cluster of smooth, hard, recent bowlders to give evidence that the Wisconsin ice once did in reality visit the locality.

Taking the Pleistocene deposits throughout, their average depth is hardly fifteen feet. The greatest depth reported to which a well has been sunk, is 135 feet. This is the well at Livermore. The drift here is 132 feet. South of Owl lake wells 100 to 120 feet deep encountered no rock. At Renwick rock is 125 feet below the surface of the ground. In the west half of the county, as already stated, the depth of the drift is far less, ranging from nothing to twenty or sometimes fifty feet. As far as now known the rocky foundation of the county is strikingly even and uniform, dipping to the east and south only a little more rapidly than the clayey mantle of the drift.

SOILS.

The soils of Humboldt county are strikingly uniform. Except the alluvium along the rivers, which in some parts is sandy, we have in general the rich black loam of the prairie, of great depth and of seemingly exhaustless fertility. The topography of the Wisconsin lends itself everywhere to the formation of marsh; and sedges, swamp grasses, rushes and mosses seem to have covered this latest till from the very beginning. The perennial moisture checked the waste by fire, and the amount of organic material and vegetable detritus, contributed to the surface soil has been immense. The present methods of drainage bringing all nature's marsh lands under the plow, place at the service of the farmer the accumulated wealth of ages. Nor is this all. The unusual amount of lime, pulverized or in rapidly decomposing pebbles which form so prominent and conspicuous an element in the Wisconsin soils, seems to offer an exceptional foundation for the cultivation of cereals of every description, especially wheat. Humboldt county, therefore, joins itself to the great wheat raising region of the world, a region which stretches far north and west, including, in the United States, northern Minnesota and the Dakotas. Along the rivers there are a few steep banks and sharply eroded, short ravines, which are unsuited to cultivation, and have been wisely left to grow up to timber, but aside from these limited areas, once the present system of drainage is completed, there will be left of untillable land in Humboldt county scarcely an acre.

ECONOMIC PRODUCTS.

The natural products of Humboldt county include limestone, suitable for building purposes and for the manufacture of lime, native wood for fuel, and peat These we may now consider briefly.

Building Stones.

The exposures of Kinderhook and Saint Louis limestones already described have, from the earliest settlement of the county, furnished an abundant supply of rubble-stone, much of it of a superior quality. From Dr. Welch's quarry were taken stone for erecting the fine buildings of Humboldt College; this in the early history of the town. From the same quarry came the rock for the piers of the bridge of the Chicago & North-Western railway, erected in 1881, south of Dakota City. In the city of Humboldt quarries are common, and numerous handsome stone business blocks attest the activity and energy of its people. Indeed, it is said that the rock necessary for the erection of the walls of a business house in Humboldt may often be obtained in excavating the cellar. A beautiful stone schoolhouse, of which we present an illustration in figure 16, attests the excellence of the local supply for quarry stone. Mr. Bull's quarry is the only one now operated in the city. The rock over the area uncovered has been removed, down to what appears to be the old surface

FIG 16. Schoolhouse at Humboldt—St. Louis Limestone.

of the Kinderhook limestone. According to reports given by workmen the deeper layers are less valuable. In fact, here, as often elsewhere, the strata of quarry rock are not uniform, and for practical use the rubble must be carefully culled.

Reference has been made, also, to the excellent limestone in Weaver township, in the northeast quarter of section 9. No better stone for general use can be found than this. It is a crinoidal limestone, occurs near the surface, and is quarried with little trouble.

The flourishing town of Gilmore uses rock from the Gilmore quarries. This rock, which is certainly, in its upper beds at least, the same as that last mentioned in Weaver township, is widely known, has been quarried and shipped in hundreds of carloads, having the advantages of railway transportation. This quarry is in Pocahontas county. It is mentioned simply to show the possibilities in Weaver township if supplied with equal transportation facilities.

The Stearns quarry, in the northwest quarter of section 3, Corinth township, is another excellent exposure of building stone. The beds here are much heavier than in most of the neighboring quarries, and rock suitable for bridge piers may be easily obtained in unlimited quantities.

Lime.

Lime has been manufactured from stone taken from all horizons of the Humboldt county limestones. The oolite in particular was at one time extensively quarried at Humboldt for this purpose, a fact attested by several well constructed kilns still standing, but unused. The lime produced serves excellently for local and immediate use, but is said to be ill adapted for shipment, on account of rapid air-slacking. It appears that at present, even for local use, lime manufactured from the magnesian Niagara limestones is generally imported.

Sand.

Sand, suitable for building purposes, is not lacking, and is obtainable at various points along the river. The peculiar bed of white sand referred to on page 135 has been extensively excavated for this purpose, and deserves more thorough exploration.

Clays.

The clays of Humboldt county are not generally well adapted to the manufacture of brick or tile. The Wisconsin contains in general too much lime. Nevertheless, brick making has been successfully conducted at Dakota, and the court house and jail are built of brick, said to have been burned near by. This was many years ago. At present the only kilns operating in the county are at Livermore, where the Stitch Bros. have been busy some three or four years in the manufacture of brick and tile. The clay made use of appears to be Wisconsin. It is found in a marshy region, and close to the surface. Every effort is made to free the clay from pebbles, but, nevertheless, a sufficient number remain to make the manufacture of brick uncertain. Messrs. Stitch manufacture soft brick only, and many of these are rendered worthless by pebbles of limestone, which in process of manufacture burn into quicklime. But, notwithstanding all difficulties, the firm manufactures brick, and sells them at the rate of from 200,000 to 300,000 per year. The company is more successful with tile, which require, it appears, less burning. Tile are burned at the rate of 300,000 or 400,000 per year, and the demand exceeds constantly the present capacity of the plant. Ft. Dodge coal is the principal fuel used. Taking into account the unusual difficulties to be overcome, the enterprise is a remarkable success.

Fuel.

The fuel of the pioneer was wood. The forks of the Des Moines and the larger streams of the county were originally, more or less, continuously fringed with native woods. This native forest afforded the early settler at once shelter and fuel in advance of the advent of railways or the possibility of supplies from without. The original trees are mostly gone, but in their places stand luxuriant groves of "second growth," which, by judicious cutting, furnish their owners an abundant supply of the finest fuel, and may continue so to do for indefinite years to come. Besides these natural timber supplies, the results of almost universal tree planting on the farms are now apparent. Everywhere are groves, many containing trees of considerable size, so that the artificial forest of the county to-day furnishes no inconsiderable amount of the fuel used by the agriculturists. Humboldt county can easily raise its own fuel without seriously trenching at all upon its tillable land, at least beyond that which is necessary to afford the shelter of trees to the homes of its people.

The prospect that coal may be mined in the county is not encouraging. The coal measure exposures, as we have seen, are very narrow in extent, and even then are, for the most part, barren. It is possible that coal might be found in one or other of the localities where the coal measure shales crop out, but the chances are that the quantity discovered, if any, would be insufficient to pay the expenses of exploration. At least, so long as abundant supplies can be obtained with so much convenience in the adjoining county south, it is not likely that much effort will be made to use Humboldt county coal.

There is, however, another natural fuel supply present in considerable amount in the eastern part of the county, which seems to merit greater attention than has hitherto been accorded it. I refer to fields of peat. Almost every marsh in Lake and Norway townships contain peat, in several places in quantity sufficient to be worth considering as a fuel supply. Geologically considered, peat is the youngest member of the coal series, anthracite, soft coal, lignite, peat, *i. e.*, coal is a consolidated peat, peat an imperfect coal. Its combustibility has been abundantly shown in Humboldt county. The draining of Owl lake has left a large body of peat to dry along what was the north shore, and this has recently taken fire and burned over many acres, to the depth of several feet, leaving vast beds of ashes and half-burned organic matter. A similar combustion has recently taken place on the west side of section 2 of Lake township. It will surprise some people to learn that peat has a higher heating power than dry wood. The distinguished chemist, Remsen, estimates the calorific energy of bituminous coal at 75, dry peat at 48, and dry wood at only 28; peat is, pound for pound, 75 per cent better than wood. Unfortunately, in this country, peat has never been widely utilized, and a supply of fuel, which certainly will one day be needed, is now suffering indiscriminate waste.

Water Supply.

The two branches of the Des Moines river are unfailing sources of water supply for the western and central portions of the county. Indian creek, a perennial stream, finds its source in a beautiful spring, Indian spring, which, with a temperature of 54° F., wells up through a bed of white sand, in the Nw. qr. of the Sw. ¼ of Sec. 21, in Corinth township. The spring is on a level prairie, only about twenty-five feet lower than the highest land in the neighborhood. Wells on the adjoining farms furnish unfailing supplies of water, from a depth of fifty feet. An effort was made some time ago, by filling up the spring, to make the water rise higher. The result was to convert what was formerly a beautiful pool into a miry morass. The spring might be made an attractive resort. Another spring of considerable volume furnishes the principal water supply of the town of Humboldt, and all along the west fork, at least, springs are abundant. However, for the county at large, the water supply is from deep wells, generally sunk in the drift, though, in the western townships, often in the limestone rock, as heretofore described.

Water Powers.

Both branches of the Des Moines afford water power and convenient mill sites. Mr. C. H. Brown owns a fine flouring mill at Dakota, an excellent water power, which has been in use a great many years. A similar power drives the mills of Humboldt. Rutland, as it appears, once possessed a like advantage, and is now attempting to restore it.

In short, from an economic standpoint, the county before us is abundantly furnished with all that may contribute to the wealth and prosperity of a happy people; soil of exceptional depth and fertility, remarkable even in fertile Iowa, waters abundant and pure, springs and perennial streams, limestones to furnish building material for all time, native groves to beautify every stream and furnish, if cared for, fuel for generations to come, planted groves that well might make the prairie wooded,—such a county needs no praise; it is itself its own encomium.

ACKNOWLEDGMENTS.

In preparation of this report the author has enjoyed the constant assistance and encouragement of the director of the Survey, Prof. Samuel Calvin, as also of his assistant, Mr. H.

F. Bain, at Des Moines. The author is also under obligation to Prof. Stuart Weller, of Chicago, for aid in identification of the Saint Louis beds, as herein defined and described; to Mr. John F. Prouty and Mr. C. T. Webber, of Humboldt, for valuable individual aid in conducting the work in the field; to Mr. B. B. Brayton, of Davenport, Iowa, for notes of level and topography. To all these, as to many other gentlemen in Humboldt county, who generously responded to every call for assistance or information, the writer here extends his grateful acknowledgment.

FORESTRY NOTES FOR HUMBOLDT COUNTY.

A glance at the accompanying list of forest trees native to Humboldt county is sufficient to show that we have here nearly all the species commonly occurring in other more definitely wooded regions of the northern United States. This of itself is enough to refute the old but yet persisting opinion which would maintain that the prairies have in themselves, in their very make-up, something inimical to the growth of woodland species. Humboldt county is a typical prairie county, and yet certain localities were, until recently, covered with heavy timber. Walnut, oak, elm, linden and ash grew to dimensions suitable for the mill. Trees eighteen to thirty inches in diameter were not uncommon. These were in the rich soil of the creek and river valleys, the finest, perhaps, near the mouth of Beaver creek. Certain species of trees have been planted over the prairie and have, in the main, done well; but the drought of recent years has destroyed some of those thought to be most suitable for prairie planting, notably cottonwoods and poplars. But trees will grow in Humboldt county anywhere, if planted and protected. The fact remains, too, that the trees in every way best adapted to general planting in Humboldt county are those originally found growing there. For ornamental trees, for instance, none are more beautiful than wild plums and crab apples, and these are native. Hawthorns and sumac may be used effectively for the same purpose. These will all grow anywhere, and it is a matter of wonder that for decorative purposes they are not more generally employed. The native oaks, hickories and walnuts cannot well be transplanted from the woods, but in good soil, if cultivated, they grow from the seed much more rapidly than is generally supposed. The hickories, and especially the bur oaks, have, in Iowa, been so far proof against all drought. The bur oak grows slowly, but it is by all odds the hardiest tree we have. Since our agriculture is now becoming established, our occupancy of the country permanent, as we begin to build permanent houses and barns, it is at least time to inquire whether our temporary tree planting, which involved the use of soft woods, rapid growers only, should not now begin to give way to something permanent and enduring? Is it not proper to introduce in appropriate places on our farms, and especially about our homes, trees of slow growth indeed, but trees which will endure to the enjoyment and shelter of the generations to follow us, which shall form part of our real estate, permanent, abiding as the soil itself? In the older parts of the world, primeval forests are few; all, or nearly all, of the present forests are artificial. We are rapidly, in the United States, approaching a condition of affairs when the same thing will here be true, and trees of the more valuable sorts will characterize, not forest reservations only, but be, in fact, a part of the product of every well tilled farm. When that time comes the trees which the pioneer found growing in each locality will doubtless be found the most valuable species for permanent and profitable plantations.

The peculiar distribution of forest and prairie in Humboldt county to-day corresponds probably pretty closely with that discovered by the earliest civilized residents. Before the advent of civilization the principal check to the general extension of forest domain was found, not so much in the variation of the soil, as in the prevalence of prairie fires. The trees were limited to the occupancy of those parts of the country less severely visited by the perennial conflagrations. The present distribution of woodland and prairie in Humboldt county affords a striking illustration of this fact. Sometimes prairie fires came late in the fall, after the frosts had thoroughly killed the prairie vegetation, or in the spring, after the snows were nearly gone. They moved in general from the west. In such conflagrations seedlings and small trees universally perished, where exposed to the fires' full heat. Special localities, however, favored trees. Thus a sandy or rocky hilltop afforded no fuel, and the young tree survived. Lowlands generally were unfavorable to fire. Sometimes too wet to burn; sometimes subject to overflow, and deposition of new soil covering all fuel. In Humboldt county, as the present distribution of the timber shows, it was sometimes the river, sometimes a marsh, sometimes a steep bank, sloping to north or east, and on this account more moist, longer covered with snow in spring, that gave refuge and respite to the trees. In Wacousta township the woods are mostly east of the river, near Bradgate they are on both sides, protected on the west by bluffs, on the east by swampy or marshy ground. In the central part of Avery, down about to the west line of Rutland, the fires seem to have swept everything on both sides of the stream, crossing readily by the generally low banks. Further east, and in the vicinity of Humboldt and Dakota City, steep bluffs again gave foothold to the woods. The mouth of Indian creek, on the west fork, and the lower valley of Beaver creek, where that stream enters the east fork, offered to the trees the advantage of both conditions favorable to the retention of moisture, the steep bluff and the lowland. There are beautiful groves along the east fork, successors of primeval forest areas, whose existence in the midst of a prairie county must be explained by reference to similar topographic conditions.

The following list of the trees and shrubs of Humboldt county is believed to be reasonably complete. For its accuracy the author is much indebted to the assistance of

Miss Mae Webber, who has long enthusiastically studied the flora of the county.*

Tilia americana L. The Linnwood or Basswood tree; common in all the native groves of the county, and occasionally planted.

Xanthoxylum americanum Mill. Northern Prickly ash. Quite common. Abundant near the mouth of Beaver creek. Sometimes attains a height of ten or twelve feet. Ornamental; otherwise of small value.

Acer saccharinum Wang. Hard maple, Sugar maple. Scarce, occurring chiefly along rocky banks, and in rich alluvial soils.

Acer dasycarpum Ehrh. Soft maple, Silver maple. Common along streams, and everywhere planted for artificial groves. For this purpose the most useful tree in Iowa. Its rapid growth and hardy vigor adapting it particularly to our prairie conditions.

Negundo aceroides Moench. Box elder. Common everywhere along streams, also universal in cultivation, though not so general in plantations as the last species. Less hardy, also, than the Soft maple; more sensitive to drought and to winter changes.

Rhus glabra L. Sumac, Smooth sumac. Common on hillsides near the wooded regions. Small in stature; not attaining anything like the vigor exhibited in some quarters, but manifestly holding its own.

Robinia pseudacacia L. Locust, Black locust. Common in cultivation, or escaped from early plantings. Probably not indigenous.

Gymnocladus canadensis Lam. Kentucky coffee tree. Planted for ornament. Not native.

Gleditschia triacanthos L. Honey locust, not native. Occasionally seen in cultivation.

Prunus americana Marsh. Wild plum. Common.

Prunus virginiana L. Choke cherry. Not uncommon along the rivers, especially in rocky places.

*The nomenclature in this list is that of Gray's Manual, 6th ed.

Prunus serotina Ehrh. Wild cherry. Not common. Here and there along the rivers.

Pyrus coronaria L. American Crab apple. Everywhere common on hillsides, especially in the neighborhood of the streams. Sometimes forming small clumps or thickets where there is no other tree, by the smaller streams, or even in ravines. One of our most delightful native trees. The American forest shows nothing more beautiful, nothing sweeter than a crab apple in the perfection of its bloom.

Cratægus coccinea L. Common hawthorn. Not rare along the sandy flood plains of the rivers.

Cratægus coccinea L., *var. mollis*, Torr & Gray. Red hawthorn. Not rare. Recognized in late summer by its large, edible, bright scarlet fruit.

Cratægus tomentosa L. Occurs sparingly in the southern part of the county, Reported, also, from the northeastern corner of the county. Fruit larger, dull red or orange.

Amelanchier canadensis Torr & Gray. Shadbush, Service berry, Juneberry. A few along the river near Beaver creek.

Cornus asperifolia Mx. Dogwood. Reported not rare.

Cornus stolonifera Mx. Red-osier dogwood. Reported from the southern part of the county.

Sambucus canadensis L. Common everywhere, especially in hedgerows, gardens, etc.

Viburnum lentago L. Black Haw, Sheep berry. Not infrequent in thickets along the streams.

Viburnum prunifolium L. Black Haw. Occurs sparingly with the other. Both species of haw are becoming extinct in Iowa, unable to endure the close pasturage, and the browsing to which, in our torrid summers, all shrubby vegetation is more and more subjected.

Cephalanthus occidentalis L. Buttonbush, not rare in wet places by the rivers, and on sandy islands.

Fraxinus americana L. White ash. Not uncommon in all the wooded region, and not infrequently planted. A most valuable tree.

Ulmus fulva Mx. Slippery elm, Red elm. Not uncommon.

Ulmus americana L. American elm, White elm. Very common along all streams, and now everywhere planted. Specimens south of "Owl lake" were observed, eighteen inches in diameter. Our most valuable street and general shade tree.

Celtis occidentalis. Hackberry. Rare. A few reported from the southern part of the county.

Morus rubra L. Not indigenous. Planted in some localities for hedgerows and wind-breaks, where it appears hardy and efficient.

Juglans cinerea L. Butternut, White walnut. Not uncommon along hillsides and by the streams. This tree grows rapidly from the seed, in good soil, and would make a valuable shade tree as part of a plantation.

Juglans nigra L. Black walnut. Not common. Reported as once abundant along all the streams of the county. This species also comes on, in good soil, rapidly from seed, but does not bear transplanting.

Carya alba Mott. Hickory. Small trees of this species are not uncommon on higher ground, in the wooded regions, especially along the east fork. A very hardy species. Stands the drought and abuse of all kinds remarkably well, and furnishes most valuable timber for wood.

Carya amara. Bitternut, Pignut. Common in similar locations with the last species. By far less valuable.

Betula papyrifera Marshall. White birch. Occurs in cultivation, and is reported "abundant along the Boone river, east." Perhaps comes within the limits of the county in the northeast corner.

Corylus americana Walt. Hazlenut. Very common, especially on hillsides.

Ostrya virginica Wild. Ironwood, Hop horn-beam. Occurs sparingly along hillsides, on both forks of the river.

Carpinus caroliniana Wild. Ironwood, Blue beech, Water beech. On rocky banks, near the water's edge. Reported formerly common. Certainly less common than the preceding.

Quercus alba L. White oak. Not uncommon on the high ground near the rivers.

Quercus macrocarpa Michx. Burr oak. Very common, by far the most common oak in the county, as it is the most hardy. Found everywhere, in good soils and poor. A fine grove of them in the sandy soil north of the ford in Rutland township, section 34. Often makes a grove of more or less stunted trees, far from any other trees, and so everywhere constitutes, toward the west especially, the van-guard of the forest. Excellent, both for wood and lumber, for all purposes requiring strength and durability. A tree of slow growth.

Quercus coccinea Wang. Scarlet oak, Black oak. The form occurring is that common throughout Iowa. This is neither *Q. coccinea*, as described, nor yet *Q. coccinea*, var. *tinctoria*. The scales of the cup are yellowish, downy, instead of being glabrate and close adpressed, as the type should be. Common in all the native groves.

Quercus rubra L. Red oak. Not infrequent on uplands in all the wooded districts. Large trees of this species are reported from the valley of Beaver creek, and from the east fork.

Quercus coccinea Wang., var. *tinctoria* Gray. Is reported to have been represented, not long since, by large trees.

Salix nigra Marsh. Black willow. Common along the streams.

Salix cordata Muhl. Reported rare; "a few specimens only."

Populus tremuloides Michx. American aspen, Quaking asp. Common all through the wooded portion, especially at the edge of the woods, and in low grounds.

Populus grandidentata Michx. Large-leafed aspen, poplar, Quaking asp. Common on high ground everywhere in the native groves. A tree of rapid growth, short-lived, but useful as a nurse for more valuable and enduring species.

Populus monilifera Ait. Cottonwood, Necklace poplar. Common throughout the county, and commonly planted. Surprising to relate, some of the planted trees in the higher situations have, in these later years, succumbed to drought.

Populus dilatata Ait. Lombardy poplar. Is commonly planted. The species is not native to the United States, and, although a favorite ornamental tree in many localities, is, nevertheless, short-lived, and, on the whole, unsatisfactory.

Juniperus virginiana L. Red cedar, Juniper. Reported formerly common; not rare.

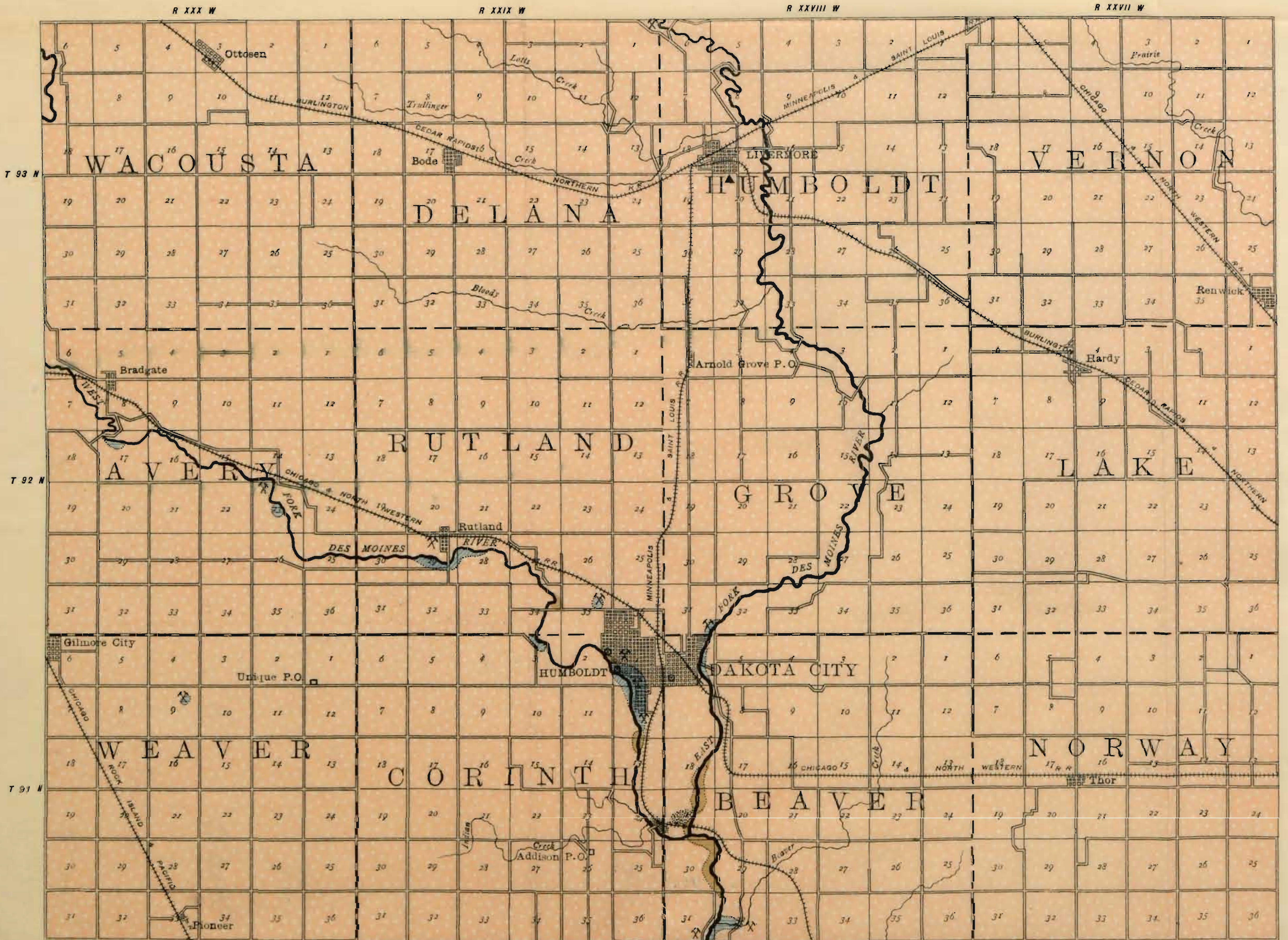
IOWA GEOLOGICAL SURVEY

MAP OF THE SURFACE FORMATIONS OF HUMBOLDT COUNTY, IOWA.

BY

T. H. MACBRIDE

1899.



Scale 1/125000

0 1 2 3 4 5 Miles

0 1 2 3 4 5 Kilometers

LEGEND

GEOLOGICAL FORMATIONS

- WISCONSIN DRIFT
- DES MOINES (Coal Measures)
- SAINT LOUIS
- KINDERHOOK

INDUSTRIES

- QUARRIES
- COAL MINES
- CLAY WORKS
- LIME KILNS
- BUCHANAN GRAVEL

IOWA LITHO CO DES MOINES

DRAWN BY F. C. TATE

GEOLOGY OF STORY COUNTY.

BY

SAMUEL WALKER BEYER.

GEOLOGY OF STORY COUNTY.

BY SAMUEL WALKER BEYER.

CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Story county occupies the geographic center of the state, and comprises the usual sixteen congressional townships common to interior counties, containing approximately 576 square miles. It is bounded on the north by Hamilton and Hardin counties, on the south by Polk and Jasper, while Boone county bounds it on the west, and Marshall forms its eastern boundary. Geologically the county is of some interest, for, while lying wholly within the area credited to the coal measures, it is now known that a detached area of the Lower Carboniferous of considerable dimensions appears in the western portion. And it is, perhaps, worthy of mention that the county serves to connect areas already reported on; Boone, in volume V, and Polk and Marshall, in volume VII of this Survey; while the field work in Hardin is practically completed.

PREVIOUS GEOLOGICAL WORK.

In the early history of the state the area under consideration possessed little to attract the civilian, the geologist or the physiographer. The immature character of its surface, with its numerous ponds and marshes and its general prairie character, proved uninviting to the husbandman familiar with the wooded hills and dales of the east. The all but perfect concealment of the stratified rocks by the ice *debris*, and the general surface monotony, did not appeal to the pioneer geologist as the "land of promise." The chief thoroughfares across the continent lay outside its borders, and hence specific geologic mention comes late in the history of the state, although the county was within the general area mapped by Nicollet as early as 1841.

The classic works of Owen and Hall, who laid the foundation for all subsequent geologic work in the Mississippi valley in general, and in Iowa in particular, possessed but a word concerning either the physical features or the natural resources of Story county.

The first specific reference to the geology of the county is to be found in White's* Geology of Iowa. Here the beds exposed along Onion creek are mentioned, and definitely referred to the Saint Louis and dismissed without further comment. In his discussion of moraines White makes mention of the ridges and knobs in northwestern Story, and intimates their probable morainal character.

A decade later Upham† visited the field, and definitely mapped the Gary moraine across the morthwest corner of the county.

Aside from the above reports, McGee‡ records certain observations concerning the Skunk river system, and considerable data as to the details of the region have been collected and recorded by the students in the geological department of the Iowa State College.

PHYSIOGRAPHY.

TOPOGRAPHY.

The region is almost entirely included within the area covered by the last drift sheet, and is characterized by general topographic immaturity. There is an entire lack of concordance between the drainage lines and the salient features, as the streams have exerted very little influence in shaping the topography. The surface is gently rolling, and, when viewed broadly, departs very slightly from a plane. It is the

*Vol. II, pp. 259-260. Des Moines, 1870.

†Ninth Annual Report Geol. and Nat. Hist. Surv. of Minnesota, pp. 288, et seq. Saint Peter, 1891.

‡Eleventh Ann. Rept. U. S. Geol. Surv., p. 357. Washington, 1891.

typical saucer topography so characteristic of the younger drift sheet.

When examined in detail the surface is notably scalloped by crescentic chains of ridges and kame-like aggregations, which suggest interrupted recession of the ice and tend to break the monotony of the general surface relief. The most noteworthy of these ridges is the Gary moraine, which crosses the northern portion of the county. The Gary moraine enters the county from Boone, about two miles south of the Hamilton county line, traverses Lafayette township from northwest to southeast, just below Keigley's branch, crosses Skunk river at Soper's mill, trends north of east and joins the Altamont moraine almost due east of Zearing. Spurs are given off in the form of concentric loops, the first of which passes west of Roland between Long Dick and Beaver creeks, a second appears between Roland and McCallsburg, and a third separates the latter place and Zearing, thus showing that the contraction of the ice tongue was not only longitudinal but lateral as well. The continuation of the outer ridge of the moraine to the westward is known as "Mineral Ridge," an outlying spur of which bears the name of "Pilot Mound."

The width of the morainal tract varies greatly. In the western half of the county the belt extends almost to Ames, indicating that the recession was extremely dilatory. In the eastern half the ridged portion varies from one to three miles, and the differential relief is less pronounced.

A second morainal tract enters the county near the middle line of Washington township, appears as mild ridges at Kelly, fades out toward the river, but reappears much accentuated in northern Union and in southern Grant townships, where kame-like aggregations are a prominent feature. It continues across Indian Creek and Nevada townships, turns southward and spreads out over New Albany and northern Collins townships and fuses with the Altamont. Maxwell hill, a marked eminence rising more than 100 feet above the surrounding country and lying immediately west of the town of Maxwell, appears to be an outlying spur belonging to this system. This hill is more than three miles in length, averages from one-half to a mile in width, trends northwest and, as revealed by road cuts, is composed of more or less stratified sands and gravels. Only bowlders of small size are present, and the hill possesses the essential characters of the kame.

Outside of the morainal tracts, and away from the immediate vicinity of the larger streams, the surface is but little dissected. Chains of kettle holes and swales with a prevailingly northwest-southeast trend, connected only in the springtime or during seasons of protracted wet weather, and separated by complimentary systems of hummocks and ridges, the local inequalities seldom exceeding twenty or thirty feet, — these are the features which characterize the great interfluviatile and inter-morainal areas of the region. The majority of the secondary streams have cut back but a few furlongs, or at most but a few miles, into this maze of kettles and sloughs, while well defined channels of tertiary branches are usually measurable in rods only. The most vigorous topographic features are to be noted where the lateral tributaries break through from the water-sheds to the valleys of the major streams. In short, the valleys of the master stream and its largest confluents are encompassed by belts of broken land which comprise the most rugged features to be found in the region.

In the extreme southeastern corner of the county, outside of the Altamont moraine, is to be found a sample of erosional topography, where the physical features are not only in harmony with, but are the result of, the drainage lines. The area comprises scarcely more than a square mile.

The highest point in the county is on the Gary moraine near Summit, with an altitude of 1,075 feet, and the lowest level is reached on the flood plain of the Skunk, where that stream makes its exit from the county, at an elevation of 830 feet above tide.

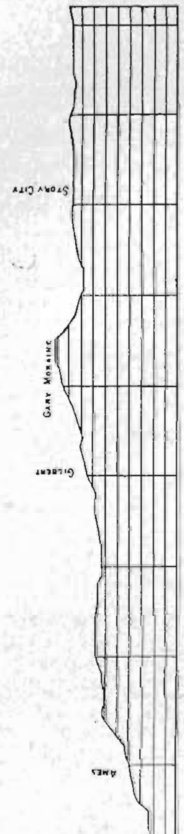


FIG. 16. Profile of the Chicago & North-Western railway.

In the subjoined table the elevations of the most important points in Story county are tabulated alphabetically.

Table of Elevations.

PLACE.	Altitude above tide water.	AUTHORITY.
Altamont moraine near Collins	1022	Barometer.
Altamont moraine near Colo.	1016	Barometer.
Ames	926	C. & N. W. Ry.
Bloomington	1041	Barometer.
Cambridge	854	C., M. & St. P. Ry.
Collins	997	C., M. & St. P. Ry.
Colo	981	C. & N. W. Ry.
Elwell	983	C., M. & St. P. Ry.
Gary moraine near Summit	1075	Barometer.
Gilbert	1003	C. & N. W. Ry.
Huxley	1031	C., M. & St. P. Ry.
Kelly	1035	C. & N. W. Ry.
Maxwell	866	C., M. & St. P. Ry.
Nevada	1005	C. & N. W. Ry.
Ontario	1005	C. & N. W. Ry.
Sheldahl	1042	C. & N. W. Ry.
Slater	1032	C., M. & St. P. Ry.
Story City	1022	C. & N. W. Ry.
Summit	1056	Barometer.

DRAINAGE.

The drainage lines are but poorly developed. The larger streams have apparently reopened, in part at least, pre-Wisconsin channels, and have taken on the aspect of mature streams. They are, nevertheless, characterized by a dearth of small tributaries. Undrained areas are everywhere common on the upland, and at many points can be found within a stone's throw of the bluffs which border the best developed valleys. In scores of sections which constitute the watersheds, the water which falls upon them, save during periods of very high water, cannot escape save through seepage, evaporation or tiling. Many of these ponds persist throughout the year.

Seven-eighths of the run-off of the region finds its way to the "Father of Waters" through Skunk river, while small areas in the southwest and northeast corners of the county contribute to the Des Moines and Iowa drainage systems respectively.

The Skunk River System.—As has been said, the Skunk river with its tributaries afford a convenient outlet for the surplus waters which fall upon the major portion of the county. The Skunk proper traverses the county in a general north and south direction, separating the area into two unequal parts. It enters the county from the north and, crossing back and forth the line which separates the western tier of townships, has a general southerly course until reaching Union township, where the stream veers abruptly eastward and then continues southward, dividing the township into east and west portions that are almost equal in area.

On physiographic grounds the stream is readily divisible into two parts. The first comprises the portion from the point where the river enters the county to the great bend

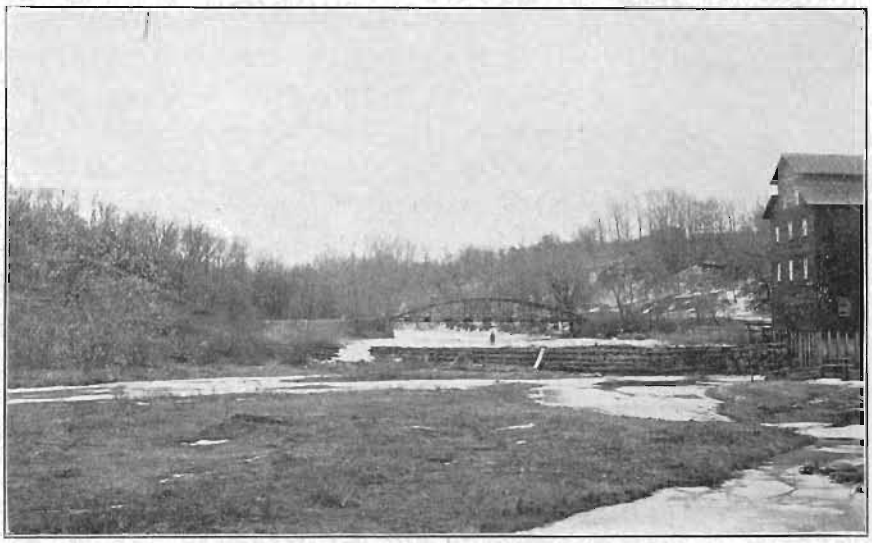


FIG. 17. Gorge on the Skunk river, at Soper's mill.

about two miles north of Ames, and is characterized by a comparatively narrow valley, which in places, as at Soper's and Hannom's mills, narrows to a gorge and is rock-walled. At such points the stream has all the characters of adolescence and is still in the channeling stage, or at most has made but little progress in the formation of a valley. At Story City the trench cut is scarcely more than twenty-five to thirty feet below the general upland. The channel deepens gradually to the southward until the Gary moraine is reached, where the bluffs rise from fifty to seventy feet and increase to upwards of 100 feet at some distance away from the stream.

FIG. 18. The Skunk river, below Hannom's mill. An example of an unstable channel.

Numerous embayments appear in the bluff boundary on the west. The most noteworthy of these appears at Hannom's mill. Here an embayment, occupying approximately a square mile, trends northwest from the great bend which marks the terminus of the newer portion of the stream.

The lower course of the Skunk is strikingly different from the upper. From Hannom's mill southward the valley rapidly widens to a mile near Bloomington, nearly three miles at Ames, and averages about two miles in width throughout the remainder of its course in the county. In Polk county it attains an even greater width. Through this broad alluvial flat, outlined, but not confined, by low banks of its own making, the present stream pursues a most tortuous course, touching the restraining bluffs here and there, but at no point south of Ames revealing the country rock. Deserted channels in all stages, from crescentic lagoons, almost silted in, to the fresh cut-offs, attest the complicated meanders and the numerous attempts of the stream to straighten its course. When closely inspected the stream bottom is seen to be very uneven, and to consist of a series of basins separated by broad, fan-shaped sandbars. Often during the late summer season, or during periods of extended drouth, the stream consists of a series of detached ponds, some of which are ten feet or more in depth, and only connected by sub-surface circulation through the gravel fans. The entire assemblage of superficial features are those characteristic of an old stream. Wells sunk at Ames and Cambridge, on or near the flood plain, tell the same story. The country rock is reached only after penetrating from eighty to upwards of 100 feet of alternating beds of glacial and fluviatile materials. From the great bend in the Skunk, north of Ames, to the point where the river crosses the Polk county line, a distance of sixteen miles, as the crow flies, the fall is about sixty feet, or an average gradient of less than four feet per mile. To follow the stream meanders would more than double the distance, and hence halve the gradient. From the same starting point to the Hamilton county line, the direct route is about ten miles and the total vertical fall is 110 feet, or an average declivity of eleven feet per mile. Taking into account the sinuosities in the stream the gradient would be reduced, at low water, to about five feet per mile. In both sections the impotency of the stream is clearly due to lack of volume rather than to lack of gradient. Thus is readily seen the reason for the stream's multiplied velocity and great destructiveness at flood time. This destructiveness is increased by the additional velocity gained by ignoring the great majority of the meanders and taking a direct route.

At Bloomington the bluffs rise more than 120 feet above the flood plain; at Ames they are reduced to scarcely more than fifty feet, while in southern Grant, and in Union township, they again rise to fully 100 feet above the bottom land. The most important tributaries of the Skunk are Keigley's branch, Squaw, Walnut and Ballard creeks from the west, and Long Dick and Bear creeks from the east, while the various branches of the Indian, Clear and Willow creeks belong to the system, but become confluent outside the area under consideration.

Keigley's branch crosses Lafayette township diagonally, from northwest to southeast, and joins the Skunk at Soper's mill, about one mile south of the township line. The course lies just within the main body of the Gary moraine, and the creek has done little work in valley cutting. Near its *embouchure* it enters a profound depression, probably a preglacial channel. The Skunk is manifestly displaced at this point, and escapes, through the innermost ridge of the moraine, through a narrow, rock-walled gorge. The branch flows through a well marked artesian basin, and drains the major portion of Lafayette township. Numerous springs issue from its banks, many of which persist throughout the year.

Squaw creek is the most important tributary of the Skunk in this section. It enters the region near the middle line of section 7, in Franklin township, continues in a general southeasterly direction into Washington township, and joins the parent stream about two miles southeast of Ames. The Squaw is nearly as large as the Skunk above the junction, and has all of the more important characteristics of the latter. It meanders through an alluvial bottom which varies from a sixth to a half mile in width. This bottom is, in turn, included within a terrace-bordered valley, of much greater width.

Ames, in the main part, is built on a delta-shaped terrace which separates the two streams, and the combined depressions exceed three miles in width. On section 33, in Franklin township, is a marked constriction in the valley of the Squaw, and the stream bears evidence of being displaced to the southwest. North of the point where the creek turns strongly to the east a prominent hill rises more than sixty feet above the water level, its crest immediately overlooking the creek. This hill slopes rapidly away from the stream to a depression which crosses the bend. The termini of the depression are now occupied by small streams which issue from veritable peat bogs. The ridge itself is only one of many similar ones to the northward, and is, apparently, merely one of the advance guards of the Gary moraine. The elbow in the Squaw is probably due to displacement by the ice tongue.

Squaw creek drains less than a township in Story county, and its principal tributaries are Montgomery, Onion, Clear and College creeks, all entering from the west. Of these, Onion creek is rock-bound, the Saint Louis limestone appearing at numerous points along the lower portion of its course. None of these streams have done much work in the way of valley-making, although both Onion and Clear creeks possess narrow flood plains. All are dry throughout a considerable portion of the year, though the upper reaches of Clear and College creeks are fed by seeping springs, which issue at the base of the loess and persist in these parts, even through the driest seasons. Terraces do not appear along any of the tributaries, and it seems reasonable to infer that none of these had a place in the pre-Wisconsin history of the system.

Walnut and Ballard creeks have their sources among the swales and kettle-holes of the Skunk-Des Moines water-shed. From this water-shed they take their sinuous easterly courses across Washington and Palestine townships respectively and enter Union township, where they parallel, and finally join, the master stream. Both have high gradients, and have cut from fifty to seventy feet below the upland level in their lower courses. Neither has succeeded in exposing the country rock. In all probability both are post-glacial streams. The areas drained are about twelve and thirty square miles respectively.

Long Dick and Bear creeks, which enter the Skunk from the east, are long, branchless streams, which are little more than prairie sloughs through the greater portion of their courses, and lie almost wholly within the Gary moraine. Both have their sources in Hardin county, cross Howard township diagonally to the southwest, and have done but little cutting save near their junctures with the greater stream. Bear creek has cut through the drift, exposing the coal measure shales at Roland and the Saint Louis limestone at a number of points before escaping from Howard township. Both creeks cease to flow during the dry season. Both show evidence of appearing at a late date in the history of the system.

Indian creek, with its two unequal branches, known as the West and East Indian, of which the former is the smaller and joins the larger at Iowa Center, almost completely monopolizes the drainage from the tier of townships terminated by Warren and Indian Creek townships on the north and south respectively. The stream is a vigorous competitor of the Skunk for a considerable portion of Grant and Milford townships on the west, and has invaded Sherman, New Albany and Collins townships on the east. It is an outlet for the superficial waters of more than a third of the area of the county. In vertical cutting the work done by the Indian compares favorably with that done by the Skunk; the latter, at its exit, having cut less than twenty feet lower than the former where it makes its exit from the county. In lateral trenching the Skunk is greatly in the lead. The terrace-bordered valley of the Indian varies from a fourth of a mile to a mile in width from Iowa Center, the junction of the east and west forks, to the south line of the county. North of the junction the west fork has done very little in the way of depositing alluvium, while the valley of the East Indian gradually narrows until at the north line of Nevada township the flood plain is scarcely mapable. Indian creek has more and better developed tributaries in the southern half of its course than any stream in the region, and hence Nevada and Indian Creek are the best drained townships in the county. The more mature drainage of this portion of the county is not so much a question of stream gradient, but is rather the result of a difference in surface materials. In Indian Creek and adjoining townships the Wisconsin drift is comparatively thin, merely a veneer over the older drift sheets, and the present features are dominated largely by the pre-Wisconsin topography. Cuts along the roadways reveal the loess in many places, with the ferretto zone of the Kansan oftentimes appearing at a lower level. Palestine and Union townships are equally as well circumstanced, so far as drainage lines are concerned, as is Indian Creek, but the old topography is almost completely obscured by the later drift.

Wells sunk on the Maxwell terrace show more than sixty feet of alternating alluvial and glacial deposits, and indicate that Indian creek has, at least at this point, partially reopened an old valley.

Above the forks characters suggesting an extended career are not so apparent. Terraces follow the East Indian to the middle of Nevada township, and it seems safe to conclude that a considerable stream occupied the valley up to this point at the time of the retreat of the Wisconsin ice. Northward there is no reason to doubt the post-Wisconsin character of the stream. Long finger-like projections of the system extend across the northern half of the county and even enter Hardin county, but afford very inadequate drainage for the area through which they pass.

Clear creek, with its tributary, Willow creek, drains the greater portion of New Albany and the northeast fourth of Collins township, and joins the Skunk at Mingo, in Jasper county. Willow creek occupies a profound depression, all out of proportion to the insignificant stream which at present occupies it. The bottom of the trench is from sixty to eighty feet below the upland. But very little alluvium has been laid. On the Collins township line the stream impinges upon the Altamont moraine and is deflected west of south, then shifts east of south, and finally turns abruptly to the east and breaks through the moraine near the middle of the east line of the township. Clear creek has its source in Sherman township, occupies a less important valley, but has done about the same amount of cutting. Both streams fail to show any of the indurated rocks.

The Des Moines River System.—Big creek and Four Mile creeks make their way lingeringly among the ponds and glades of Palestine township, and are the only representatives of the Des Moines in the county.

Iowa River System.—Lincoln township and a small area in Warren belong to the drainage basin of the Iowa. South Minerva creek is the chief representative of that system, and has its source in the swales about McCallsburg. The stream occupies a narrow valley, and affords a convenient gateway through the Altamont moraine for the Story City branch of the Iowa Central railroad.

STRATIGRAPHY.

General Relations of the Strata.

Story county lies wholly within the great basin of the western coal fields. The frontier of the Iowa coal measures lies at least a dozen miles east of the county. In the west central part of the county there is an arching of the indurated rocks, and the Lower Carboniferous strata have been pushed up through the coal measures, assuming the role of country rock over a considerable area.

The Pleistocene series comprises at least two distinct drift sheets, which are included between and separated by pre-inter- and post-glacial deposits which give a clue to the several climatic variations and surface oscillations to which the region has been subject. The physiographic features are almost wholly expressed in the Pleistocene deposits, as the older rocks are essentially below the level of the present stream beds, and hence almost entirely concealed.

The taxonomic relations of the formations represented are shown in the following synoptical table:

GROUP.	SYSTEM.	SERIES.	STAGE.	FORMATION.
Cenozoic.	Pleistocene.	Recent.		Wind deposits. Alluvium.
		Glacial.	Wisconsin Iowan. Buchanan? Kansan Aftonian?	Drift. Loess. Gravels. Drift. Gravels.
Paleozoic.	Carboniferous	Upper Carboniferous or Pennsylvanian.	Des Moin's.	
		Lower Carboniferous or Mississippian.	Saint Louis.	

It is obvious from the preceding table that the formations which occur in Story county belong to discordant series separated by an enormous time interval; a time unit of the first magnitude. The entire Mesozoic era is unrepresented in the stratigraphic column. The indurated rocks are exposed at but few points. The Saint Louis limestone appears sporadically along Skunk river, between Ames and Soper's mill, and at several points on Onion creek, in Franklin township, while the coal measures are sparsely represented by outcrops along Bear and Indian creeks.

Rocks older than the Carboniferous are not visible within the confines of the county, though the well sections at Ames and Nevada amply demonstrate that every great period of the Paleozoic is represented and appears in reverse order of deposition in a vertical section underlying the county.

At Nevada the following is the sequence and nature of the strata penetrated, as determined by Professor Norton, and published in his report on artesian wells:

NEVADA WELL.

Driller's Record.

	STRATA.	Thick-ness	Depth.
28.	Clay, yellow	30	30
27.	Clay, blue	6	36
26.	Clay, yellow	10	46
25.	Sand	55	101
24.	Clay, tile	20	121
23.	Shale	50	171
22.	Clay, black	75	246
21.	Slate	3	249
20	Coal and slate	1	252
19.	Clay, light gray		267
18.	Shell lime rock	15	282
17.	Lime rock, white, mixed with flint	50	432
16.	Granite, blue	50	482
15.	Limestone, blue	93	575
14.	Shale, red	8	583
13.	Limestone, blue	80	663
12.	Soapstone	8	671
11.	Limestone, white	90	769
10.	Limestone, blue	40	801
9.	Clay, blue	3	804
8	Limestone, blue	55	859
7.	Limestone, white	40	899
6.	Sand rock, dark	35	934
5.	Sand rock, white	10	944
4.	Sand rock, red	12	956
3.	Sand rock, white	8	964
2.	Sand rock, red	4	968
1.	Limestone, white	12	980

Interpretation by Professor Norton.

NOS.	FORMATION.	THICKNESS.	A. T.
25–28.	Pleistocene	101	904
19–24.	Coal measures	166	738
16–18.	Mississippian	215	523
15.	Kinderhook	93	430
7–14.	Devonian	324	106
1– 6.	Silurian, penetrated	81	25

In the above section it is interesting to note the rather unusual character of the Pleistocene deposits. Numbers 27 and 28 are referable to the younger drift, while 26 and a portion of 25, when considered in the light of recent developments farther west, show the presence of a considerable deposit of loess. The top of the coal measures is at least fifty feet lower than the west branch of Indian creek, while more than sixty feet lower than the uppermost shales exposed at the McHose clay pit, one mile west of the mouth of the well. The Silurian shows an unusually arenaceous facies, and is the principal source of water for the city supply.

The college well at Ames explores the earth's crust down to a depth of two-fifths of a mile, and is located about ten miles due west of the Nevada well. The following is a record of the beds penetrated in sinking the well:

DETAILED RECORD* OF STRATA PENETRATED IN SINKING THE COLLEGE DEEP WELL AT AMES.

NO. OF SAMPLE.	DESCRIPTION.	DEPTH OF SAMPLE.
1.	Till, yellow; sandy to gravelly; upper portion modified into soil	1-16
2.	Till, blue, sandy	16-32
3.	Till, blue with some yellow clay	35
4	Sand, yellow	40-50
5.	Till, greenish-blue, containing an abundance of gravel; numerous cherty limestone pebbles are present; matrix effervesces freely with dilute hydrochloric acid	40-50
6.	Silt, ash-brown, with a greenish tinge; calcareous and absorbent, loess-like, but finer	62-97
7	Silt, slightly arenaceous	102
8.	Sand, very fine, light yellow	105
9.	Sand with coarse gravel, water-bearing; limpid and vein quartz pebbles abundant; limestone fragments present	110-120
10	Shale, light, bluish-gray; calcareous and cherty	126
11.	Limestone, blue-gray, argillaceous and pyritiferous	151
12.	Limestone, gray, argillaceous, with some limpid quartz	160-170

*The record is based upon sample borings preserved by the foremen of the crews in charge of the work. The writer is also dependent on the drillers for the data concerning the depths at which the samples were taken. There is reason to believe that more than ordinary care was observed by those in charge in collecting and correctly locating the samples. Therein the record is more complete and reliable than is usual in such borings. Prof. W. H. Norton, of Cornell College, has generously lent his skill in unraveling the drillings, for which acknowledgments are gladly given.

NO. OF SAMPLE.	DESCRIPTION.	DEPTH OF SAMPLE.
13.	Limestone, light gray, soft, even-textured and cherty; effervesces very freely with weak HCl	185
14.	Limestone, slightly argillaceous	200
15.	Limestone and shale	210
16	Shale and limestone	240
17.	Shale, blue, non-calcareous and pyritiferous	310
18	Limestone, argillaceous, tending toward an oolitic facies; effervesces strongly with dilute HCl	315
19.	Shale, with fragments of white limestone; fossiliferous and pyritiferous	320
20.	Shale, earthly-blue and arenaceous	325
21.	Shale, light, reddish-brown, with some green shale; slightly calcareous	330
22.	Limestone, blue-gray; green shale and brown limestone present	375
23	Limestone, brown, pyritiferous	385
24.	Limestone, brown, with fragments of white cherty limestone and angular quartz grains present	395
25	Limestone, brown, argillaceous	400
26.	Shale, light gray and highly calcareous	415
27	Shale, gray-blue, calcareous	416-420
28	Limestone, yellowish-gray, with some carbonaceous matter	420
29.	Limestone, white, compact	440-456
30.	Limestone, white, fossiliferous	460-475
31	Shale, light, bluish-gray	495
32.	Shale and limestone	540
33	Limestone, white and shale, greenish-blue, non-calcareous	550
34.	Shale, ash-blue, calcareous	560
35.	Limestone, gray-blue, with fragments of brown limestone and green shale	570
36.	Limestone, gray-blue	580
37.	Limestone, gray, and blue-green shale	590
38.	Limestone, fossiliferous	600-610
39.	Limestone, gray-brown, sub-crystalline	615-640
40.	Limestone, gray-brown, and shale	645-660
41.	Limestone, buff, sub-crystalline	660-680
42.	Limestone, buff, earthly luster, soft; effervesces moderately when treated with HCl	690
43.	Limestone, blue and buff; the latter is part vesicular and magnesian	700

NO. OF SAMPLE.	DESCRIPTION.	DEPTH OF SAMPLE.
44.	Limestone, drab, highly argillaceous	710
45.	Limestone, of various kinds; one a buff, earthy limestone, finely laminated, and effervesces slowly; the laminæ are marked by dark gray bands	720
46.	Dolomite, light gray	730
47.	Dolomite, brown and gray, sub-crystalline; varying in hardness and color	740
48.	Limestone, buff	750
49.	Limestone, buff, with fragments of olive green shale (the shale was at 775 feet)	775
50.	Limestone, buff	815–830
51.	Shale and limestone	840–850
52.	Dolomite, ash-gray	860
53.	Dolomite, white	870
54.	Shale, green, plastic, non-calcareous	880
55.	Shale, reddish-brown, slightly calcareous	890
56.	Shale, earthy brown, non-calcareous	900
57.	Shale, blue and green, non-calcareous	930
58.	Shale, brownish, slightly calcareous	940
59.	Shale, brownish, with white shale	950
60.	Shale, blue, non-calcareous	960
61.	Shale, earthy brown, calcareous	970
62.	Shale, blue	980–990
63.	Shale, earthy and calcareous	1010–1020
64.	Shale, blue, calcareous	1030
65.	Limestone, sharp drillings in an argillaceous powder	1040
66.	Limestone, white	1050–1060
67.	Limestone, white, with much argillaceous material	1080–1090
68.	Limestone, gray blue, with blue shale and white chert	1100
69.	Limestone, gray-blue, compact, with white chert in abundance; drillings sharply angular	1110–1130
70.	Limestone, same as above, but less chert	1140–1170
71.	Limestone, slightly earthy, gray blue	1180–1190
72.	Limestone, gray blue, marly	1200
73.	Limestone, buff, magnesian, marly	1210–1230
74	Limestone, ash-gray	1240–1260
75.	Limestone, ash-gray, with fragments of non-calcareous, black and green shale	1270
76.	Limestone, brown, soft	1280
77.	Limestone, gray and brown, cherty	1290

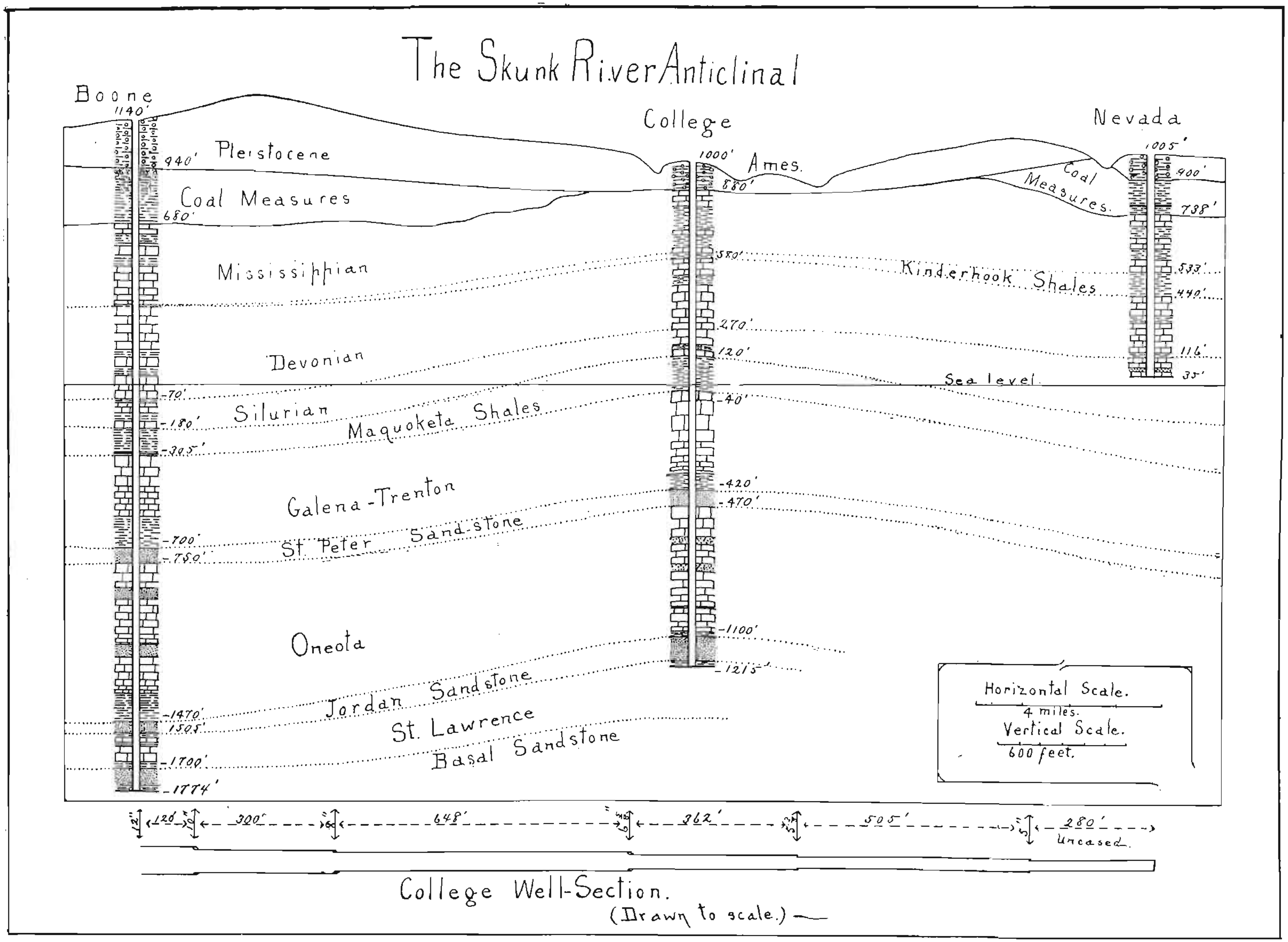
NO. OF SAMPLE.	DESCRIPTION.	DEPTH OF SAMPLE.
78	Limestone, gray, with considerable reddish-brown residual material	1300
79	Limestone, cherty	1310
80.	Limestone, gray, with green shale	1320
81.	Limestone, gray, siliceous	1330–1380
82.	Shale, green, fissile, non-calcareous; fossiliferous and pyritiferous	1385–1410
83.	Sandstone, fine textured, white; grains even and well water-worn	1420–1460
84.	Sandstone, calciferous	1470–1480
85.	Dolomite	1490–1500
86.	Dolomite and sandstone; beautiful doubly terminated quartz crystals present	1510
87.	Sandstone	1520
88.	Dolomite	1530
89.	Dolomite, some coarse sand and green shale present	1540
90.	Sandstone and dolomite; sand varying in grain	1550
91.	Sandstone, grains angular	1560
92.	Dolomite	1570
93.	Dolomite, arenaceous	1580
94.	Dolomite, arenaceous and cherty	1590–1600
95.	Sandstone, fine-grained, angular; calcareous cement	1610
96.	Sandstone, yellow, with much siliceous dolomite	1620
97.	Dolomite, highly arenaceous	1630–1640
98.	Dolomite, white, finely qua'tzose	1650
99.	Dolomite, arenaceous	1660–1680
100	Marl, yellow, in an argillo-calcareous powder; cherty and quartzose	1690
101	Dolomite	1700–1710
102.	Dolomite, highly arenaceous	1720–1730
103	Dolomite	1740–1750
104.	Dolomite, with chert and sand	1760
105.	Sandstone	1770–1790
106.	Dolomite	1800–1830
107.	Dolomite, arenaceous	1840
108.	Dolomi'e, argillaceous and arenaceous	1850
109.	Dolomite	1960–1880
110.	Dolomite and sand	1890–1910
111.	Dolomite, highly arenaceous	1920
112.	Dolomite	1920
113.	Sandstone	1930
114.	Dolomite	1950–1960

NO. OF SAMPLE.	DESCRIPTION	DEPTH OF SAMPLE.
115.	Dolomite, arenaceous; sand grains well water-worn	1970-1990
116.	Dolomite, arenaceous, with green shale	2000-2010
117.	Dolomite	2020-2040
118.	Dolomite, highly arenaceous	2050
119.	Dolomite	2060-2070
120.	Dolomite, argillaceous	2080
121.	Shale, blue, non-calcareous	2090
122.	Sandstone, with dolomite and a little blue shale	2100
123.	Sandstone, white and water-worn; a small percentage of the grains iron-stained	2110
124.	Sandstone, white; grains fine, sharp	2120
125.	Sandstone, as above, with coarser, well-rounded grains	2130
126.	Sandstone, white; grains fine, even, well worn	2140-2175
127.	Sandstone, white; texture variable	2185
128.	Sandstone, grains stained red with iron oxide; red and green shale present; grains larger than above, and more angular; iron pyrites and a black metallic mineral present	2195
129.	Shale, brownish-red, arenaceous	2205
130.	Shale, green	2215

Summary of Formations.

Number.	FORMATION.	Thickness —feet.	Elevation at top—feet.
1-9	Pleistocene	120	1000
10-27	Mississippian	300	880
28-45	Devonian	310	580
42-53	Silurian	150	270
54-64	Maquoketa	160	120
65-82	Galena-Trenton	380	—40
83-84	Saint Peter	70	—420
85-121	Oneota	510	—490
122-130	Saint Croix (penetrated)	115	-1100

The glacial debris is, perhaps, about the average thickness for Story county. The deposits of fine silt reached at sixty-two feet outcrops along Clear creek, about one-half mile west of the college, where it attains a thickness of twenty feet, and possesses the faunal remains, concretions and physical


The Skunk River Anticlinal
Boone
1140'
940'
680'
Pleistocene
Coal Measures
Mississippian
Devonian
-70'
-180'
-305'
Silurian
Maquoketa Shales
Galena-Trenton
-700'
-750'
St Peter Sand-stone
Oneota
-1470'
-1505'
Jordan Sandstone
St. Lawrence
-1700'
Basal Sandstone
-1774'
College
1000'
Ames.
880'
580'
270'
120'
-40'
-420'
-470'
-1100'
-1215'
Nevada
1005'
900'
738'
Coal Measures.
533'
440'
Kinderhook Shales
116'
35'
Sea level
Horizontal Scale.
4 miles.
Vertical Scale.
600 feet.
126'
300'
648'
362'
505'
280'
Uncased.
College Well-Section.
(Drawn to scale.)

properties which characterize the loess in its typical develop ment. The level of the outcrop is somewhat higher than its equivalent reached in the well. The silt grades downward into fine sand, similar to the sub-loessial sands exposed so freely along the southern margin of the Iowan till sheet in Polk, Marshall and Tama counties. The drift affords more than the usual proportion of sand and gravel. A water-bearing layer occurs within sixteen feet of the surface, a sand and gravel bed ten feet in thickness was encountered at forty feet below the surface, and the superficial deposits terminate in a bed of sand and coarse gravel which is also water-bearing.

The coal measures are not represented in the above section, although the utmost diligence was exercised in the search for the slightest clue to their presence. Coal is mined at Summit, about eight miles north of the college, and 165 feet of shales and clays represent the Upper Carboniferous series at Nevada, ten miles east; while at Boone, twelve miles west, 266 feet of sandstones and shales may be referred to this formation. It is reported that coal was found when sinking the well at the Experiment station, about a quarter of a mile northeast of the deep well. While this is altogether possible, and even probable, it seems reasonably certain from other data at hand that if coal *in situ* does really exist at that point it can be little more than a detached basin or "pocket," of very limited area. It is more probable that the fragments of coal which appeared in the slush bucket were derived from included fragments in the base of the drift.

The Mississippian series consists of 100 feet of limestone, followed by 200 feet of alternating shales and limestones. The Kinderhook shales at the base of the series, which reach such a marked development in southeastern Iowa, rapidly feather out to the northwestward. The terrain is represented by 175 feet of shale at Marshalltown, 93 feet at Nevada, 20 feet at the college, and is scarcely recognizable at Boone.

The Devonian is represented, chiefly, by a series of limestones, and, as in the case of the Carboniferous, is not water-bearing in this locality. The assemblage of beds thickens westward, reaching about 400 feet at Boone.

Dolomitic limestone, interbedded with thin bands of shale, constitute the Silurian. At Nevada arenaceous beds are present, and the city draws its water supply from this source.

The Maquoketa consists of non-calcareous green shales, earthy-brown and blue shales, varying in lime content from slightly calcareous to strongly calcareous at the base of the terrain. The formation thins slightly westward.

The Galena-Trenton is represented largely by a massive white limestone, highly siliceous in certain layers. The silica is chiefly in the form of cherty concretions and limpid quartz. The lower portion of the assemblage contains intercallated bands of green shale, and the Saint Peter sandstone is crowned by a thick band of highly fossiliferous green shale. The drill brought up fragments of this shale which contained in abundance the remains of a marine fauna. Pygidia of at least two species of trilobites: Dalmanites and Isotelus (Asaphus), resembling some forms of *I. gigas* DeKay, and several species of brachiopods were recognized. Impressions of the dorsal valve of *Rafinesquina alternata* are perfectly preserved. So, also, some very good specimens of *Orthis subæquata* and *O. fissicosta* were found, along with other small Orthides, which were not so well preserved, and not capable of specific determination. All of the fossils brought up by the drill are found in typical outcrops of the Lower Trenton shales, but *Orthis subæquata* is the only species whose range is limited to that horizon. The Maquoketa, with the Trenton shales, forms an impervious roof which effectually prevents the escape upward of the water in the great sandstone reservoirs of the Lower Paleozoic. Although the water thus imprisoned lies far below the sea level in central Iowa, hydrostatic pressure brings it within pumping distance of the surface when the shales are penetrated, and thus renders the storage supply available. The area of intake in Wisconsin and Minnesota is higher than the average upland surface of Iowa.

The Saint Peter comprises about seventy feet of strata, the greater portion of which is composed of white beach sand. The constituent grains are remarkably uniform in size and well rounded. These layers of water-worn sands are but slightly compacted, the drill penetrating about thirty feet during a single "watch." The lower portion of the terrain contains a calcareous cement and is more highly indurated.

The Oneota is essentially a massive dolomite bisected unequally by a well-marked sand bed. Sandy layers appear at other points, and siliceous grains occur in greater or less abundance throughout the formation. The principal sandstone band is known as the New Richmond by the Minnesota geologists, and is one of the chief water-bearing horizons in that state. The Oneota grades downward into shales and arenaceous shales, which make an easy transition from the Saint Croix sandstone to the massive dolomite above.

The Saint Croix in central Iowa can be separated into three fairly well marked divisions: an upper sandstone, a median series of dolomites and shales, and a lower member, which comprises sandstones, marls and shales. The upper two are known as the Jordan sandstone and the Lawrence limestone member is the Basal sandstone, according to W. H. Nor- respectively, of the Minnesota geologists, and the lower ton.* Of these divisions of the Saint Croix, the college well penetrates only the Jordan, which has a thickness of one hundred feet, and ends in the St. Lawrence. The Jordan sandstone, with the New Richmond and the Saint Peter, are the great reservoirs from which the well may draw. Their ability to contribute to the general water supply, according to pumping tests from these horizons, is in the proportion of 15, to 4, to 1, respectively.

*Iowa Geological Survey, vol. VI, p. 140.

Geological Formations.

MISSISSIPPIAN SERIES.

Of the above series, only the uppermost member known to occur in Iowa is represented, and appears in the west-central part of the county. White* mentions an exposure of impure limestone in this region, and referred the beds to the Saint Louis of Shumard, named after the city whose location is near where the rocks of this epoch are typically developed.

The Saint Louis is supposed to underlie the entire county, and to form the basement for the coal measures. It is known to be the country rock over an irregular area in Franklin and Washington townships, and perhaps extends into Milford and Howard. The chief outcrops occur along the Skunk and its immediate tributaries between Ames and Soper's mill, and along Onion creek, in Franklin township. The beds exposed consist, in the main, of impure limestone, but arenaceous layers and calcareous shales are usually also present.

Northward from Ames, an earthy, buff limestone appears above the river bed, about thirty rods south of the Washington-Franklin township line, and continues in view for a few rods. This is the southernmost outcrop of the Saint Louis limestone in the region.

Perhaps the most typical exposure occurs on the Se. qr. of the Sw. ¼ of Sec. 25, in Franklin township. Here the following section may be observed:

SECTION I, NEAR BLOOMINGTON.

		FEET.
5.	Drift	5–10
4.	Limestone, earthy, yellow; very much disintegrated and rubbly; bedding planes almost eliminated	4
3.	Limestone, fossiliferous	1

*Geology of Iowa, vol. II. pp. 259-60. Des Moines, 1870.

		FEET.
2.	Limestone, similar to 4; bedding planes apparent, but showing tendency to become marly and assume a fissile structure in places	3
1.	Limestone, buff to gray-buff when unweathered and massive; layers from ten to twenty inches in thickness; compact, lithographic in texture, fracture conchoidal to uneven; and earthy when weathered (exposed)	6

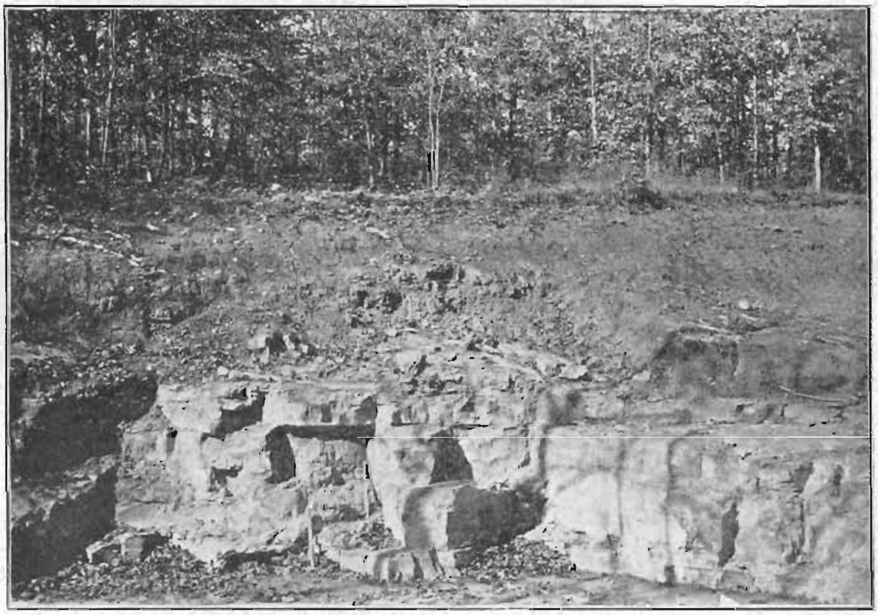


FIG. 19. Saint Louis, as viewed near Bloomfield, and described in Section II. X, near the top, shows the position of the fossil horizon.

The lowest layers exposed lie about twenty-five feet above low water in the Skunk. The drift cannot be differentiated at this point, and apparently only the Wisconsin is represented. Limestone fragments are very abundant near the base of the drift, and in places the rubble layer graduates almost insensibly into undoubted till. The small stream which the quarry faces contains numerous masses of chert, which apparently belong to layers higher in the series. The parent ledge, to which these fragments belong, is not visible in this vicinity. Many of the masses are cavernous, and take on a geode-like character; the cavities oftentimes being decorated with well developed quartz crystals, which project in towards the center. The cherty layers may be seen *in situ* at Soper's mill, where it appears from ten to fifteen feet above the water level.

The entire assemblage of beds is characterized not only at this point, but over the entire area, by a buff or earthy buff color when weathered, and gray-buff to blue-gray when unweathered. The beds are lithographic to earthy in texture, this depending on the various stages of weathering. A Fenestelloid Bryozoan and a Syringoporid coral occur throughout the upper half of the section.

The fossiliferous band is really a reef composed of Cyathaphylloid individuals of very complex forms and entwined in a most complicated manner. The internal coralline structure of the individuals represented is entirely destroyed, and the molds are filled with crystalline calcite. Associated with the corals are the following forms, which leave little doubt as to the Saint Louis character of the beds.

Productus marginicinctus Hall.
Athyris subquadrata Hall.
Spirifer keokuk Hall.
Terebratula (*Dielasma*) *turgida*.
Lingula Sp.(?)

All of the faunal remains are very imperfectly preserved and are obtained only with great difficulty. The fossil-bearing zone is very persistent and can be recognized throughout the area wherever the equivalent beds are exposed.

Two hundred yards north of the preceding section, the Saint Louis beds appear on both sides of a ravine which enters the small creek just mentioned. The beds equivalent to the upper half of the section just described have been removed, and the profoundly planed, grooved and striated surface presented by the indurated rocks is but the unmistakable imprint of the agent which effected the removal. The striæ maintain a constant direction and trend 32° east of south. Two drift sheets and a gravel layer are present. The section is as follows:

SECTION II, NEAR BLOOMINGTON.

		FEET.
4.	Till, pale yellow, slightly oxidized and leached, and containing numerous limestone fragments and bowlders	6
3	Gravel and sand, more or less stratified and cross-bedded, and carrying numerous greenstone pebbles	1-2
2.	Till, blue, jointed; stained yellowish-brown along the joint planes; very compact; can only be removed by use of the pick; greenstones predominate	2
1	Limestone, gray-buff, compact and massive: the same as No. 1, in the first section (exposed)	10

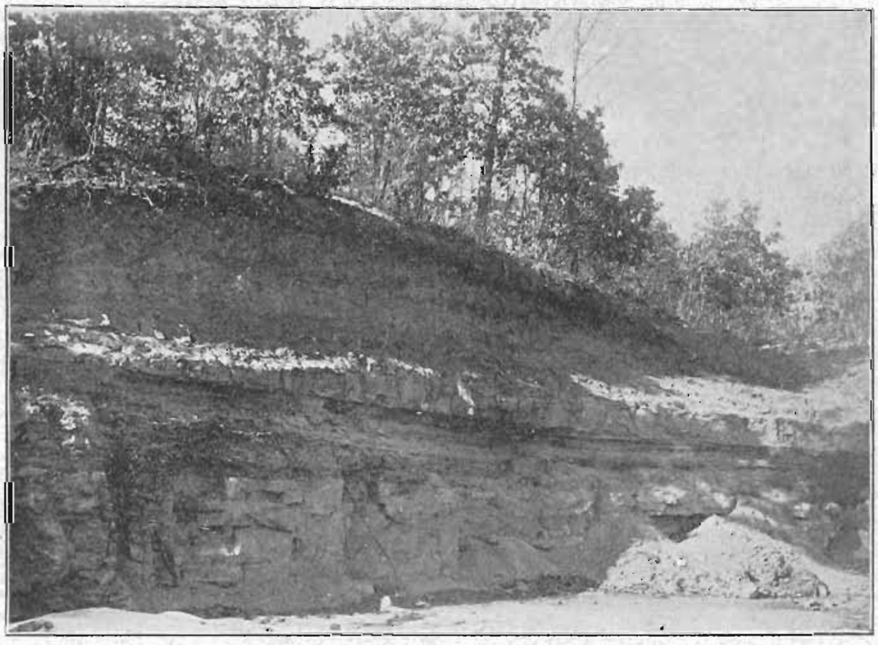


FIG. 20. Saint Louis, planed and scored; two drift-sheets, and inter-glacial deposits present; described in Section II.

It appears evident that the planing and grooving was done during the time of the first glaciation represented by No. 2, and that the ice which formed the later till did not touch the stratified rocks at this point.

In section 26, the low ridge which skirts the flood plain of the Skunk on the east appears to be rock-supported, but no indurated deposits are visible until the southwest quarter of section 23 is reached. East of the wagon bridge, the former site of Hannom's mill--and still known by that name—continuous outcrops appear on both sides of the flood plain; on the south, forming a low bench from which the drift has been almost entirely removed, and on the north, appearing at the base of the bluffs which have retreated some distance from the present stream channel. The river runs against the south bank, and the bench is bounded by an escarpment which exhibits the following sequence of beds:

SECTION III, AT HANNOM'S MILL.

		FEET.
6	Soil and bowldery wash	3
5.	Limestone, residual and concretionary	½
4.	Limestone, arenaceous, yellowish-gray to blue-gray, thinly-bedded and much fractured; in places argillaceous, while in others tends towards the massive; the fissility is apparently a function of weathering; small cherty concretions present	6
3.	Sandstone, grayish-blue friable; shaly below	2
2.	Limestone, impure, grayish-buff, uneven to earthy fracture; compact and heavy-bedded	4
1.	Limestone, gray-buff, compact, almost lithographic in character	5

The base of the above section is the water level in the river. The "coral reef" with its associated fauna bisects No. 1, and occurs at a level nearly twenty-five feet lower than at the type section near Bloomington. The sections are removed from each other about two miles in a northwest-southeast direction, presumably coincident with the line of strike. The average dip would be therefore about twelve feet per mile and only demonstrates the presence of a local undulation. The beds exposed north of the flood plain are for all practical purposes a duplication of those exposed on the south side.

North of Hannom's mill the Lower Carboniferous rocks pass from view, being concealed by the Pleistocene deposits until

Soper's mill is reached. Here, as stated in the discussion of drainage, the river flows in a new channel, having been diverted by the last ice-sheet and obliged to cut directly through a hill. The Saint Louis limestone appears in both sides of the gorge, and about twenty-five feet of earthy buff limestone, with considerable chert interspersed throughout, is exposed. The section is very much obscured by talus and drift, but the following is a fair approximation.

		FEET.
4.	Drift, pale yellow, bluish below, unoxidized and unleached	10
3.	Limestone, rubbly, with occasional heavy ledges	10
2	Limestone, cherty, concretionary, cavernous; some of the larger caverns coated with calcite crystals, which consist of complicated combinations of the scalenohedron and rhombohedron, and smaller quartz decorated caverns	5
1	Limestone, gray buff, compact; heavy, but irregularly bedded; some of the layers two feet in thickness	10

The strata in the above section cannot be correlated with the preceding sections with absolute certainty. Diligent search was not rewarded by even a trace of an organism. The arenaceous beds were not noted at this point. Aside from this the dominant characteristics are so nearly identical with those observed in the preceding quarries, that these beds doubtless may be referred to the same formation with a high degree of certainty.

North of this point no further exposures are known along the Skunk. Similar outcrops, on a smaller scale, appear along Bear creek for some two miles up stream, when the Saint Louis disappears beneath the coal measures.

Although Squaw creek has cut to practically the same level as the Skunk, and the restraining bluffs have, at several points, the appearance of being rock-supported, no exposures are known to exist. Onion creek, however, breaks into the flood plain of the Squaw from the west, through a rock-bound gorge. The Saint Louis is visible at numerous points on section 32, in Franklin township, and attains a maximum of twenty feet above the water level in the creek. The beds are less constant here than are their equivalents on the Skunk.

On ascending Onion creek from the flood plain of the Squaw, the first important exposure appears on the left bank, where the following sequence may be observed.

SECTION V, NEAR THE MOUTH OF ONION CREEK.

		FEET.
7.	Drift, very bowldery	2
6.	Limestone, impure, very much shattered and weathered	1½
5.	Limestone, heavy-bedded, forming a projecting ledge	1½
4.	Limestone, shaly, and containing numerous remains of a Fenestelloid Bryozoan (Fenestella zone)	1
3.	Limestone, yellowish-buff to gray buff; close textured, and bedding planes not apparent; the upper 15-inch layer more indurated than the lower portion; non-fossiliferous throughout	7
2.	Sandstone, gray to yellowish-gray, calcareous and shaly; but slightly indurated and irregularly bedded	4
1.	Limestone, buff, thinly and unevenly bedded; exposed	2

Organic remains here, as elsewhere, are very scarce. Aside from the Bryozoan, a Syringoporoid coral appears in the limestone layers, and seems to be common to nearly all of the limestone exposed in the region.

About 100 yards up stream from section 5 the following beds, on the opposite side of the creek, may be viewed:

		FEET.
6.	Drift, as in the preceding; only one drift sheet can be identified in any of the exposures of the area	5
5.	Limestone, much weathered and shattered	2½
4.	Limestone, buff, compact to earthy; heavy-bedded; the lower layer approximates two feet	5½
3.	Limestone, cherty, concretionary and cavernous, and containing much iron in the form of limonite and pyrites; forms a projecting ledge in the quarry face	1½
1.	Sandstone, argillaceous, fissile; becoming shaly below, exposed	3

The base of the section is about two feet above the water in the creek. The beds are, apparently, absolutely devoid of organic remains. The creek impinges against the bank at this point, and the softer layers below, by undermining, aid in maintaining an escarpment. See figure 21.

FIG. 21. Representative section of Saint Louis limestone, as it appears along Onion creek.

One hundred and fifty yards southward the beds exposed to view indicate that shore conditions with variable currents prevailed while the deposits were being put down. Bryozoan remains are very sparsely distributed in the limestone layers. The section shows:

		FEET.
6.	Drift, almost entirely removed	0–2
5.	Limestone, rubbly, thinly-bedded and much weathered, stratification planes almost entirely eliminated; beds graduate upward into a residual clay	4
4.	Limestone, impure, yellowish-buff to gray-buff, compact to earthy; heavy-bedded	7
3.	Limestone, finely arenaceous and marly; contains beautifully preserved mud cracks and ripple marks	2
2.	Sandstone, white to bluish-gray, friable; obliquely laminated and fissile; readily undermined by the creek during seasons of high water	1½
1.	Limestone, concretionary; contains much limonitic iron; exposed above the water level	2

Near the center of section 32, where the creek changes from a west to east course and flows almost due north, about ten feet of the older rocks appear. A fossiliferous band occurs here, and is probably the equivalent of the fossil-bearing zone described in the Bloomington section.

The Brachiopodal remains are confined to a layer scarcely a foot in thickness, while the corals and Bryozoa have a wider range. All of the organic remains are in a bad state of preservation, and cannot be specifically determined. Of the Brachiopods, representatives of Productus, Spirifer and Athyris prevail. In the drift a fragment of sandstone, bearing casts of *Inoceramus—sp?* and a portion of a keeled Ammonite, very similar to *A.* (*Placenticeras*) *placenta* DeKay, were found. The lowest beds in the Onion creek area outcrop here, and dip at a low angle both to the north and to the west. In the latter direction they soon pass from view beneath the heterogeneous materials of the drift.

The Lower Carboniferous deposits are reached at many points in Franklin, Washington, Milford, and Grant townships and apparently are not overlain by coal measures; but outside of the area described, they are not known to appear at the surface.

PENNSYLVANIAN SERIES.

THE DES MOINES STAGE.

So far as now known the coal measures are present over seven-eighths of the area of the county. The Saint Louis floor is fully as irregular as the present surface, and is responsible, in a large measure, for the great variability in the thickness and the anomalous distribution of the beds belonging to this stage. The outcrops of the Saint Louis have elevations of 950, 940 and 975 feet A. T. for Onion creek, Hannom's and Soper's mills respectively. While well sections show that the same formation is reached at 880 feet A. T. at the college, 900 A. T. at Story City, and 774, 800 and 700 feet A. T. for Nevada, Maxwell and Collins respectively. The general inclination of the coal measure basement is to the east and tilts slightly to the south.

While so widely distributed, outcrops of the Des Moines are very rare, and are wholly confined to a narrow zone which extends from Story City and Roland in a southeasterly direction across the county by way of Nevada and Maxwell. This band forms a distinct ridge in the indurated rocks, and exposures occur wherever the more important streams cross it.

About one mile southeast of Story City alternating bands of sandstone and shale appear a few feet above the water level in the river. Clay-ironstones are noted in the stream, and the flood plain is much constricted at this point, being scarcely more than one hundred yards in width. Eastward, in section 18, near the mouth of Long Dick creek, a fissile, highly carbonaceous shale, coaly in places, rests upon a gray-blue fire clay, the top of the clay being almost coincident with low water level. In certain places a highly ferruginous shale appears above the coaly layers. The iron appears in the form of limonite concretions, and where exposed assumes a deep red-brown. The maximum exposure does not exceed four feet. The water in the almost isolated ponds which represent the river during seasons of low water, continues murky for some distance down stream, but the coal measures are not visible below the junction of the above mentioned creek.

Near Roland, at Swenson Brothers' coal pit, several feet of clay shales over sandstone are exposed along Bear creek; while at Nevada, at the McHose clay pit on the West Indian creek, eighteen feet of shales are exposed, and at Maxwell, fifteen feet of argillaceous deposits may be viewed. The above outcrops represent the maximum exposures of the Des Moines in the county. Data collected from wells and shafts give more information concerning the distribution, thickness and nature of the Upper Carboniferous deposits.

The Larson well, on the northeast quarter of section 5, in Lafayette township, penetrated twenty-five feet of sandstone and shale; and the Tilden well, in section 17, in Franklin township, revealed twenty feet of the same material. Both wells passed through thin seams of coal. The following is the driller's record of the well put down for the C. & N.-W. Ry. Co. at Story City.

		FEET.	INCHES.
18.	Soil and yellow clay	12	
17.	Clay, blue	22	
16.	Quicksand, fine, white, with a little water		6
15.	Clay, blue	51	6
14.	Quicksand, with water	1	
13.	Earthy material, hard, black		6
12.	Fire clay	3	
11.	Sandstone, very hard, white	2	6
10.	Fire clay	1	
9.	Sandstone, with seams of clay, one to two inches in thickness, intercallated	9	
8	Chert		6
7.	Sandstone, ferruginous; magnetized the drill	1	6
6.	Fire clay	4	
5.	Chert and fire clay in alternating layers, varying from five to fifteen inches each	8	
4.	Sandstone and chert	1	2
3.	Sandstone, with much water	12	
2.	Chert, transitional	5	
1.	Chert and clay, as before	22	

Pyritiferous bands and layers of coal from one to four inches in thickness were reported to be associated with the fire clays. The section is scarcely susceptible of more than a tentative interpretation on account of the doubtful nomenclature used. The drift attains a thickness of eighty-seven feet, but it is impossible to delimit the coal measures. The great abundance of chert reported may, perhaps, be a case of "mistaken identity" and is confusing. Clay-ironstone would be more in harmony with the fire clay and coal with which it was said to have been associated. In any case, the Des Moines is certainly present, and is represented by the usual alternating sandstones and shales with carbonaceous layers.

A well at Summit exhibits the following sequence; the record being furnished by Mr. W. S. Johnson.

WELL SECTION AT SUMMIT.

NO.	DESCRIPTION.	FEET.	INCHES.
25.	Soil	3	
24.	Clay, yellow	20	
23.	Clay, blue	5	
22.	Sand, bluish	1	
21.	Sea-mud	46	
20	Sand, yellow	20	
19.	Hard rock	1	
18.	Clay, sandy	3	
17.	Coal		4
16.	Fire clay	1	
15	Coal		5
14.	Fire clay, bluish	11	
13	Coal		5
12.	Fire clay	7	
11.	Coal, good	2	
10.	Slate, dark blue	4	
9.	Slate rock, hard	3	
8	Slate, blue	8	
7.	Coal	4	6
6	Fire clay	3	
5	Rock	1	6
4.	Fire clay	18	
3.	Coal	1	
2	Fire clay	38	
1.	Shale, black	5	

An interesting feature of the above section may be noted in the Pleistocene deposits. Number 21 is designated "sea-mud" by the drillers, and probably represents the loess—a fact which will be elaborated in the proper place. The lower 112 feet are clearly referable to the Upper Carboniferous, and consist essentially of clays and clay shales alternating with arenaceous layers and thin seams of coal. The shale which forms the roof to the principal seam of coal at number 7, contains numerous specimens of *Lingula mytiloides* of Meek and Worthen.

The Nevada well shows 166 feet of shale, which represents the entire thickness of the coal measures at that point.

At Maxwell, a well located near the clay pit of the Maxwell Brick and Tile works, passes through the following layers, as reported by Charles McHose, proprietor of the works.

		FEET.	INCHES.
40.	Soil	6	
39.	Sand rock	2	
38.	Soapstone	2	
37.	Sand rock, gray	2	
36.	Soapstone, gray	2	
35.	Potter's clay, red	2	
34.	Potter's clay, gray	2	
33.	Sandstone, gray, blue	5	
32.	Soapstone	2	
31.	Slate, dark	4	
30.	Coal		6
29	Sandstone	11	
28.	Sand rock	2	6
27	Soapstone	5	
26.	Slate, decomposed, black	11	6
25.	Slate, bowldery below	7	
24.	Coal		8
23.	Fire clay	1	
22.	Slate, various shades of gray	13	
21.	Soapstone and fine grit	6	
20.	Fire clay	2	
19.	Soapstone	4	
18.	Slate	16	
17.	Black-jack, impure coal		6
16.	Fire clay	2	
15.	Soapstone	4	4
14	Sandstone		6
13.	Coal, rotten		3
12.	Soapstone, pure	3	3
11.	Sandstone, soft	2	
10.	Soapstone	2	2
9.	Slate, black		7
8.	Fire clay	1	
7.	Soapstone	5	7
6.	Slate, black	4	3
5.	Slate, shelly	9	4
4.	Soapstone	1	
3.	Shale, gray	1	8
2.	Fire clay		3
1.	Shale, gray		6

Arenaceous beds and grits are more in evidence here than they are in the Summit and Nevada sections. The mouth of the well is located on the bottom of a small ravine which enters Indian creek from the east. Add to the beds penetrated by the drill the shales exposed at the pit, which lie above the mouth of the well, and a total of more than 160 feet of coal measures are present in this portion of the county.

In Collins township, section 34, a shaft sunk on the bottom land along Wolf creek, penetrated seventy feet of glacial debris, and more than seventy feet referable to the Des Moines.

SUMMARY.

So far as now known, the coal measures underlie the entire eastern two-thirds of the county, and occupy the whole of Palestine and Lafayette, and considerable areas in Washing and Franklin townships. From Soper's mill south, the Skunk river has doubtless entirely removed the coal-bearing beds over at least the area mapped as flood plain, and, perhaps, in addition, the terrace areas as well.

The beds referable to the Des Moines are overwhelmingly argillaceous. Fire clays, clay shales and shales of various compositions and textures greatly predominate. Arenaceous beds and carbonaceous seams form an integral, but minor part of the section. The beds probably attain their maximum thickness in the south central portion of the county where they exceed perhaps 200 feet.

THE PLEISTOCENE SERIES.

Beds referable to the Pleistocene period almost completely mantle the county, and consist of bowldery gravels, sands, silts and clays, usually commingled in a most complicated manner, and forming a heterogeneous deposit known as the "drift." Only the more important drainage lines have completely cut through the drift, and these at but few points. Hence the physical features find their expression wholly in the Pleistocene deposits. Not only is the present landscape dependent upon this superficial mantle, but the latter is the chief source of the wealth of the community as well.

While to the layman an attempt to classify and arrange the constituent elements in this confused mass of rock debris would appear to be a profitless and hopeless task, a careful examination shows that it is possible to correlate certain of the beds and bring some order out of chaos. The Pleistocene deposits in Story county show the presence of at least two drift sheets, which demonstrates that the region must have been subjected to an equal number of ice invasions. The till sheets are separated by, and overlain by, deposits characteristic of interglacial and post-glacial times. In many well sections gravel and sand in considerable amount, containing pebbles foreign to the locality, are found resting upon the indurated rocks underlying the lower till sheet and suggesting the possibility of a still earlier ice invasion.

KANSAN DRIFT.

Deposits referable to the Kansan stage were produced by the Keewatin glacier, which, at its maximum extension, crossed the Missouri river into Kansas, a fact which suggested the name of this sheet of drift. The Kansan ice sheet undoubtedly planed and scored the entire region, and the till formed by it appears to be equally widespread, save that over certain insignificant patches it has been removed by erosive agents subsequent to its deposition. Although so generally distributed, it is even more obscured by the later deposits than are the indurated rocks, and our knowledge of its characteristics, thickness and distribution have been gained almost wholly from artificial exposures and sections. The only natural outcrops known to the writer occur about Hannom's mill and Bloomington along the Skunk, and in the vicinity of Maxwell along road cuts and ravines. In all of these cases the exposures are very insignificant, and never exceed a few feet. At Bloomington, the ferretto zone of the Kansan is very sparingly exhibited near the base of the bluff. At the quarries, about two feet of very compact bowlder clay rests directly upon the Saint Louis, and is referred to this stage. Of the individual bowlders, the greenstones predominate. Near Hannom's mill, the ferretto is more in evidence. Along a small creek entering the Skunk from the north, several feet of till, oxidized to a deep brick-red and thoroughly leached, is exposed. Greenstones are abundant, and the granitic pebbles and bowlders are in an advanced stage of decay. In the Maxwell area the ferretto appears some twenty feet up from the base of the V-shaped draws and ravines; it is generally overlain by the loess, and contains the characteristic bowlders. In no case is the unoxidized portion open to inspection. At all other points where the stratified rocks are exposed, the Kansan appears to have been entirely removed, or else it is wholly concealed by talus slopes of the younger deposits. From the extreme paucity of natural exposures, even where the country rocks are laid bare, it is obvious that either the Kansan till sheet in this area was never comparable in thickness with equivalent deposits in other regions, or else the younger ice sheet dealt with it very harshly. To gain a more correct idea of the importance of this till sheet, well sections must be examined.

LARSON WELL, NE. QR. OF SEC. 5, LAFAYETTE TOWNSHIP.

		FEET.
10.	Soil and yellow clay	10
9.	Clay, blue	5
8.	Quicksand	5
7.	Clay, blue and yellow mixed	5
6.	Quicksand	1
5.	Clay, blue	77
4.	Sandstone, gravel, water-bearing	50
3.	Sandstone	6
2.	Chert	2
1.	Shale, blue. Shale, black Coal Fire clay Shale, black	15
	Total	176

Interpretation.

Number.	NAME OF FORMATION.	Thickness—feet.	Depth—feet.
9–10	Wisconsin	15	15
8	Loess (?)	5	20
5–7	Kansan	83	103
4	Aftonian (?)	50	153
1–3	Coal measures	23	176

The heavy deposit of sand and gravel, number 4, is somewhat anomalous, and may signify a preglacial channel. The mouth of the well is not far distant from Keigley's branch, and the top of the gravels is about the level of the water in Skunk river. The Kansan, as interpreted in the above section, shows the ferretto zone slightly developed and a heavy deposit of blue till. Number 8, which is reported as quicksand by the drillers, may be loess.

TILDEN WELL, NE. QR. OF SEC. 12, FRANKLIN TOWNSHIP.

		FEET.
5.	Soil and yellow clay	45
4.	Sand and clay	10
3.	Clay, blue	63
2.	Slate	12
1.	Sand, with coal and water	8
	Total	138

This well obviously entered the coal measures after passing through 40 feet of Wisconsin, 10 of loess, and 63 of Kansan.

In the college well, at Ames, no material can be referred to the Kansan with certainty, although the loess is underlain by fine sand and ten feet of coarse gravel conglomerate. In Palestine township detailed records are not obtainable. The drift is upwards of 100 feet in thickness, which, after deducting the Wisconsin and making some allowance for the loess, which is known to exist in the township, reduces the Kansan to much below its normal thickness for central Iowa. Excepting in probable preglacial channels, the Kansan rarely exceeds fifty feet in thickness in the western half of the county, and the ferretto zone is not obvious enough to attract the attention of well drillers, save in rare instances.

In the eastern portion of the county glacial deposits attain a much greater thickness. As nearly as can be determined from the well records the drift varies from 100 to 300 feet in Collins and New Albany townships, and from 150 to more than 300 feet in Sherman and Lincoln townships. While it is possible to obtain approximately the total thickness of the Pleistocene deposits, it is impossible, with the data at hand, to differentiate them into the various drift sheets and interglacial beds.

BUCHANAN GRAVELS (?).

In College park, at Ames, certain coarse, much weathered gravels appear along the roadway which winds around the base of the bluffs skirting Clear creek (figure 22). These gravels consist, chiefly, of well worn bowlders of granite,

FIG. 22. Buchanan gravels? College Park, Ames, Iowa.

greenstone, chert, and a few ironstones. Limestones are represented only by the cherts. The granites and all of the coarser-textured rocks are in an advanced state of decay, and many of these appear in the side of the road cut, broken directly across, instead of being removed from, their matrices. The entire deposit is deeply iron-stained, and bears the unmistakable marks of age. It is clearly overlain by the Wisconsin till, and what appears to be modified loess lies above it. Gravels occupying a similar stratigraphic position have been noted along Squaw creek at several points, and all are provisionally referred to the Buchanan stage.

THE LOESS.

The Iowan till is not known to be present within the confines of the county, but the loess, which is supposed to be genetically related to the Iowan, has been recognized recently at several points, and is believed to cover a considerable portion of the area. This most paradoxical of deposits is unconformable with the Kansan below and with the later drift above. It grades upward from fine sand and sandy silt to silt and clayey silt, and carries much lime throughout. In the upper portion lime concretions known as loess-kindchen and loess-mannchen are commonly present, and in some places root-casts, and even wood fragments, are not uncommon. Molluscan shells are usually present, and oftentimes occur in great numbers.

The loess is exposed at numerous points along the flanks of the deeper cuts in Indian Creek and Collins townships. Over a very small area in the extreme southeast corner of Collins township the loess has never been covered by the later drift, and hence forms the surface soil. There are occasional exposures in Franklin and Washington townships along the tributaries of Skunk river and Squaw creek.

Inferentially, from a consideration of well sections, spring lines and topographic features, the loess covers a much larger area. The best exposures are located on sections 5 and 34, in Washington township. That on section 34 exhibits nearly

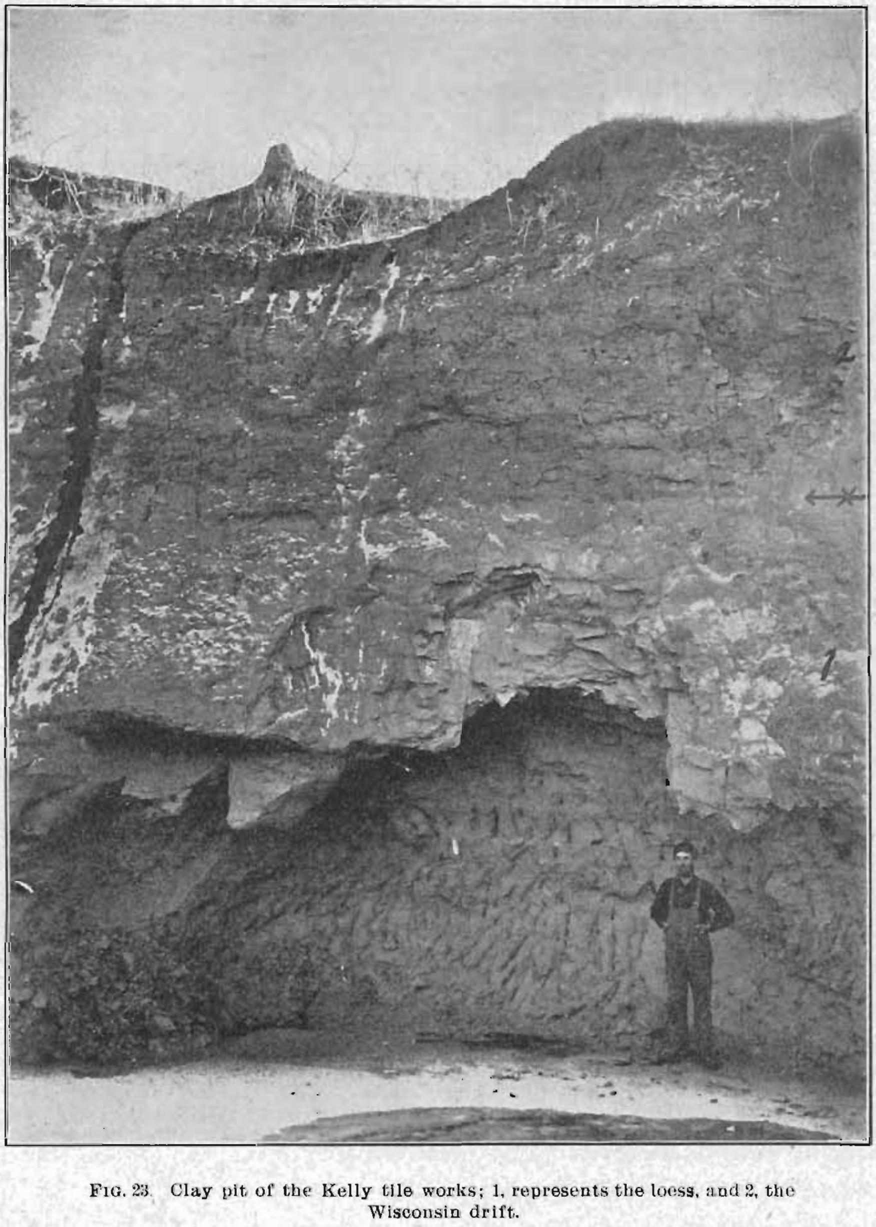


FIG. 23. Clay pit of the Kelly tile works; 1, represents the loess, and 2, the Wisconsin drift.

twenty feet of silt, silicious below, underlain by a gravelly bowlder clay, and covered by from five to twenty-five feet of Wisconsin till. The silt is distinctly jointed above and stained a faint yellow-brown along the joint planes. It grades downward into a massive, structureless, pale blue, clayey silt, which contains an abundance of root-casts, wood fragments, and black, carbonaceous spots, and emits a distinct swamp-like odor. The entire deposit is highly calcareous and carries a rich gastropodous fauna. The majority of species represented are strictly terrestrial in their habits. The following species were identified by Prof. B. Shimek.

1. *Zonitoides shimekii* (Pils) P. & J.
2. *Sphyradium edentulum alticola* (Ingers) P. & G.
3. *Pupa muscorum* L.
4. *Bifidaria pentodon* (Say) Sterbi.
5. *Vertigo ovata* Say.
6. *Conulus fulvus* (Mull).
7. *Polygyra multilineata* (Say) P. & J.
8. *Pyramidula striatella* (Anth) P. & J.
9. *Vallonia costata* (Mull) Sterbi.
10. *Succinea lineata* Binn.
11. *Succinea avara* Say.
12. *Limnæa humilis* Say (?).

Loess concretions are relatively scarce and are diminutive in size. The deposit shows no signs of oxidation or leaching where the drift covering is thick, but where the covering is so far reduced as to afford imperfect protection from the weathering agents both leaching and oxidation may be noted; and here alone are lime concretions to be found. It is obvious that little or no alteration took place prior to the deposition of the overlying drift.

The outcrop in section 5 is an almost exact duplicate of the section just described. The drift mantle is thinner, and from two to five feet of the loess has been stained to a yellowish-buff. Loess concretions are more in evidence, thus attesting the greater progress made in leaching. Here, again, the upper portion is distinctly jointed, while lower, the deposit is apparently structureless. The jointing is due, no doubt, to the pressure exerted by the Wisconsin ice. Gastropod shells abound throughout.

WISCONSIN DRIFT.

Many of the larger, and essentially all of the minor physical, features are impressed in the Wisconsin drift sheet. This drift is represented, chiefly, by a bowldery clay which has suffered little change since its deposition, either physically, chemically or mechanically. The till contains numerous patches and lenses of sand and gravel, in whose deposition running waters was obviously an active agent. These sand and gravel deposits oftentimes form conspicuous surface features and appear as knobs and kames. Bowlders are numerous and, in many instances, attain an enormous size. Barring the younger volcanics they include nearly all of the rock species known to lithology. Gray and red granites predominate, but there is a liberal sprinkling of limestone blocks, and the gneissic and basic rocks are well represented. All of the erratics* are remarkably fresh, and many show one or more planed or faceted surfaces. Of the smaller bowlders and pebbles clay-ironstone and fragments of calcareous and cherty rocks are very abundant. The deposit is not only rich in lime pebbles and bowlders, but it contains an abundance of lime concretions; and the clayey matrix, even at the surface, effervesces freely when treated with dilute hydrochloric acid.

The topographic features of the Wisconsin are remarkably immature. Ponds, undrained basins and incipient drainage lines are the rule, and afford corroborative testimony as to the extreme youthfulness of the deposits.

The Wisconsin till attains a thickness of from twenty to eighty feet over the general upland, but it probably consider-

*A bowlder of native copper was found on the farm of Wm. Arrasmith, about two and one-half miles north of Ames. The mass was much abraded and flattened, and bore evidence of rough usage in general. It weighed four pounds. Bowlders of the copper conglomerate are not uncommon and make it reasonably sure that the Des Moines lobe of the Laurentian glacier came by way of the Lake Superior copper region.

ably exceeds 100 feet in the morainal regions. The upper portion of the till, varying from three to thirty feet, is stained a pale yellow through incipient oxidation of the iron constituent, and the color grades downward into a gray-blue. Faceted pebbles and bowlders increase in commonness downwards. Wood fragments and earthy bands, presumably indicative of old soils, are often encountered at or near the base of this till sheet.

The eastern margin of the Wisconsin drift is marked by the Altamont moraine, the inner border of which crosses the extreme southeast corner of the county and continues northward nearly parallel to the Marshall-Story county line. The main body of the moraine lies in Marshall county.

In Story county the Wisconsin is clearly separable into an earlier and later stage, with the Gary moraine as the dividing line. The time interval between the stages, measured in terms of oxidation and leaching, and topographic development, was certainly greater than the time which has elapsed since the retreat of the ice from the county. Outside of the Gary moraine, well sections show that the yellow till attains a thickness of from fifteen to forty feet over areas which have suffered little loss through erosion, and have received no gain from deposition. Over similarly circumstanced areas inside of the moraine, the slightly altered zone rarely exceeds from five to ten feet. The streams which have established themselves on the earlier drift have cut vertically from thirty to seventy or even eighty feet, and have made some progress toward the formation of valleys. On the later drift, stream trenching is inconsiderable, and, if Hamilton county be included, a glance at the map is sufficient to show the great disparity in the development of the drainage lines in the two areas.

As has been mentioned earlier in this report, the retreat of the Wisconsin ice from the region was interrupted by numerous halts, marked by a succession of recessional moraines. One of these, in addition to the Gary, is believed to possess sufficient individuality to deserve a name—the Walnut creek moraine.

Contemporaneous with the heaping up of glacial debris at the end of the ice were certain streams issuing from the melting ice. These surcharged streams were competent to carry coarse sand, gravel, and even bowlders of small size, which were redeposited over the flood plains of the then existent streams in their lower courses. These gravel beds and bars have been removed in part since the retreat of the ice, and broad benches or terraces are the result. A system of terraces has its beginning at the Walnut creek moraine, and thus establishes more firmly the reality of the ice-halt at that point. Cambridge, on Skunk river, and Maxwell, on Indian creek, are built on terraces belonging to this system and attaining heights of twenty-five and twenty feet above the flood plains of the respective streams. Terraces continue northward on East Indian creek to the three forks in sections thirteen and fourteen in Nevada township, where they have a height of twenty-five feet above the flood plain and are composed of very coarse materials; much coarser than at Maxwell. The equivalent terrace was not recognized on the west fork of the Indian.

Along the Skunk the Walnut creek terrace may be traced northward to the creek of the same name, where it is superseded by a younger terrace, the contemporary of the Gary moraine. The gravel train produced by the Gary, reaches its maximum development, both areal and in vertical section, in the vicinity of Ames along both the Skunk river and Squaw creek. At Soper's mills the Gary rises twenty feet above the flood plain; at Ames, it rises thirty feet, after which it grades down gradually to ten feet in southern Grant township, and finally merges into the Walnut creek bench. Figure 24 shows the cross-section and gradient of the terraces in comparison with the cross-section and gradient of the present stream.

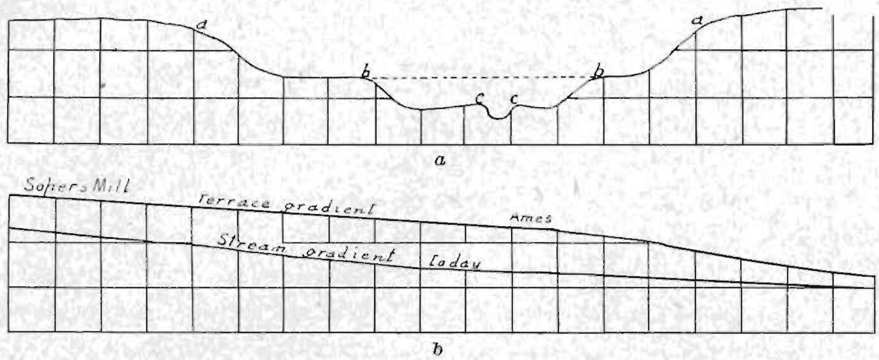


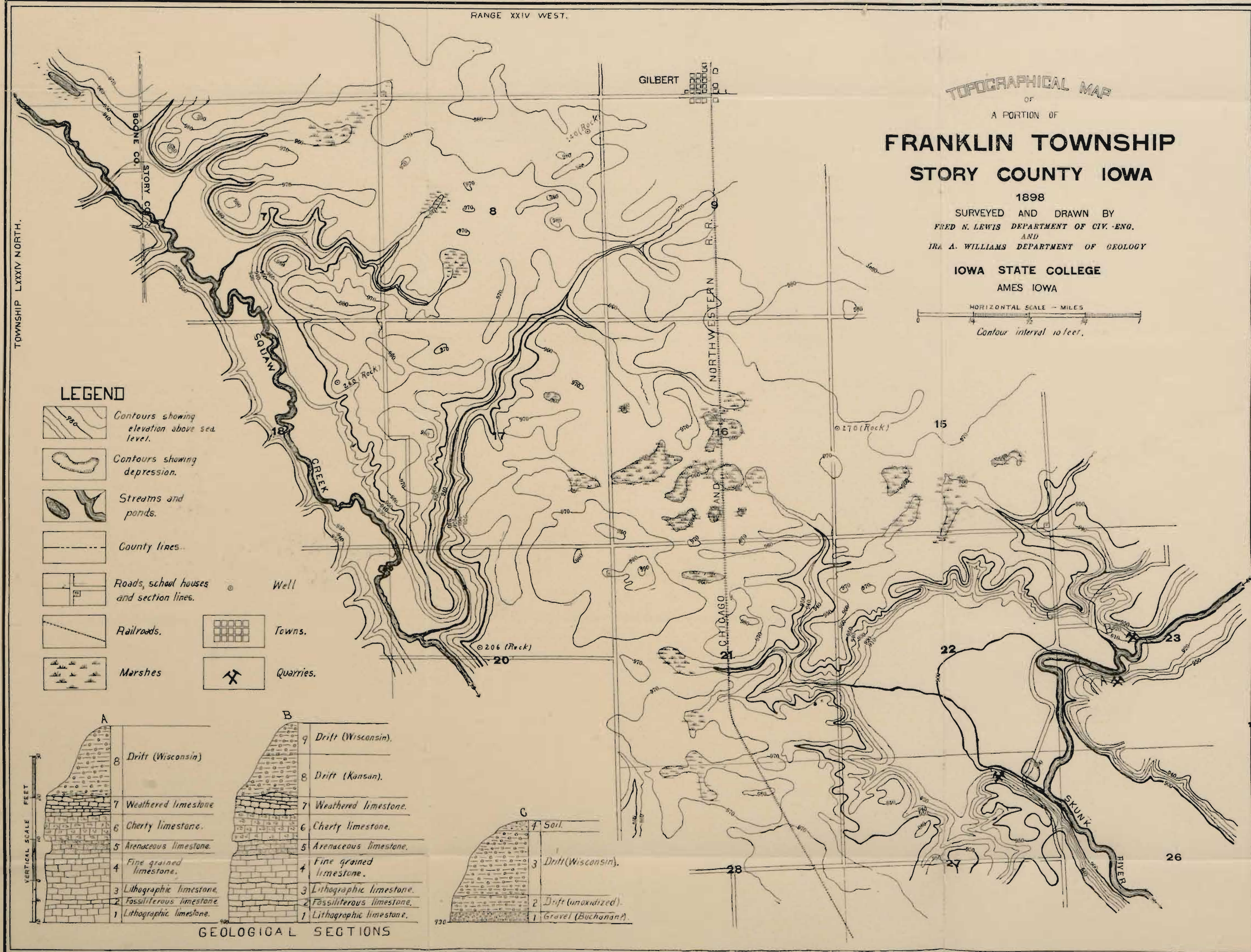
FIG. 24. *a*, Cross-section of Skunk river. The space below the broken line, bb, represents the amount of material removed since the retreat of the Wisconsin ice.
b, Stream and terrace gradients compared.

Development of the Skunk River System.—The towns of Ames and Cambridge are built on gravel bars located at the confluences of Squaw and Ballard creeks, respectively, with the Skunk river. Records of wells put down at these points show a series of sands and gravels separated by heavy beds of clays and silts. At Ames the basal gravels are reached at a depth of from fifty to eighty feet below the bottom of the present stream. The creamery well at Cambridge, which is located upon the Walnut creek gravel train, shows:

	FEET.
5. Loam and yellow clay	10
4. Sand and gravel	10
3. Clay, blue	25
2. Sand, fine	10
1. Gravel, coarse	10
Total	65

Borings at other points tell the same story. The country rock under the area mapped out by the terrace and flood plain lies from fifty to one hundred feet lower than in the walls of the valley.

The flood-plain terrace deposits average two miles in width south of Ames. The low ridges which bound these deposits rise gradually away from the river, so that the real depression possesses a much greater width. North of Ames the scene soon changes. At Hannom's mill the valley cross-section is



This map shows the topography typical for the Wisconsin drift; also the marked constriction in the flood plain of Skunk river, which marks the probable point of divergence of the present stream from its pre-Wisconsin channel. The sections at the lower left-hand corner show the sequence of strata which outcrops at A, B and C, on the map.

reduced to less than one-third of its dimensions a mile below. The stream is not only rock-walled, but rock-bottomed. The broad, depressed U-shaped valleys, indications of old age, have been replaced by the narrow U to the V-shaped gorges which are only retained during the early stages in the development of a stream. The river occupies no well-marked depression wider than the flood plain.

In the valley of the Squaw the old age characters are still retained. The creek meanders through a notable depression, much wider than indicated by the flood plain and terrace deposits, and wholly comparable with the depression below Ames. Artificial sections demonstrate that the indurated rocks lie much lower in the valley than under the general upland. Alternating clays and gravels, similar to those penetrated at Ames and Cambridge, are encountered. Briefly told, it would appear almost a certainty:

First.—That the lower course of the Skunk river proper is very old, certainly older than the Wisconsin, and probably preglacial. Above Hannom's mill the stream is much younger. Here its history is somewhat contradictory. In places well sections located in or

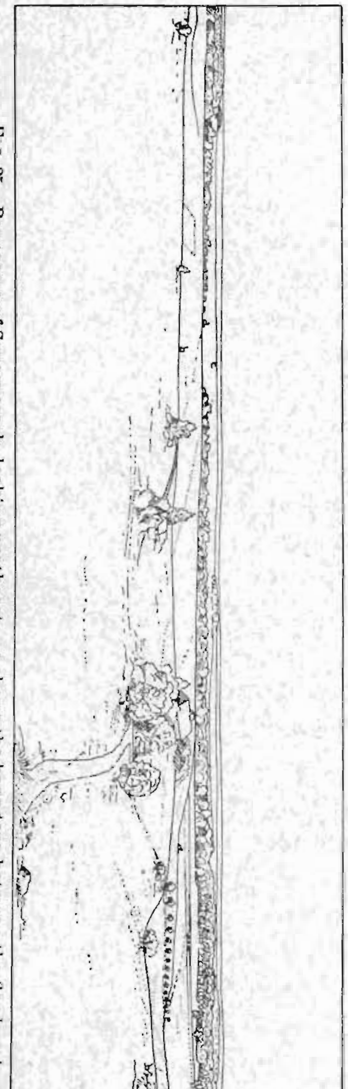


FIG. 25. Panorama of Squaw creek, looking northeast; aa shows the boundary between the flood plain and terrace, and bb separates the terrace and upland.

near the flood plain penetrate deeply buried silts and gravels At other places, at Hannom's and Soper's mills, its youthfulness is unquestionable. Suffice it to say that the Skunk has, perhaps, in this section, sought out and partially resurrected one of the important tributaries of the preglacial system.

Second.—That the river which was capable of cutting a gorge more than 100 feet in depth, and at least two miles in width, was immensely greater than its insignificant descendants, and, if the preglacial climate was not materially different from that of to-day, the progenitor of the Skunk drained a much larger area than the present stream.

Third.—That near Ames the principal channel pursued a northwest-southeast course, which was filled in, in large measure, with glacial debris, and has been only partially reopened by Squaw creek. The precise point of departure from the old course cannot be located definitely. From the great embayment below Hannom's mill a depression continues in a northwesterly direction, and becomes tangent with the valley of the modern Squaw near the Boone-Story county line. The general surface features and stream trend would lead one to suspect this to be an opportune point. The well data at hand fully accords with this view, but is scarcely sufficient to demonstrate it beyond a doubt. That the rock surface as a whole is rapidly depressed to the southwest and reaches its minimum elevation in the Squaw valley proper there can be little question. This arrangement would be in strict accordance with the almost universal northwest-southeast pre-Wisconsin drainage systems of the state.

Fourth.—It has been stated in previous reports* that the Des Moines river, above the city of Des Moines, flows in a post-Wisconsin channel, while its lower course occupies a much older valley. This fact, taken in connection with the facts derived through the present investigation, suggests very strongly that the last ice invasion despoiled the Skunk of much of its territory, and the Des Moines was the gainer. In

*Geology of Polk county, vol. VII, Geology of Boone county, vol. V.

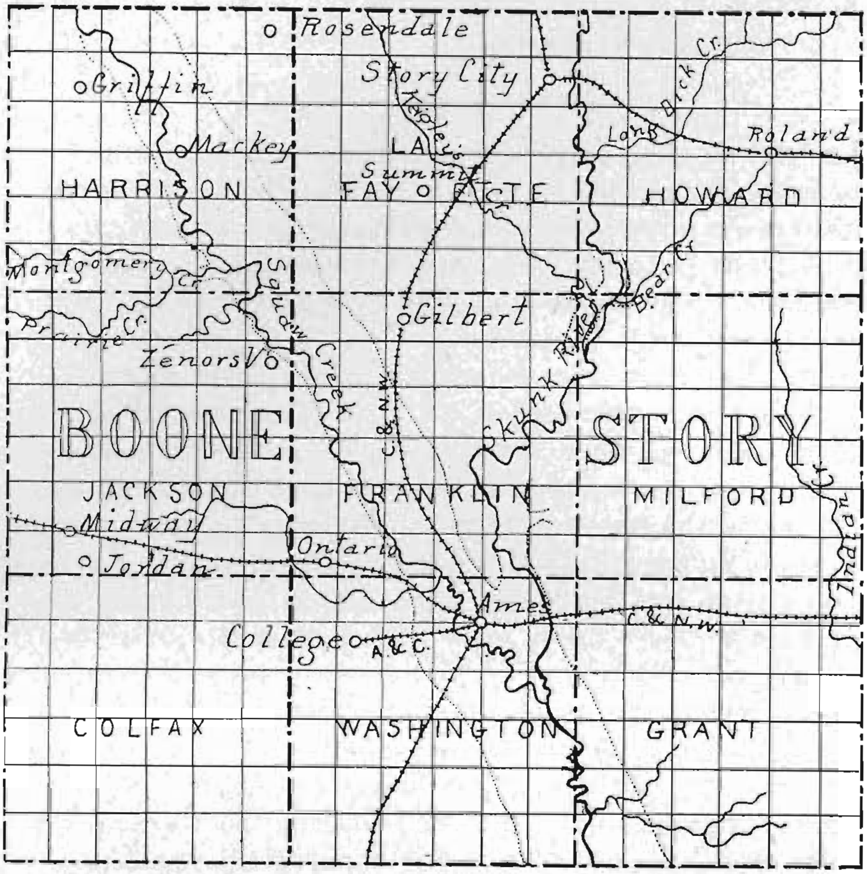


FIG. 26. Map showing the probable course of Skunk river in pre-Wisconsin times.

fact, it appears highly probable that the headwaters of the present Des Moines found their way to the Mississippi formerly through the Skunk. Or, in other words, the Skunk was literally "beheaded" by the Wisconsin ice. One tributary of Squaw creek extends within a mile of the Des Moines river to-day, at Stratford, in Hamilton county.

Aside from Squaw creek the tributaries of the Skunk can be dismissed with slight mention. Indian creek, in its lower course, has a well developed valley which is terraced, and at Maxwell is underlain with alternating clays and gravels similar to those of the Skunk and is, perhaps, the only tributary represented in the early history of the system, all of the others being post-Wisconsin.

REMAINS OF THE MAMMOTH.

"Sometime during the summer of 1894 an interesting find was made on the farm of Dr. H. M. Templeton, in Washington township. The discovery was made by the occupant of the farm, while engaged in digging a well. The well was being sunk in one of the numerous depressions which are a frequent surface mark in this section of the county. This depression formerly contained a few feet of water, and it still receives surface drainage in times of heavy rainfall. The center of this basin, which comprised two or three acres, was but a few feet below the level of the outer rim. The soil was composed of the washings from the surrounding land and the remains of marsh vegetation characteristic of similar surface conditions on the Wisconsin drift. When the digging had proceeded to the depth of four or five feet, a deposit of bone fragments was discovered. This included the bodies of four or five dorsal vertebræ, a portion of the upper extremity of one rib, a short section from the lower end of the tibia and the lower extremity of the left femur, besides a number of fragments rather difficult to assign to their exact location in the skeleton. The masses would very nearly fill a half-bushel measure. There were none of the long bones complete, and none of the pieces would give a very correct notion of the entire length of any of these portions of the skeleton. The parts giving the best idea of proportion are the vertebræ, the head of a rib, in quite good state of preservation, and the lower extremity of the femur. The vertebræ show both anterior and posterior articular surfaces in a perfect state of preservation. The transverse and vertical measurements of these surfaces are nearly exactly the same; four and one-half inches. The antero-posterior diameter, or the vertebral body, is exceedingly short, considering the immensity of the other measurements. The length is but two and one-half inches.

This must have given the creature a back grotesquely short in comparison with its gigantic size. The articular facets on the inner surface of the head of the rib, measures three and one-half inches. The excavations at the anterior and posterior extremities of the vertebral bodies almost blend into one another. The part giving the most correct notion of the enormous size of the animal is the remains of the thigh-bone. The fragment represents a section from the lower end of the bone, just long enough to show the femoral trochlea and the two condyles. These are almost perfect, with the exception that a small fragment has been broken away from the external posterior part of the external condyle. The internal condyle is in a perfect state of preservation. The extreme length of the articular surface extending from the lower border to the external condyle to the upper margin of the trochler surface, on which the patella glides, is sixteen inches. The transverse measurement through the center of the condyles is eight inches. This mass is from eight to ten times the size of the corresponding part of an average sized horse.

All the parts are quite firm, and in such state of preservation that they have not in the least been affected by exposure since their removal from the ground. The conditions were such as to lead to the conclusion that the bones could never have been buried to a greater depth than that at which they were discovered. The superincumbent covering must have been increasing in thickness, rather than diminishing, on account of the process of gradual filling now going on in these shallow prairie basins. A number of trial excavations were made in different parts of the depression, without unearthing any additional portions of the skeleton."*

A perfectly preserved molar tooth of *Elephas primigenius* was found by a C. & N.-W. Ry. employee, at Polk City, during the present summer. The tooth occurred in the gravels which occur at that place and are evidently late Wisconsin in age.

*The above description was written by Prof. M. Stalker, of Ames, Iowa.

These finds are interesting in that it makes it reasonably certain that these huge Proboscidians roamed over Story county during late Wisconsin, or even during post-glacial, times.

POST-WISCONSIN DEPOSITS.

Aside from the terrace gravels whose deposition was contemporaneous with the retreat of the Wisconsin ice, and the alluvium accumulated since the retreat, both of which have been discussed sufficiently, certain arenaceous to silty gray-brown deposits, remarkably homogeneous and devoid of pebbles and bowlders, border some of the larger streams and are, perhaps, worthy of special mention. These highly siliceous deposits flank the Skunk and the Squaw, are noticeably present along the lower course of Indian creek, but are most in evidence along the eastern margin of the Skunk river valley below Bloomington. The deposits attain a maximum thickness of from three to five feet on the brow of the bluffs, thin rapidly inland and are scarcely recognizable more than a mile from the bluff scarp. These deposits are responsible for the heavy, sandy roads along so many of the streams in the Mississippi valley, and are shunned alike by the teamster and the bicyclist. They are often known locally as "White Oak soils," because that very well known and desirable species of oak finds in them a congenial host. The deposits are thoroughly oxidixed and leached, and appear to be wholly devoid of structural or bedding planes. The coarsest materials which enter into their composition are found nearest the flood plain, and the size of grain diminishes gradually as the deposit feathers out away from the river. The source of the materials and the transporting agent are not difficult to apprehend. The process of accumulation is going on to-day. The wind, sweeping across the broad flood plain, gathers up such material as can be transported and moves it toward the restraining bluffs. Perhaps only the very finest materials are given continuous passage for any considerable distance. But through successive short excursions the coarser silt-particles and even fine sand grains eventually reach the brow of the bluff and are deposited in the reverse order of their fineness*.

The position of these deposits is determined essentially by the surface contours. The wind crossing the valley impinging against the hill flanks is deflected upward, and, coming in contact with the still air above, loses velocity, and being unable to carry its load further, deposits it over the brow of the hill. In this location its position is reasonably secure, though the entire assemblage of deposits possesses the proclivities of the sand dune and may progress bodily inland.

This process of wind transport and accumulation of materials may readily be witnessed. During early spring and late autumn, when large tracts of bottom land are unprotected by vegetation, dust storms are common, and often during a single "blow," a measurable deposit is accumulated. If this be true now, how much greater must have been the efficiency of the winds which blew across the wide flats before vegetation had time to reclaim the valleys so recently vacated by the Wisconsin ice?

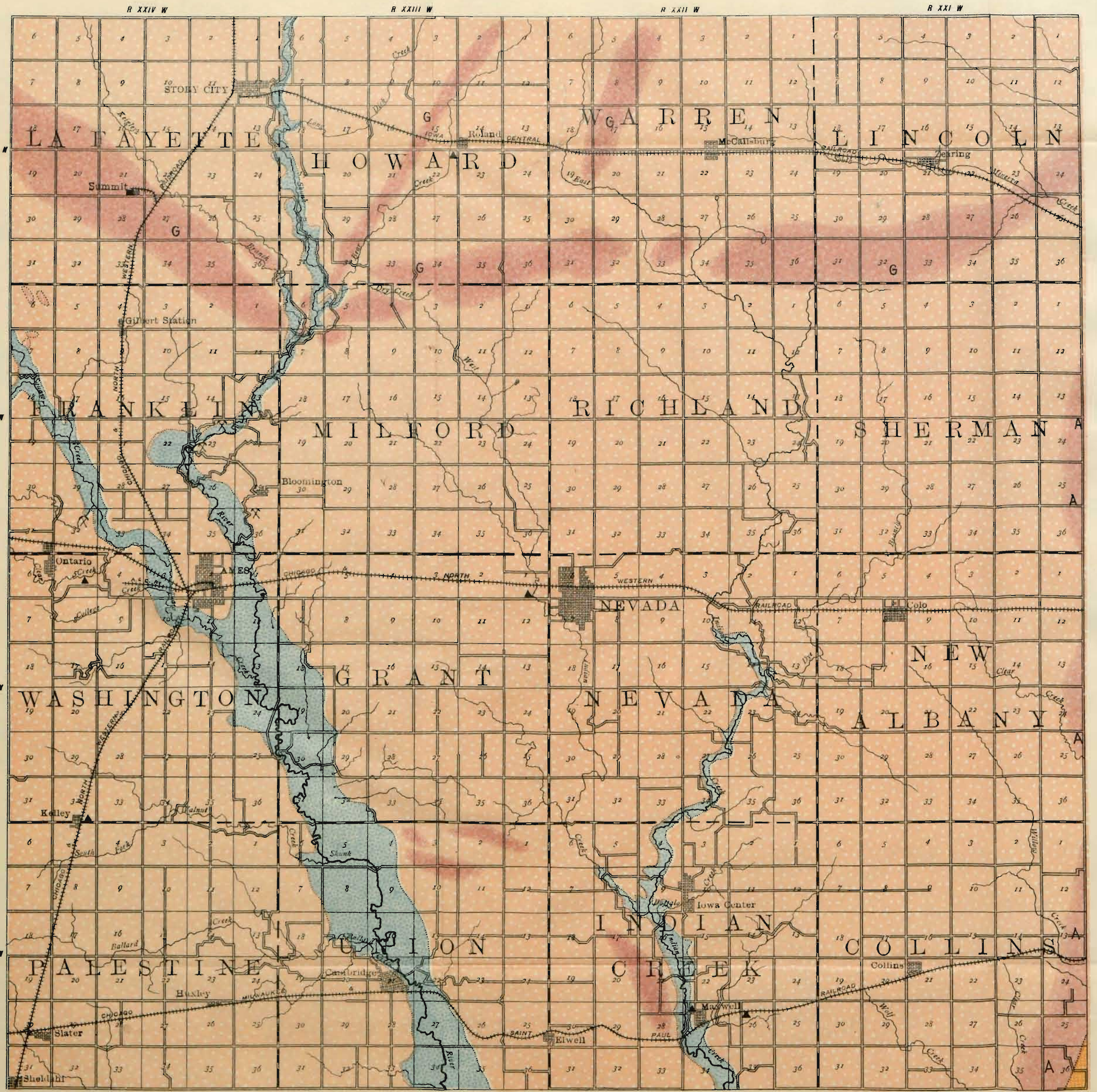
The prevailing winds for central Iowa during spring and fall are from the west, and hence the greater accumulation of æolian deposits on the eastern flanks of the streams.

These deposits are worthy of more than passing notice, when viewed analytically, on account of their striking similarity, in many respects, to the loess. Structurally, texturally, and in composition and distribution, there is a remarkable resemblance. Both are essentially devoid of stratification planes, possess a uniform, open texture, are highly siliceous,

*A most luminous and helpful discussion of wind erosion, transport and deposition, will be found in Professor Udden's Memoir, entitled "The Mechanical Composition of Wind Deposits," published by the Lutheran Augustana Book Concern, of Rock Island, Ill., 1898. The subjoined table gives the approximate maximum distances over which quartz fragments of different dimensions may be lifted, by moderately strong winds, in single leaps:

Gravel (diam. from 8 to 1 mm.), a few feet.
Coarse and medium sand (diam. 1 to ¼), several rods.
Fine sand (diam. ¼ to ⅛ mm.), less than a mile.
Very fine sand (diam. ⅛ to 1-16 mm.), a few miles.
Coarse dust (1-16 to 1-32 mm.), 200 miles.
Medium dust (1-32 to 1-64 mm.), 1,000 miles.
Fine dust (1-64 mm. and less), around the globe.

being composed chiefly of silt and fine sand, and appear to be genetically related to the chief water courses, along which they attain their maximum development. True, the loess is usually highly calcareous, but this may readily be referred to a difference in the condition of the materials drawn upon, and be wholly independent of the process of accumulation. It is now pretty generally conceded that the loess is genetically related to the Iowan drift, perhaps the overwash from that sheet. It is also well known that the Iowan carried the largest and freshest bowlders of any sheet, and it is reasonable to suppose that the finer materials were equally fresh at the time they were deposited. This is evidenced by the Iowan drift itself, the surface only showing any signs of weathering. The mud flats were doubtless much more important then than now and if atmospheric circulation was equally as vigorous as at the present time, wind erosion and deposition would be much more widespread and important, and the rate of accumulation might be so much accelerated that oxidation and leaching of the rock meal would be imperfect or almost wholly wanting. The loess deposits which have been protected by the Wisconsin drift lend credence to this view. The exposures near Kelly and Ames are not only unoxidized and unleached, but still retain their original blue color, which is so characteristic of unaltered secondary deposits. These deposits also emphasize the extremely short time interval between the deposition of the loess and the Wisconsin advance. The loess, where unprotected, is a straw to gray-brown throughout, and the lime concretions sufficiently attest that incipient leaching has begun. In places where the deposit has neither lost by erosion nor gained by deposition, the leached zone varies from two to four feet in thickness and is identical with the wind accumulations along the streams of to-day. The loess, in all probability, originated through the rapid accumulation of perfectly fresh materials from the extensive mud flats and overwash plains, which formed an apron to the Iowan till sheet, while the latter represent the much slower assembling



IOWA GEOLOGICAL SURVEY

MAP OF THE

SUPERFICIAL DEPOSITS

OF

STORY

COUNTY,

IOWA.

BY

S. W. BEYER

1899.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

ALLUVIUM

WISCONSIN DRIFT

ALTAMONT MORAINE — A

GARY MORAINE — G

KAMES

IOWAN LOESS OVERLYING KANSAN DRIFT

of the leached and oxidized materials from the alluvial plains of to-day.

While the processes which obtained during the deposition of the two sets of deposits cannot be demonstrated to have been identical, their inherent resemblances and environments are certainly very striking. Aside from the comparisons already made they are very closely related faunally. Professor Shimek* has shown that with a few unimportant exceptions the loess Mollusks were all air-breathers whose habitat must have been very similar to that which prevails in the Iowa-Nebraska region of to-day.

Unconformities and Deformations.—Outside of the county in areas where the Des Moines and Saint Louis occur together, and the contact plane can be observed, the former is seen to overlie the latter unconformably. In Story county the glacial debris effectually conceals the contact zone between the two formations, and yet the uneven surface presented by the basement of the coal measures, as already sufficiently elaborated, makes it reasonably certain that the Des Moines occupies erosion hollows in the Saint Louis.

There is everywhere a profound unconformity between the Pleistocene and the older deposits, and a break of minor importance separates the two drift sheets known to be present in the county.

While the epeirogenic movements of the area have been several times repeated on a scale sufficiently large to be recorded in recurrent series of deposits, differential uplifts are more elusive in a drift-buried country, and only one can be definitely recognized in the geological structure of the county.

The Skunk River Anticlinal.—Prof. W. J. McGee, in his "Pleistocene History of Northeastern Iowa,"† records a series of more or less parallel flexures in the strata of Iowa. The general trend of these deformations is northwest-

* The exhaustive memoirs which embody the results of this keen, conscientious observer and conservative writer may be found in the recent volumes of the Iowa Academy of Sciences.

† Eleventh Annual Report, U. S. Geological Survey, p. 336 et seq.

southeast, and as a rule their amplitudes are so slight that "their presence is only detected by a comparison of altitudes at different points, by anomalies in outcrop, or by the topographic configuration determined by them." Among the salient flexures an anticlinal is mapped whose axis is approximately coincident with the Skunk river, and McGee has denominated it the Skunk River anticlinal. Its recognition was based largely upon inferences from geologic outcrops, and its establishment was scarcely beyond the pale of hypothesis. The College well record, when taken in conjunction with the well records from Boone and Nevada, establish the existence of such a convex flexure beyond the peradventure of a doubt. (See plate iv.) The average difference in elevation of equivalent strata between the College and Boone is about 300 feet. If the dip is assumed to be constant between the two points, this would give a gradient of 25 feet per mile. Between the college and Nevada the average fall of equivalent strata is about 150 feet, or 15 feet per mile. The strike is presumably northwest-southeast, and is essentially parallel to the supposed direction of the anticlinal axis. Hence, the average dip would be about 35 and 21 feet per mile for the southwest and northeast limbs of the fold, respectively.

ECONOMIC PRODUCTS.

Coal.

As has been previously stated, Story lies wholly within the Iowa coal field. Although seemingly as favorably situated as other counties, which surpass it in production, the county does not rank as one of the great coal counties of the state. In 1898 only one mine was in active operation. The output for 1897 scarcely exceeded 12,000 short tons, the greatest for any year in the history of the county. Desultory attempts have been made to develop the coal resources of the county near McCallsburg, in Warren township, and in Collins township, near the Polk county line, and some prospecting has been done at other points. At present the only mine in operation is located at Summit, in Lafayette township.

Summit.—North Star Coal & Mining Co. During the fall of 1892 and the spring of 1893 a shaft was sunk on land owned by W. S. Johnson, Sw. qr. of Sec. 21, Lafayette township. Operations have continued with slight interruption since. The vein worked is about 135 feet from the surface. The sequence of strata penetrated in sinking the shaft, as given by W. S. Johnson, is as follows:

Number.	DESCRIPTION.	Thickness—feet.	Depth-feet
19	Soil	3	3
18	Clay, yellow, gravelly	20	23
17	Clay, blue	5	28
16	Sand, bluish	1	29
15	Sea-mud (loess, probably)	40	69
14	Sand and gravel (till, perhaps)	26	95
13	Hard rock	1	96
12	Clay, sandy	3	99
11	Coal "blossom"	1/3	99 1/3
10	Fire clay	1	100 1/3
9	Coal	1/3	100 2/3
8	Fire clay, bluish	11	111 2/3
7	Coal	1/3	112
6	Fire clay	7 1/2	119 1/2
5	Coal, good	2	121 1/2
4	Fire clay, bluish	4	125 1/2
3	Shale, hard	3	128 1/2
2	Shale, blue	6	134 1/2
1	Coal, excellent	4 1/2	139
	Fire clay, exposed	3	142

At least five coal horizons were penetrated, only one of which was thought to be of commercial importance. At least one vein is known to exist below the one worked. The mouth of the shaft is located on the north slope of the Gary moraine, about 1,050 feet above sea level. The mine is equipped with modern top-works, a steam fan, and the "room and pillar" plan is pursued in mining the coal. Owing to the nature of the underlying strata some trouble is experienced from "creep," and even with the most approved methods of working, under existing conditions, it is scarcely possible to win more than 60 per cent of the total coal. The vein runs fairly even, thickening towards the basins and thinning towards the "rolls." The maximum variation in elevation does not exceed ten feet. The roof is rather weak and treacherous, and renders careful mining imperative to avoid accidents. The coal is of excellent quality, comparing favorably with the best product of central Iowa. The mine supplies a large local trade, but it, nevertheless, ships a considerable percentage of its output. A spur of the C. & N.-W. Ry. has been extended to the shaft, so that the coal may be loaded on the cars without rehandling.

The coal developed at Summit is apparently an eastward extension of the Squaw creek basin. This is evident from the general stratigraphic similarity of the coal horizons in the two areas. The veins mined in both localities have practically the same elevation. This basin is divided by Skunk river, but the coal reappears in the vicinity of McCallsburg, where some prospecting has been done. At this point a vein of coal, three feet in thickness, is said to have been found, and mining operations, in a crude way, were carried on during short intervals for several winters. A seam of cannel coal was at one time reported, but upon examination the find proved to be a highly carbonaceous shale associated with the coal seam. The Mormon Ridge coal, in Marshall county, appears to mark the eastern terminus of this basin, and the territory lying between this point and the Squaw creek fields, in Boone county, will undoubtedly yield a fair return to systematic prospecting.

Collins.—Well drillers report coal at numerous and widely distributed points over the southeastern quarter of the county. While this is generally known almost no systematic prospecting has been done, and only in a single instance has any serious attempt been made to develop the bed. On the farm of Silas McQuiston, located on the Ne. qr. of the Sw. ¼ of Sec. 34, in Collins township, a shaft was sunk some years since, and operated during the winter season. The entire output found a ready sale at the mine, but was never great enough to supply the local demand. The mouth of the shaft is located on the bottom land along Wolf creek, and the strata penetrated are essentially as follows:

		FEET.
5.	Drift	70
4.	Coal measure shales and clays	60
3.	Coal	2
2.	Fire clay and shale	7
1.	Coal	3½
	Total	142½

The coal has a good reputation among the consumers. The vein was reported to run fairly uniform in thickness, but the roof, as in the case of all Story county coal, was of rather uncertain character. The mine was last operated, some two years ago, by Marshall & Crow, of Boone county. Prospect holes have been put down, both east and south of the above mine, and demonstrate that the coal continues some distance in those directions.

The outlook for the development of the coal industry in Story county, while not brilliant, is certainly not wholly discouraging. Practically no systematic prospecting has, as yet, been done. Numerous well records show the presence of one or more coal seams throughout most of the coal measure area. It is scarcely probable that so wide an area, showing the presence of coal horizons, will not, sooner or later, be found to include veins of commercial importance. The most hopeful areas would appear to be in the line of the Squaw creek-Summit basin and in the vicinity of Collins. An intelligent and judicious use of the core drill in these areas may be reasonably expected to earn a moderate reward.

Clay.

Story county is supplied with an adequate quantity of clay for furnishing brick for all structural purposes, for paving the streets of its towns, and making the draintile necessary for properly draining its immature surface. The younger drift covers practically the entire county, and when unmodified, yields no clays suitable for either brick or tile. The alluvial deposits, which attain considerable importance along Skunk river and its greater affluents, and the wind accumulations along the bluffs which border these streams, afford unlimited quantities of material suitable for handmade brick capable of meeting all requirements for the less imposing structures. The larger streams have removed the younger drift at numerous points, and have greatly reduced its thickness at many others, so that the clays and shales of the older terrains have been rendered available. In Washington, Indian Creek and Collins townships, important deposits of loess are easily accessible, while at Story City, Roland, Nevada, and Maxwell, from ten to twenty feet of Carboniferous clays and shales are exposed. The coal measure shales are at present being developed only at the last three places mentioned.

COAL MEASURE CLAYS.

Nevada.—Several factories have been operated somewhat intermittently, in the vicinity of Nevada, during the past fifteen years. Of these, Lyman & Company operated continuously for more than a dozen years. Draintile and structural brick were the chief manufactured products. The works were located along West Indian creek, immediately north of the C. & N.-W. right of way. The raw material was obtained from the east bank of the creek.

The Paul Nelson Tile works were in operation a number of years at this place. The plant is situated near the railway station, and the raw material used was obtained south of the railway track near the Lyman pit. While neither of the above plants are entirely dismantled, neither was in active operation during the current year. In 1897, the S. M. McHose Brick and Tile plant was established on the West Indian creek, just south of the Ames-Nevada wagon road. Here nearly twenty feet of clays and shales are available with comparatively little stripping. In the following section, all save the drift and the arenaceous layer is utilized.

		FEET.
7.	Drift, bowldery, calcareous	5
6.	Shale, blue, variegated; containing much ferruginous staining along the joint planes and known as "calico clay"	12
5.	Sandstone, gray	$\frac{1}{3}$
4.	Clay, gray blue, jointed; containing some concretionary matter	3
3.	Shale, carbonaceous	$\frac{1}{4}$
2.	Fire clay	2
1.	Shale, jointed, highly ferruginous; exposed	2

The plant is equipped with dry-pan, pugger and Hoosier Brick and Tile mill. Ample drying sheds are provided, and both air and steam are used. Three days are required to dry the brick by steam, while two days proves sufficient for tile. Four round, down-draft kilns, of 48,000 brick capacity each, are used in burning. Ordinary brick is burned in seven days. For common brick and tile one part of alluvium or hillside wash is added to two parts of the clay shales. The loam heightens the color and facilitates the burning, though it weakens the product. Common structural brick and drain-tile, the latter varying from three to twelve inches in diameter, constitute the chief product. Fire brick and pavers have been produced in small amounts. The paving brick examined were "end cut" and the lamination exhibited in cross-section was very pronounced. The product vitrifies very well, and the lamination could be, in large measure, prevented by more careful mixing and tempering, or it could be rendered less pronounced by side-cutting the brick. However, the plant can scarcely be said to be fully installed as yet, and the intelligence and good judgment displayed in its equipment are certainly very commendable.

Roland.—In the southern part of town is located the Swenson & Co. Brick and Tile works, which have been in operation for nearly a quarter of a century. The plant has been under the present management since 1886, though until the past year the firm name was Swenson Bros. The clay is obtained from the bank of Bear creek. Seven or eight feet of shales of good quality are exposed, black below, and light grey to a variegated yellow above. Underlying the material used is ten or twelve inches of dark blue to black clay, containing iron pyrites; while overlying the deposit is a foot of sand and gravel, followed by a foot of black loam. The loam and some sand is mixed with the shales in treating them to deepen the color and render the ware more easily worked. The Potts disintegrator and Brewer machine are used. The ware is air dried and burned in a round, down-draft kiln. Tile, ranging from three to ten inches in diameter, form the chief product, though of late years a considerable number of common brick have been manufactured.

Maxwell.—The Charles E. McHose Brick and Tile works are located about a mile east of town, on the Chicago, Milwaukee and St. Paul railway. The plant is equipped with a Potts disintegrator and the Ideal brick and tile machine, made at Decatur, Ill. Drying is done chiefly through natural heat, though aided somewhat by exhaust steam. One down-draft kiln of 30,000 capacity is employed in burning. The time required is eighty hours. Draintile from threes to eights inclusive, and side-cut common, and end-cut paving, brick constitute the manufactured product. The milling and tempering of the raw material is very imperfect, and the small kiln capacity, which leads to forced burning and too rapid cooling, are responsible for the great loss suffered through checking of the ware and for the poor quality of the manufactured product.

The pit is located about one-half mile south of the works. About fifteen feet of Carboniferous shales are available, and very little stripping is required. The section is as follows:

		FEET.
4.	Drift, weathered above, but calcareous below	6
3.	Shale, gray; slightly arenaceous	8

2. Shale, variegated, much iron-stained along the joint and bedding planes; a limonitic, concretionary layer occurs about two feet from the base; iron concretions are common throughout.............................. 7
1. Sandstone, exposed...

The shales are of good quality and an enormous quantity is in sight. Number 3 is difficult to burn when used alone, but when mixed with number 2 yields more readily, and takes on a more desirable color for structural purposes.

The coal measure shales have been developed intermittently at other points during the last decade. Several firms have operated from time to time in the vicinity of Story City, but none were in operation during the current year.

PLEISTOCENE CLAYS.

Ames.—Clay working has been practiced in the vicinity of Ames for almost a third of a century. The plants were located along Clear creek, a branch of the Squaw, about three miles west of the railway crossing at Ames. Many of the brick used in the construction of the main college building, and the rough brick used in several of the later buildings, were made in these yards. Here a heavy bed of loess occurs and has been utilized for soft-mud brick. At the pit the following beds are exposed to view.

	FEET.
2. Drift, yellow; upper portion modified into soil......	5–10
1. Loess, the upper portion oxidized a yellowish-buff in color, two to five feet; lower portion a gray blue, exposed, five to eight feet........................	12

Gastropod Mollusks, as mentioned in an earlier paragraph in this paper, abound throughout the loess. Lime concretions are somewhat abundant in the slightly oxidized zone, and when worked in with the raw material have a deleterious effect on the manufactured product.

Cameron & Lyon operate the works at present. Some brick and draintile of the smaller sizes constitute the sole manufactured product.

Kelley.—The Kelley Tile works, J. M. Stark, proprietor, were established in 1887. The plant is located just east of the railroad station, though the raw material is secured from a pit along Walnut creek, about two miles east of town. Common brick and the more common sizes of draintile are the chief products. A smooth-roller, Penfield crusher, and a Hoosier brick and tile machine constitute the machinery used. Round, down-draft kilns are used, and the siliceous clay withstands much heat. There is considerable lime, in a finely divided state, in the raw material, and to prevent air slacking it is necessary to heat to high enough temperature to vitrify slightly the product, and, perhaps, to fix the lime completely in the form of the silicate. The raw material here, as at Ames, is the loess. Considerable stripping is made necessary in order that the deposit may be worked. The loess is blue gray, jointed above, and grades downward into a massive, structureless deposit, which is finally terminated by a gravelly layer of an earlier drift sheet. The deposit is highly siliceous and fossiliferous throughout.

Maxwell.—Prince Shope owns and operates a small plant near Indian creek. Hillside wash and alluvium are wrought into mud brick.

Numerous other small factories have operated during brief seasons and then were abandoned. Handmade brick were the more common product.

Scarcely more than $6,000 worth of clay goods, manufactured in Story county, were sold during 1897. The entire output was consumed at home, and in not a single department was the output sufficient to supply the local demand. From the beginning of the tile industry the production has never been equal to home consumption, and the deficit has been supplied by neighboring counties no better equipped, so far as the natural resources for tile making is concerned, but, perhaps, more resourceful in using what they had. Only a minor portion of the common brick used were made within the county, and no attempts have been made to produce dry-pressed and fancy brick. A few pavers and fire brick have been manufactured, sufficient, merely, to demonstrate the possibilities along that line. The Pleistocene deposits afford an abundance of material suitable for structural and dry-pressed brick, and draintile, while the coal measures offer, in addition, material suitable for the vitrified pavers and more refractory fire brick.

Building Stone.

Story county is poorly supplied with stone suitable for structural purposes. The Saint Louis limestone affords a limited quantity of stone adapted to foundation work and use in the rougher grades of masonry. The rock is, as a rule, highly absorbent and does not stand frost well. Its earthy-buff to gray-buff color gives it a dull, somber appearance, which increases rapidly on exposure on account of the readiness with which it takes up foreign matter. Some quarrying has been done at nearly every one of the outcrops in the county, though in no instance does the annual output of any single quarry exceed a few dozen cords of rough stone. The ledges developed are practically the same at all points. The section exposed north of Hannom's mill may be considered a fair average, and is as follows:

		FEET.
6.	Till, pale yellow; unoxidized and unleached.........	0-6
5.	Till, oxidized to a deep, reddish-brown and thoroughly leached; much weathered limestone and many decayed granite bowlders, and numerous, tolerably fresh greenstones present..........................	1-3
4.	Limestone, residual; reduced to an iron-stained, cavernous chert	1
3.	Limestone, arenaceous; where unaltered, a bluish-gray, but weathering stains it a yellowish-brown; not thoroughly indurated, though when unweathered presents a massive appearance	5
2.	Sandstone, bluish-gray, shaly; presents a fissile character after being exposed to the weather, and forms a marked re-entrant in the quarry face.....	3
1.	Limestone, impure, buff to earthy-yellow, gray buff when unweathered; heavy bedded, compact; lithographic in part, chief quarry stone, exposed......	8

At the Bloomington quarries more of No. 1 is exposed.

Well borings and other artificial excavations seem to indicate that no other quarry rock may be looked for in the region. The drift, especially in the morainal regions, affords great numbers of bowlders suitable for nearly all purposes to which stone can be put. They range in size from the cobble to great blocks, large enough and of suitable quality for monuments. In the early history of the county bowlder land was very much shunned by the pioneer settlers, and any attempt to render it arable was sure to prove a heroic test of the Christian fortitude of the would-be tiller. Splendid granites were piled up in fence corners and along roadways. In recent years the bowlders are being rapidly transformed into shapely blocks which appear in the foundations of substantial structures. It is found that these rough masses of stone yield readily to skillful treatment, and when tastefully arranged in a wall the effect is most pleasing and the structure is almost imperishable. In a measure, then, the Pleistocene bowlders make good the deficiency of structural materials in the older terrains.

Soils.

Agriculture is the chief industry of Story county, and the wealth of the community depends upon the fertility of the soil. The county possesses no barren or untractable land. A considerable percentage of its surface has not yet been brought under cultivation, but this is not a matter of any inherent property of the soil, but is wholly due to outside environment. As has been previously stated, the surface is immature. Nature has not had sufficient time to establish perfect drainage systems, and many undrained basins of small area persist. By the introduction of tile drains man is simply abridging natural processes, and at no distant day it may be confidently expected that no land will lie idle on account of improper aeriation and drainage.

The soils of the county resolve themselves readily into three groups, viz: alluvial, terrace and upland. The first are coincident with the flood plains of the larger streams, and comprise an area of about twenty square miles. The alluvium, when mixed with organic matter, forms a rich, black loam, and is one of the most tractable and productive soils in the area. Its low level, however, renders it liable to inundation during seasons of high water, and hence subjects the farmer to occasional losses.

The terrace soils are limited to Skunk river and its greater affluents, and comprise the smallest area of any of the types mentioned. They are uniformly underlain with gravel, and hence do not retain water well through seasons of extended drouth. On the face of the terraces where the gravels outcrop seeping springs are formed. Ordinarily small grain does well on the terrace soil, but underdraining is rather too rigorous to ensure a good crop of corn unless the season be unusually wet.

The upland type comprises by far the greater portion of the county. It is essentially a modified Wisconsin till, stained a gray black with humus, and varies from six inches to three or four feet in thickness. In the numerous basins it is heavily charged with humus and assumes a jet black color. When properly drained and aeriated, the upland type compares favorably with the bottom land in productiveness, and is not subject to periodic inundation. To show that the productiveness of the Wisconsin drift soil depends largely upon ventilation and drainage the subjoined table has been compiled. This table also shows, in a general way, the relative value of the principal drift-sheets as producers. Corn has been selected because it is believed to respond more readily to soil treatment along the lines outlined above, is the most generally grown of any of the cereals, and requires the entire season in which to mature, for which reasons it ought to give a more correct measure of the real productiveness of the soil. Story county may be considered typical for the Wisconsin drift, Grundy for the Iowan and Poweshiek for the loess-covered Kansan. The first is characterized by a surface very imperfectly drained and but little stream dissected. In the second the surface is monotonously even, but the drainage is fairly complete though the water escapes slowly, while the last represents a perfectly drained area. In the first period selected tile-draining was in its infancy and but little drain-tile had been laid in any of the counties. In the last trio of years selected artificial drainage has been extended greatly in Story county, and to this cause more than to any other is the greatly increased yield per acre ascribed.

Yield of Corn, in Bushels, Per Acre *

COUNTY.	CORN YIELD PER ACRE FOR—				CORN YIELD PER ACRE FOR—				Av. gain—per cent.
	1885	1886	1887	AV.	1895	1896	1897	AV.	
Story	30	15	20	$21\frac{2}{3}$	47	37	31	$38\frac{1}{3}$	77
Grundy	37	30	25	$30\frac{2}{3}$	41	50	33	$41\frac{1}{3}$	31
Poweshiek	30	20	40	30	41	42	30	$37\frac{2}{3}$	26

Road Materials.

Along the larger streams the terrace gravels afford an abundance of material suitable for road macadam. The railroads have developed these gravels at Maxwell along Indian creek, and west of Ames along Squaw creek. About ten feet of gravel is available at each place, and comparatively little stripping is required. Away from the streams, in the morainal regions, numerous gravel knobs and kame-like aggregations furnish great quantities of material suitable for road making. At other points in the county ballast is scarce, and the roads in the country and the streets in the towns are uniformly bad in wet weather and almost impassable in the Spring of the year.

Building Sand.

Sand in every way suitable for building purposes and for plaster is found in nearly all of the stream channels, and in the gravel terraces and the sand and gravel knobs so much in evidence in the morainal regions of the Wisconsin. The

*The statistics are taken from the Iowa Agricultural Reports.

FIG. 27. The Gary terrace at Soper's mill, showing course bowlder gravel overlying undisturbed Wisconsin till.

extensive sand flats along the Skunk furnish unlimited quantities of sand adapted to the rougher grades of masonry, while the finer grades of sand are often obtained in pockets in the morainal and terrace accumulations.

Potable Waters.

Until recent years, within the region under discussion, water of good quality and adequate in quantity for domestic purposes was derived from shallow drift wells. Such wells varied from ten to rarely more than fifty feet in depth. During later years the increased supply demanded by stockmen, and the series of dry years, caused the shallow wells to be abandoned, as they proved inadequate to meet the greater demands placed upon them under such trying conditions. Accordingly, deeper wells have been put down throughout the county. The chief sources of water appear to be the sands and gravels at the base of the Wisconsin drift or of the entire Pleistocene series, the interstratified sands and silts in the valleys of the Skunk river, Squaw and Indian creeks, and certain arenaceous layers in the Lower Carboniferous series. Several pretty well defined artesian areas belong to the first group. Of these, Keigley's branch, Zearing and Dye's branch constitute the most noteworthy artesian basins in the order of their importance. "Watkins' well" is the strongest well in the Keigley's branch basin, and may be considered typical of the area. The sequence of strata passed through is as follows:

		FEET.
5.	Soil	3
4.	Clay, yellow	17
3.	Clay, blue	35
2.	Gravel and sand, water bearing	7
1.	Blue clay, penetrated	

It is reported that the drill dropped nine feet on reaching the gravel, and that water carrying gravel with it, spouted out with great violence. Bowlders of several pounds weight were thrown out. A sample of the water was analyzed by the U. S. Geological Survey in 1885, and the result is herewith appended:

Total Solids, 0.471 Grams Per Liter.

SOLIDS FOUND.		Per cent of total.	PROBABLE COMBINATION.	
SiO_2	0.0250	5.31	SiO_2	0.0250
Fe_2O_3	0.0060	1.28	Fe_2O_3	0.0060
Ca	0.0796	16.90	$Ca\,CO_3$	0.1990
Mg	0.0356	7.56	$Mg\,CO_3$	0.1246
Na	0.0501	10.64	$Na\,CO_3$	0.1155
CO_3		58.12		
Total		99.81		0.4701

SO_2	None
Cl	Trace
K	Trace
$C\,O_2$	0.3920
$C\,O_3$	0.2738

Total CO_2 in one liter, determined by R. B. Riggs, deducting the CO_2 required in the third column, leaves 0.1912 grams for the bicarbonate. The water contains much suspended sediment.

Temperature	48° Fahr.
Rate of flow	28,000 gallons per hour.

There are numerous other flowing wells in this vicinity, but all of small flow. In the majority of instances the temperature is 2° or 3° higher than in the case of Watkin's well, and about 5° higher than in ordinary shallow wells in the same locality, which shows a temperature of about 45° to 46° Fahr.

In the Zearing basin all of the wells are located on the bottom land along Minerva creek, within a radius of a mile from the town of Zearing. All are of small capacity and vary from sixty to ninety feet in depth.

Along Dye's branch several flowing wells have been developed. The water-bearing stratum is reached at from eighty to 120 feet below the surface, the depth depending upon the position of the mouth of the well. The water is of good quality, but, as in the case of the preceding basins, it carries considerable ferruginous matter, as evidenced by the taste, and by the brownish rust which coats all vessels in which the water has been allowed to stand.

Several other flowing wells are known at widely separated points in the county, but in every case they are of small capacity and possess little of general interest. One fact, perhaps, worthy of repetition is that, in all cases so far as investigated, the water in flowing wells run from 3° to 5° warmer than the water in the non-flowing wells in the same localities. The temperature for the latter accords very closely with the mean annual temperature of the region while the waters which supply the former, have, perhaps, received some increment of heat by coursing through strata below the plane of variation.

Ames, Cambridge, Iowa Center and Maxwell draw their water from the alternating sands and silts of the Skunk river and Indian creek. The supply is abundant and the quality satisfactory. The railways which cross these streams secure

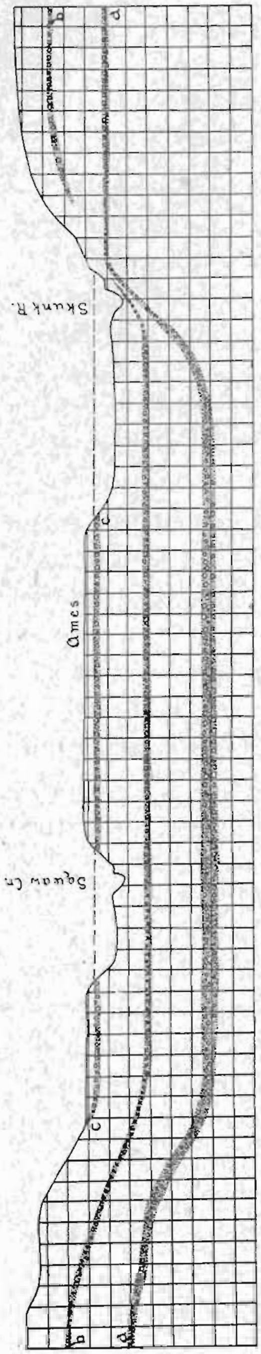


FIG. 28. Cross-section of Squaw creek and Skunk river valley at Ames, showing the gravel terrains at aa, bb and cc, all of which are water-bearing.

their water supply from the same source as the towns.

In the eastern half of the county numerous wells obtain their supply from the arenaceous beds or the limestones of the Carboniferous. The majority of these wells vary from 200 to 400 feet in depth. The water is uniformly good, but the supply is very variable. In two instances, at Nevada and Ames, the deeper strata have been explored. The former obtains a satisfactory supply from arenaceous layers in the upper Silurian, while the latter draws chiefly from the Jordan sandstone of the Saint Croix. In the latter instance, the reservoir lies more than 1,100 feet below sea level, but hydrostatic pressure brings the water within thirty feet of the surface, or 970 feet above tide. Hence the head is nearly 2,000 feet, and exerts a pressure of about 850 pounds per square inch. The supply is sufficient to sustain a continuous flow of about 8,000 gallons per hour, reducing the water level to about 250 feet below the surface. The dimensions of the well may be observed, drawn to scale in plate iii. Complete sanitary and mineral analyses of the water were made by Prof. J. B. Weems of the department of agricultural chemistry of Iowa State college, and are given below:

Sanitary Analysis.

	Parts per million.
Free ammonia	1.2
Albuminoid ammonia	Trace
Solids	1258.
Nitrogen as nitrites	Trace
Nitrogen as nitrates	Trace
Oxygen absorbed in 15 minutes	....
Oxygen absorbed in 4 hours	....

Mineral Analysis.

	Grains per gal.	Parts per million.
Silica (SiO_2)	.174	3.000
Alumina (Al_2O_3)	.406	7.000
Ferric oxid (Fe_2O_3)	....	....
Lime (CaO)	2.859	49 300
Magnesia (MgO)	1.409	24.300
Potash (K_2O)	....	....
Soda (Na_2O)	30.554	526.900
Chlorin (Cl)	11.821	203.800
Sulfur trioxid (SO_3)	24.923	429.700
Carbon dioxid (CO_2)	6.891	118.800
Water in combination	1 020	17.600
Totals	80 057	1380.300
Less oxygen replaced by chlorin	2.668	46.000
Net total	77 389	1334.300

Probable Combinations.

Silica (SiO_2)	.174	3.000
Alumina (Al_2O_3) .. } Ferric oxid (Fe_2O_3) }	.406	7.000
Calcium bicarbonate [$CaH_2(CO_3)_2$]	1.259	21.700
Magnesium bicarbonate [$MgH_2(CO_3)_2$]	5.115	88.200
Sodium sulphate (Na_2SO_4)	44.254	763.000
Potassium chlorid (KCl)	....	....
Sodium chlorid (NaCl)	19.505	336.300
Sodium acid carbonate ($NaHCO_3$)	2.355	40 600
Calcium carbonate ($CaCO_3$)	4.321	74.500
Magnesium sulphate ($MgSO_4$)	....	....
Calcium sulphate ($CaSO_4$)	....	....
Total	77 389	1334.300

Temperature Observations on the College Well at Ames, and on the Deep Well in Greenwood Park, Des Moines, Iowa.*—The condition of the earth's interior must always be an interesting question to the student of earth physics, and data which will throw any light upon this obscure problem have, in all times, been sought for eagerly by geologists and physicists alike. The rate at which the temperature increases as the earth's crust is penetrated has been recorded in numerous instances both in Europe and in America. The commonly accepted increment which has found its way into our leading text-books is 1° Fahrenheit for every fifty-three feet descent. The data upon which this unit was based were derived, largely, from mine shafts and well sections located in or near disturbed areas, or areas whose sedimentary rocks contained igneous injections. Later observations, made in regions where the sedimentary series have remained practically horizontal throughout all time and igneous rocks are absent, have tended to lengthen the interval.

Among the most recent and reliable contributions to this subject are those of Prof. William Hallock, of Columbia college, on the deep well at Wheeling, W. Va., and Mr. E. Dunker, of Halle, Germany, on the deep wells at Sperenberg, near Berlin, and Schladabach, near Leipzig. Professor Hallock's results for the Wheeling well give a gradient of 1° F. for every 81.5 feet, down to 3,200, and below this point an increase of 1° F. for every 60 feet was recorded. Mr. Dunker's observations at Sperenberg give a gradient of 1° F. for every 59.2 feet, and at Schladabach the increase is 1° F. for every 65 feet.

The temperature observations conducted under the direction of Prof. A. Agassiz† on the Calumet and Hecla mine, in the Lake Superior copper district, give results somewhat at

*The writer desires to acknowledge his indebtedness to Prof. William Hallock, of Columbia college, for many helpful suggestions. Among the many courtesies extended by the department of Mechanical Engineering of the Iowa State College, special credit is due, for devising an ingenious contrivance for lowering the thermometer and measuring distances, without which the observations could not have been made.

†Am. Jour. Sci. (3), vol. L, p. 503. 1895.

variance with those earlier reported. The plane, 105 feet below the surface, with a temperature of 59° F. was assumed as the level unaffected by seasonal changes. The mine reaches a depth of 4,580 feet and has a temperature of 79° F. at the bottom. This gives a differential of 20°, or an average increase of 1° F. for every 223.7 feet.

The wells upon which the present observations were made are practically full of water and had not been disturbed for more than a month before the temperatures were taken. Professor Hallock's investigations on the Wheeling well, both when the well was dry and when full of water, shows that convection currents are essentially *nil* and may be neglected in ordinary temperature reductions. No corrections are made for convection currents nor for conduction, in the present investigation. A Miller-Casella self-registering, maximum-minimum thermometer* was used. The instrument was lowered and the depths measured by a steel wire which passed around a calibrated drum. In the college well, readings were taken every 100 feet, while in the Greenwood park well the interval between readings was 250 feet. The results are shown in Figure 29, where the temperature gradients are

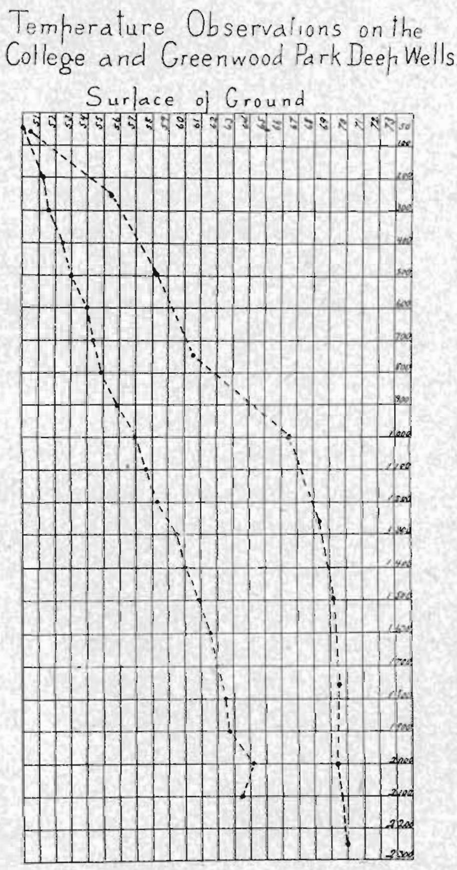


FIG. 29.

*Generously loaned by the U. S. Fish Commission.

drawn to scale. The mean annual temperature at Ames* is 47.2° F., while the temperature at 2,100 feet is 63.4° F., and the mean average gradient is 1° F. for every 129.6 feet. The mean annual temperature at Des Moines† is 48.7° F., and the temperature at 2,250 feet is 70° F., giving an increase of 1° F. for every 105.6 feet. The temperature gradient for the college well is a more or less uniform curve, while that of the Greenwood park well is a parabolic curve. In the latter instance the temperature increment is 1° F. for every 63.4 feet through the first 1,250 feet, while the last 1,000 feet measured shows a total increase of but 1.7° F.

Natural Gas.

Several years since Mr. J. F. Taylor, in sinking a well on his farm, struck a flow of natural gas. The flow was sufficient to furnish the family with heat and light, and was so utilized for several years. The gas pressure is reported to have continued undiminished until the well was filled in some two years ago. The boring was located on the Ne. qr. of the Sw. ¼ of Sec. 26 in Nevada township. The mouth of the well is on the upland, and the gas-bearing stratum was reached at about ninety feet below the surface after two feet of indurated rock had been penetrated. Two test holes were put down in the near neighborhood, and in each instance gas was reached at somewhat lower levels, but under practically identical circumstances as in the case of the first well. The gas reservoir appears to be located in the coal measures, and to be separated by several feet of more or less impervious strata from the drift. This fact is of some interest, for in most of the gas wells reported from the southwestern portion of the state, the reservoirs are located wholly within, or just at the base of, the Pleistocene deposits. The occurrence is strikingly similar to the gas and oil wells in Kansas, which draw their hydro-carbon from the Upper Carboniferous.

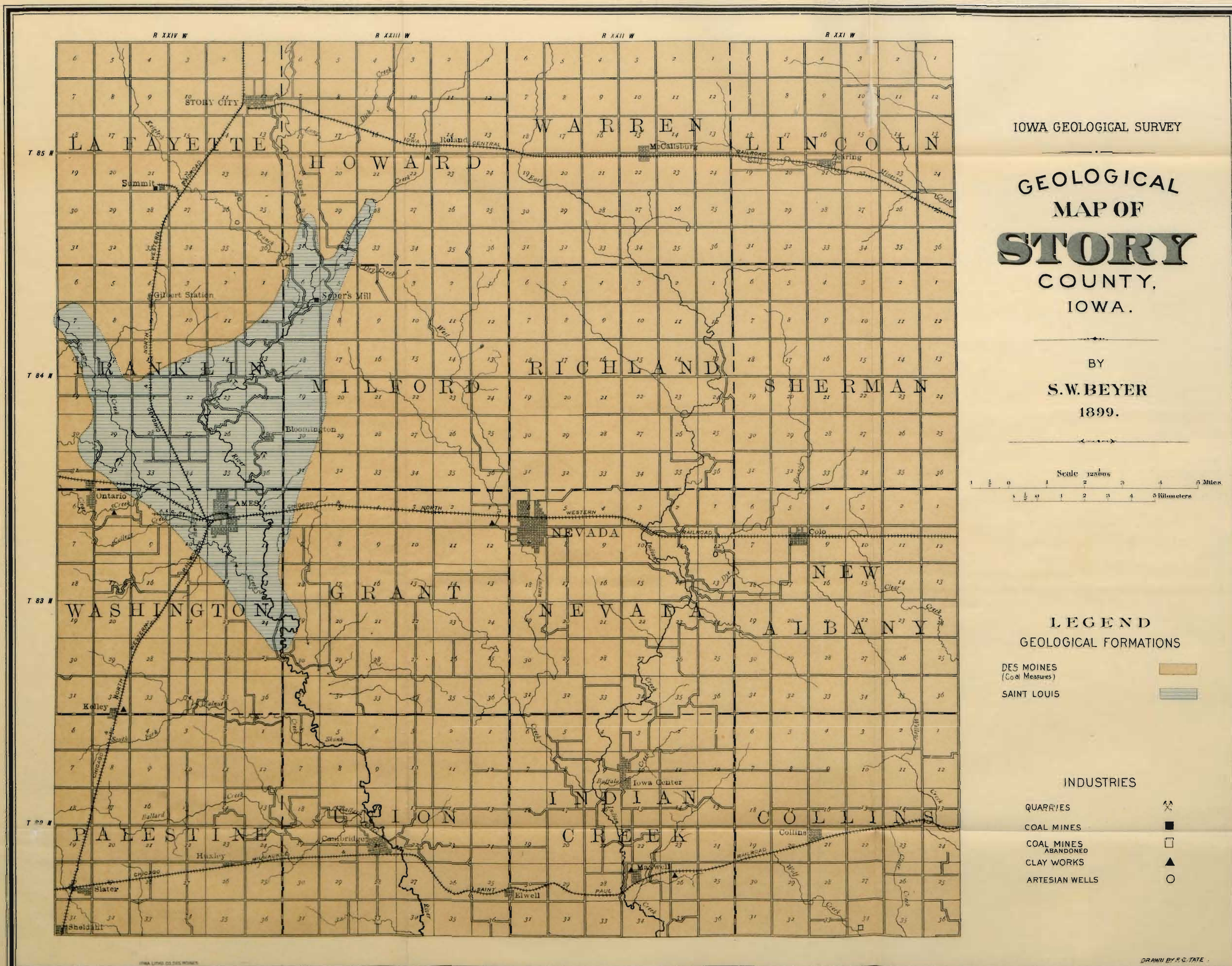
*Reduced by J. R. Sage, director of the Iowa Weather and Crop Service.

It has often been prophesied that gas and oil would be found in the Trenton limestone of Iowa, providing a low anticlinal in the formation can be found and explored. Prospecting has been carried on at great expense in Polk and Dallas counties, by parties familiar with the eastern oil fields and said to be backed by eastern capital. The records of the drillings were kept secret, and an air of secrecy surrounded the whole operation. One fact only is known to the public, and that is that nothing ever came of these ventures. In Story county the Trenton limestone has been explored at but a single point. The college well at Ames appears to be ideally located to test the "gas theory" thoroughly for Iowa. The arch of Trenton, hermetically sealed in by the Maquoketa shales, was punctured near its greatest amplitude, and so far as known not a bubble of gas or a drop of oil escaped. Prof. Edward Orton's* prediction, "there is a strong presumption that the Trenton limestone will not prove an oil rock or a gas rock in any new field" still holds unchallenged.

ACKNOWLEDGMENTS.

In the preparation of the above report the writer has received much encouragement from the friendly attitude of the citizens with whom he has come in contact. The representatives of the various industries have been uniformly cordial in their co-operation. The well data for "Watkin's well" and vicinity was, in large part, taken from a thesis prepared by Mr. Frank Leverett and accepted for the baccalaureate degree at the Iowa State College. Mr. W. O. White, of Cambridge, furnished valuable information concerning the wells in the southern half of the county. Any value this report may possess is in no small part due to the friendly advice and helpful criticism of my colleagues of this Survey, and to all who have contributed to it in any way acknowledgments are gladly given.

* Eighth Ann. Rept. U. S. Geol. Surv., p. 662, pt. 2.



IOWA GEOLOGICAL SURVEY
GEOLOGICAL MAP OF STORY COUNTY, IOWA.
BY S. W. BEYER 1899.
Scale 1/125000
Miles
Kilometers
LEGEND
GEOLOGICAL FORMATIONS
DES MOINES (Coal Measures)
SAINT LOUIS
INDUSTRIES
QUARRIES
COAL MINES
COAL MINES ABANDONED
CLAY WORKS
ARTESIAN WELLS
R XXIV W
R XXIII W
R XXII W
R XXI W
T 85 N
T 84 N
T 83 N
LAFAYETTE
HOWARD
WARREN
LINCOLN
FRANKLIN
MILFORD
RICHLAND
SHERMAN
WASHINGTON
GRANT
NEVADA
NEW ALBANY
PALESTINE
UNION
INDIAN CREEK
COLLINS
STORY CITY
Roland
McCallsburg
Zearing
Summit
Gilbert Station
Soper's Mill
Bloomington
Ontario
AMES
NEVADA
Colo
Kelley
Iowa Center
Cambridge
Huxley
Collins
Maxwell
Slater
Elwell
Sheldahl
DRAWN BY F. C. TATE

FLORA OF STORY COUNTY.

BY L. H. PAMMEL.

The flora of Story county has been well treated by Bessey*, who made various references to the plants of this vicinity. Later Hitchcock† published an exhaustive list with full notes on distribution. No attempt has heretofore been made to study the plants of this county from an ecological standpoint. For our purpose two typical areas will be considered, one a wooded area in the vicinity of the college, mostly embraced by what is known as the college park; the other, a lowland area in the vicinity of Watkin's well.

COLLEGE PARK.

This area consists of low, thickly wooded hills sloping toward the west, with several gulleys running north. The hills on the opposite side slope toward the southeast, and are almost denuded. Running through this wooded tract is a small stream which contains running water during the early summer months only. Some water remains the entire year in small pools. Perennial springs are few in number; the removal of the timber and tile drainage has largely decreased the amount of water coming from them. The surface soil is a rich humus which rests on a yellow clay sub-soil. The water of the small stream flows into Squaw creek. The flood plain varies greatly in width; it is made up of the usual rich alluvium; and, near the present bed of the river, of considerable sand.

*Bessey, C. E. Contributions to the Flora of Iowa, Biennial Report, Iowa Agrl. College, 90

†Hitchcock, A. S. A catalogue of the Anthophyta and Pteridophyta of Ames, Iowa Contri. from Shaw School of Bot., 7: 477. St. Louis Acad. Sci., 5, No. 3.

Woody Species, Ostrya Group.—It is difficult to designate any one tree as being characteristic of the narrow strip of timber remaining along the course of the streams, but along all the smaller streams in this region, and in the college park, Ostrya is typical for many others. The white oak, *Quercus alba*, and red oak, *Q. rubra*, are common in the entire region. The *Ostrya virginica* is more abundant in numbers than any other tree. Frequently dense copses are found. The black maple, *Acer nigrum*, is a typical tree and is as abundant as the black oak. The basswood, *Tilia americana*, is common only in places, especially where the soil is highly retentive of moisture, as in the vicinity of springs or on steep banks of the Squaw creek, where it naturally receives the drainage of the bench above. The *Cratægus mollis* is abundant, not only near the base of the hills, but frequently persists in the large open pastures where most other trees have been removed. The hazelnut (*Corylus americana*) is associated with the *Ostrya*, *Quercus* and *Acer*. The *Ulmus americana* encroaches on the upland area, but *U. fulva* is a typical upland species. The *Amelanchier canadensis*, *Cratægus tomentosa*, and *C. punctata* all occur in upland woods. *Fraxinus viridis*, though occurring with the above species, is not exclusively an upland plant.

The *Ampelopsis quinquefolia*, *Menispermum canadense*, *Vitis riparia*, and *Celastrus scandens* represent the climbing plants. *Lonicera glauca* and *Viburnum pubescens* are local and occur only on the steep banks near the streams. *Prunus americana* and *Rubus villosus* are common in some places. *Pyrus coronaria* is common only on the borders of the alluvial flood plains. The *Salix rostrata* near springs associated with *Caltha palustris*. The *Salix nigra* along the stream with *Sambucus canadensis Salix amygdaloides* in similar places.

Herbaceous Plants, *Viola pubescens Group.*—The upland, rich, shaded woods are marked by the common occurrence of several types. The most common of the early plants *Hepatica acutiloba* which forms large mats; the *Dicenera cucullaria*, *Sanguinaria canadensis*, *Viola cucullata* and *V. pubescens* in quantity. *Isopyrum biternatum*, *Phlox divaricata*, *Erigeron philadelphicus*, all marked early April and May plants, followed by the *Osmorrhiza brevistylis* and *O. longistylis*, *Thalictrum dioicum*. *Aquilegia canadensis*, in richer and moister places *Erigeron strigosus*. The summer and fall plants are marked by *Cystoptris fragilis*, *Solidago ulmifolia*, *Aster sagittifolius Eupatorium ageratoides*, *E. purpureum*, var. *maculatum*.

Festuca Group.—Economic grasses are not abundant. Blue grass (*Poa pratensis*) occurs in the more open places. The nodding *Fescue* grass (*Festuca nutans*) is the most abundant of all the grasses in early spring. Later a species of Brome grass occurs rather commonly, namely, *Bromus ciliatus*, var. *purgans*. *Brachyelytrum aristatum* blooms about the same time, but is less common. The *Oryzopsis melanocarpa* also occurs in these woods, but it is scarce. It has no tendency to occur in colonies, like so many of our grasses, but occurs in separate bunches. The *Diarrhena americana* occurs more frequently. *Phryma leptostachya*, *Circæa lutetiana* and *Podophyllum peltatum* are abundant. The *Caulophyllum thalictroides* is less common. *Monarda fistulosa* occurs more commonly as a border species. The *Verbesina helianthoides* borders the low grounds. *Thalictrum dioicum* is common in the woods. The dry open woods are covered with *Poa pratensis*, and later in the season *Sporobolus heterolepis*, *Elymus robusta*, *Andropogon nutans*, and *A. provincialis*; all of these, with the exception of blue grass, are indigenous prairie species.

Open Prairie Vegetation.—The praires border on the woods and are marked by several distinct types of plants. The most abundant of the early flowering plants is *Vicia americana*, and we may designate this the *Vicia* group. With this species occur the following early plants: *Phlox pilosa*, *Geranium maculatum*, *Viola palmata* var. *culcullata*, *V. petatifida*, *Litho spermum canescens*, *L. augustifolia*, *Baptisia leucophæa*, *Heuchera americana*, *Fragaria virginiana*, *Oxalis violacea*, *O. corniculata*, *Panicum scribnerianum Carex pennsylvanica* and *Thalictrum* *purpurescens*; of the later blooming plants *Eryngium yuccafolium*, *Silphium laciniatum*, *Liatris pycnostachya*, *L. scariosa*, *Asclepia tuberosa*, *Lepachys pinnata*, *Mollugo verticillati*, are contemporaneous in flower with *Elymus robdsta.* Then come the fall asters, numerous in species, *Aster azureus*, *A. multiflorus*, *A. laevis*.

The *Solidago missouriensis* is the earliest, and one of the most common species, followed by *S. rigida.* The *Solidago speciosa*, a late flowering plant and a most beautiful species. *Cnicus altissimus* var. *discolor* is common everywhere in late season. Of the grasses we find *Andropogon scoparius*, *A. provincialis* and *A. nutans.* Here and there may be found *Gentiana alba* and *G. andrewsii* and, occasionally, *G. puberula.* But a single orchid is common in this section of the state, the *Spiranthes cernua*, which occurs in great abundance on the prairies. *Sporobolus heterolepis* is an abundant and graceful grass everywhere on our prairies.

Stream Vegetation.—The vegetation along the small streams consists largely of blue grass (*Poa pratensis*), and in the lower places *Spartina cynosuroides.* The *Glyceria nervata* is rather common along the streams and in the lower places, also, *Glyceria arundinacea.* *Phleum pratense* is abundantly naturalized. *Veronica anagallis*, *Mimulus ringens*, *Eragrostis reptans*, *Cyperus diandrus*, all hydrophytic plants, are common where the water stands for considerable lengths of time.

The *Anemone pennsylvanica* and *Ranunculus pennsylvanica* are common in low grounds. The former easily typifies low grounds where a large percentage of humus occurrs. *Xanthium canadense* is abundant in sandy flood plains of the streams.

Only five woody plants are common to the prairie, namely: *Rosa blanda* var. *arkansana*, *Ceanothus americanus*, *Salix humilis*. The *Amorpha canescens* and *Ceanothus ovatus* on dry hills.

Alluvial Flood Plains.—In the alluvial flood plains occur two types of plants: (1) The mesophytic, which are abundant throughout the flat bottoms, with very few modifications. (2) The hydrophytic, which occur close to the shore lines of the stream. There is, however, an intermediate type represented by *Cenchrus tribuloides*. These occur on the drift sand, or shore line, between the water and the alluvial banks.

Mesophytic, Walnut Group.—The Black walnut is a typical alluvial species. It is never common beyond the influence of the alluvial drift. Throughout this region the species is a predominating plant in such places. It reproduces itself readily. Occasionally the butternut (*Juglans cinerea*) occurs, but only on the edges where it is seemingly influenced by the drift soil. The Kentucky coffee tree (*Gymnocladus canadensis*) is also an abundant alluvial species. *Fraxinus viridis*, and *F. americana* are local. *Ulmus americana*, *Populus monilifera* are other conspicuous species of this walnut group. The *Celtis occidentalis* occurs near the streams. The *Vitis riparia* is as abundant as it is in upland woods. *Sambucus canadensis* is an abundant species, and in clearings is almost a weedy species. *Pyrus coronaria* as well as *Cratægus mollis* sometimes form large thickets in the alluvial flood plains.

Mesophytic Herbaceous Vegetation.—The dense shade of the trees forms a most favorable place for *Claytonia virginica*, *Phlox divaricata*, *Isopyrum biternatum*, *Viola pubescens*, *Dentaria laciniata* and *Arisaema draconitum*. These are early blooming plants. Somewhat later, *Thelypodium pinnatifidvm*, *Ranunculus septentrionalis* and *R. abortivus*. During mid-summer, *Impatiens pallida*, *I. fulva* and *Rumex altissimus*. During late summer and early fall the following species are abundant: *Verbena urticæfolia*, *Scrophularia nodosa* var. *marylandica*, *Bidens frondosa*, *Aster salicifolius*, *A. diffusus*, *Helenium autumnale*, *Erichites hieracifolia*, *Solidago canadensis*. *Xanthium canadense* and *Vernonia fasciculata* are weeds in many of the low bottoms.

Hydrophytic Vegetation of the Streams.—The list of strictly hydrophytic plants is not a large one, owing to the fact that many of the streams become dry during midsummer, and these plants can only maintain themselves in the small remaining pools. The most conspicuous of these are *Scirpus* *lacustris*, *Veronicr anagallis*, *Nasturtium officinalis*, *Penthorum sedoides*, *Cyperus diandrus*, *Hemicarpha subsquarrosa*, *Ilysanthes gratioloides*. Of the plants of somewhat hydrophytic aptitudes mention should be made of *Mimulus ringens*, *Lobelia cardinalis*, *L. syphilitica*, *Steironema longifolium* and *Lythrum alatum*.

Platanus occidentalis confines itself quite closely to the shore lines of the streams.

WATKIN'S WELL REGION.

Watkin's well region is selected because it offers an interesting field for the study of a large number of marsh plants. The surface soil is a very tenacious black clay, with a subsoil of a yellow tenacious clay which prevents sub-soil drainage, and hence the marshy character of the region. A typical section of this region may be found in the immediate vicinity of Watkin's well, in the midst of the artesian basin. Trees are entirely absent, except along the small streams. Here we find *Ulmus americana*, *Salix longifolia*, *Quercus macrocorpa* and *Q. rubra* Of the shrubs *Rosa blanda* var. *arkansana*, *Amorpha fruticosa*, and *Ceanothus ovatus* on the highest hills. The *Ceanothus americanus* more commonly on the upland prairies.

Hydrophytic Plants.—In the small artificial lake, which is representative of the aquatic vegetation elsewhere in small lakes abounding in this region, the following plants occur: *Ranunculus aquatilis* and *R. multifidus* are abundant in the entire region, especially *R. multifidus* var. *terrestris*. *Ranunculus cymbalaria* is also abundant on the shores of these lakes. It is not known to occur on this side of the artesian basin. *Potamogeton natans* is abundant, as is *Chara fragilis* and *Pontederia cordata*. The *Polygonum amphibium* is abundant in the region. The allied *P. hartwrightii* is also abundant, but it is frequently found in drier situations. *Scirpus lacustris* and *Phragmites communis* both abound, as elsewhere in the state, in standing water. *Glyceria fluitans* and *Phalaris arundinacea* both in water, the latter, however, frequently in drier meadows.

The meadows which border on these lakes are characterized by the abundance of *Thalictrum purpurascens*, *Phlox pilosa*, *Juncvs*, *tenuis*, *Caltha palustris*, *Cardamine rhomboidea*, *Lathyrus palustris*, *Glyceria nervata*, and *Phalaris arundinacea*.

During midsummer *Lilium canadense*, *Habenaria leucophæa*, *Phlox pilosa*, *Poa pratensis* and *Panicum scribnerianum* are abundant. *Pedicularis lanceolata* is common in the fall, as are *Gerarella purpurea* and *Solidago riddellii*.

Low Hills—Lathyrus, *Zizia*, and *Pimpinella Group*.—Rising from the marshes are low hills. These are drier, and are covered in spring with *Lathyrus venosue*, *Zizia aurea*, *Pimpinella integerrima Poa pratensis*, *Baptisia leucophæa*, and *Pedicularis canadensis*. Later in the season *Lilium philadelphicum*, *Solidago missouriensis* are conspicuous representatives. In the autumn these are replaced by *Solidago rigida*, *Aster lævis*, *A. azureus* and *multiflorus*. These species are typical prairie species, except for the *Lathyrus venosus*, which is not common ordinarily on our prairies.

GEOLOGY OF MUSCATINE COUNTY.

BY

J. A. UDDEN.

GEOLOGY OF MUSCATINE COUNTY.

BY J. A. UDDEN.

CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Muscatine county has an area of 433 square miles. It forms a rectangle extending thirty miles from east to west and eighteen miles from north to south. In the southeast corner of the rectangle an area of about 107 square miles is cut out by the Mississippi river. Excepting this corner the boundaries of the county are formed by the straight lines of the land surveys. The Mississippi crosses the east line of the county nine and one-half miles south of the north boundary line, and from there runs a westerly course for about thirteen miles, making two gentle bends to the north. From the city of Muscatine it takes a straight south course and crosses the south boundary fifteen and one-third miles from the southwest corner of the county. The Cedar river crosses the west end of the rectangle diagonally, entering at a point two miles west of the middle of the north boundary line. From there it pursues a meandering course to the southwest, making its exit one and one-half miles east of the southwest corner. Coming from the south we find Muscatine county the fourth of the ten counties which border on the Mississippi. It has eighteen and one-half miles of river front, which is less than that of any of the other nine river counties.

EARLIER INVESTIGATIONS.

The first geologist who published observations on the territory within the limits of this county was Dr. D. D. Owen. With a corps of observers which he organized in 1839 he traversed the north tier of townships, in the autumn of the year mentioned, and brief notes on these lands are given in his Report of a Geological Exploration of a Part of Iowa, Wisconsin and Illinois, made to the commissioner of the general land office at Washington, and published in 1840 as a part of the senate documents. In 1849 Dr. Owen visited the city of Muscatine, and examined the rocks there and in the region of Pine creek. An account of his observations at this time is given in his Report of a Geological Survey of Wisconsin, Iowa and Minnesota, which is a report to the commissioner of the general land office at Washington, published by congress in 1852. On pages 80 and 81 of this document the author describes the Devonian rocks along the Mississippi river in this region, and on pages 99 and 100 he gives an account of the coal measures in the city of Muscatine. There is also a wood engraving showing some large spherical concretions then exposed in the old sandstone quarries in the river bluff. On plates III and VI he figures some fossils from these same localities.

When Prof. James Hall was engaged as state geologist in Iowa, in 1855, 1856 and 1857, he examined the rocks along the Mississippi river in this county and saw some beds near the city of Muscatine which he referred, with some of the limestones on Pine creek, to the Chemung group. In the Report on the Geological Survey of the State of Iowa, published in 1858, he discusses the Devonian rocks in the county on pages 87 and 89, and describes the coal measures on page 126. On pages 244–247 there is a brief report on this county in particular, with two illustrations showing the spherical concretions in the sandstone in Muscatine bluff. In the second volume he describes and figures several fossils from the Cedar Valley limestone on Pine creek and at Fairport, referring some of these to the Chemung group.

Dr. C. A. White, who was state geologist from 1866 to 1870, in his Report on the Geological Survey of the State of Iowa, refers to the occurrence of a peat bed near the mouth of Wapsinonoc creek, and on page 281, in the second volume, gives a figure showing the relations of this peat to the local drainage conditions. The first volume of the same report contains, on pages 139–164, a report, by Prof. Theodore S. Parvin, on meteorological observations, made at Muscatine during the years 1839–1847.

In 1889 Dr. S. Calvin, director of the present Survey, published a paper in the American Geologist* on Some Geological Problems in Muscatine County, Iowa. In this paper he shows that beds in Muscatine county, which had been referred by Hall to the Chemung, are of the same age as the beds which had been referred to the Hamilton.

In the same year W. J. McGee, of the United States Geological Survey, published his Pleistocene History of Northeastern Iowa in the Eleventh Annual Report of that Survey. He discusses in this various features of the drift exhibited in this county, giving several illustrations of exposures in the city of Muscatine, and presenting other local data bearing on the general problems of the drift.

In the second volume of the reports of the present Survey Dr. C. R. Keyes has given a brief account of the coal measures in the county, and some statistics on its coal production.

Mr. Frank Leverett, of the United States Geological Survey, has, during the last eight years, made extensive observations on the drift of Muscatine county. He was the first to note the presence of Illinoian till near Muscatine, and to trace the terminal accumulations of the Illinoian ice sheet in the county. He has published accounts of the Mud creek buried valley, and other important observations on the drift. Some of his publications containing references to the county are: Notes Bearing Upon the Changes in the Pre-Glacial Drainage of Western Illinois and Eastern Iowa,† Pre-Glacial Valleys of the Mississippi and its Tributaries,‡ Pleistocene Features and

*Vol. III, pp. 25-36.
†Proc. A. A. A. S., vol. XLI, p. 176.
‡Journal of Geology, vol. III, pp. 740-763.

Deposits of the Chicago Area,* The Yarmouth Soil and Weathered Zone, The Sangamon Soil and Weathered Zone† and The Illinoian Glacial Lobe.‡

In volume VI, of the present Survey reports, Prof. W. H. Norton published a record of the rocks explored in drilling the artesian well at West Liberty. He also gives data on the well at Wilton.

Prof. F. M. Witter, of Muscatine, is, I believe, the only resident student of geology who has published records of his observations. He has announced the occurrence of flint arrowheads in the loess in Muscatine,§ the occurrence of fossil remains of a deer in the upper part of the loess,‖ and the occurrence of mineral gas just south of the county line, near Letts.¶ He has made collections of the molluscan remains in the loess, and published a list of the same in a pamphlet, The Mollusca of Muscatine County and Vicinity, issued by the Muscatine Conchological Club in 1883, and has contributed An Outline of the Geological History of Muscatine County as an introductory chapter to a larger work on the history of the county, published several years ago.

PHYSIOGRAPHY.

TOPOGRAPHY.

The forms of topography exhibited within the limits of the county are quite varied, and may be classified as including several kinds, different in aspect and origin. We find the monotonous level of wide river bottoms presenting no reliefs, except those of a few lagoons, an occasional low sand bank, and, sometimes, a gentle slope from the bluff line to the river bank. We find upland plains dissected by a well-matured drainage system of creeks, runs and draws, with open valleys ramifying in all directions. There is, also, a belt where this

*Bul. No. 2, Geol. and Nat. Hist. Surv., Acad. Sci., Chicago.
†Pro. Iowa Acad. Sci., vol. V.
‡Mon. U. S. Geol. Surv., No. XXXIV, in press.
§Pro. Iowa Acad Sci., 1890-1891, pp. 66-68.
‖loc. cit., p. 48. 1887-1889.
¶loc. cit., pp. 68-70. 1890-1891.

ancient drainage has been rejuvenated, and where it is mingled with a more recently developed topography of deep, and more narrow, channels. Then there is a belt of drift, which retains more of its original topography, exhibited in gentle paha-like ridges and in a faintly-marked terminal moraine, the features of which have been somewhat softened by erosion and more or less concealed by a blanket of loess, but where a few small, undrained ponds are yet found. Some areas of dune topography occur east of the Cedar, where the wind has wrought intricate patterns of ridges, knolls, small blow-outs, and basins. Finally, there are some terraces along the two rivers, and some of the larger creeks, recording earlier stages in the development of the present drainage. The highest point in the county is located about three miles southwest of Stockton, where the elevation is about 800 feet above the sea level. The main topographic features are two uplands and two lowlands, roughly forming four curving and concentric belts, extending from the northeast to the southwest, and having their concave sides to the southeast. The Mississippi bottoms and the West Liberty plain are the two lowlands, and the two uplands we may designate as the Illinoian and the Kansan drift plains. (Figure 30.)

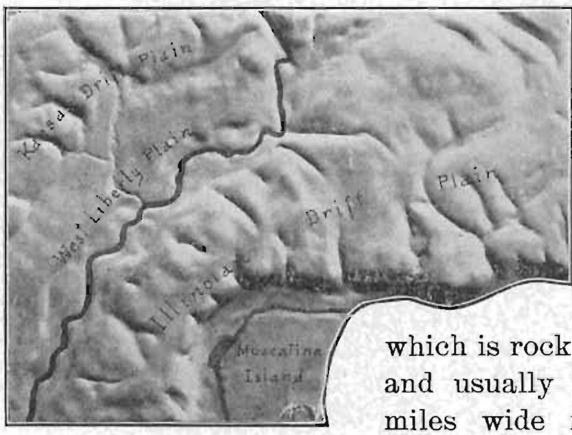


FIG. 30. Photograph of a clay model representing the main topographic features of Muscatine county.

The Mississippi Bottoms. — For a distance of about eighteen miles above the city of Muscatine, the Mississippi river occupies a rather narrow valley, which is rock bound on both sides and usually not more than two miles wide from bluff to bluff. Along that part of this valley which follows the southeast boundary of the county, the distance from the bank of the river to the base of the bluffs averages one-fourth of a mile, and at one place exceeds one-half mile. This is occupied by the bottom land, which forms a low slope away from the bluffs, at first somewhat rapid, and then more gradual nearer the river. In some places the lower part of the slope is low enough to be overflowed, but the rise toward the bluff soon brings the land above the high water level. At Wyoming Hill, below Fairport, and at East Hill, in Muscatine, the bluffs come out to the river bank leaving no bottom land, thus dividing it into two separate strips, one about seven miles in length and the other not quite six. At the bend of the river near Muscatine, the bottom lands reach out to a much greater width westward, mainly on the Iowa side, and are bounded by an abrupt, long, semi-circular line of bluffs on the north and west. This tract of land between the bluffs and the river is known as Muscatine Island. A shallow lagoon known as the Muscatine slough, separates it from a talus-like, low slope which intervenes between the slough and the bluff. In sections 23, 24 and 26, T. 76 N., R. III W., this slough widens out and forms Lake Keokuk. The elevation of the island is about 546 feet above the sea level, and it has been subject to overflow in times of very high water. Years ago it was protected by a levee built along the west bank of the river. In section 34, T. 76 N., R. II W., this levee runs up to what appears to be a remnant of an old terrace, known as the Sand Mound, which rises about thirty-five feet above the level of the surrounding bottom land. South of this isolated mound there is another levee in Louisa county. That border of the bottom land which lies outside the Muscatine slough, forms, as already stated, a low slope from the bluff to the slough. This slope occasionally rises as high as fifty feet above the bottom land on the other side of the slough. It consists of a series of confluent alluvial fans that spread out from the mouths of creeks and ravines coming down from the upland. The fans are proportionate in size to the streams. The old

Burlington wagon road, which runs under the bluffs all the way from Muscatine to the county line, presents the singular feature of having all its bridges at the highest points on the road, they being located about at the centers of these alluvial fans.

The West Liberty Plain.—This is the more extensive of the two lowlands. It is a broad valley reaching diagonally from Moscow, Atalissa and West Liberty to the southwest corner of the county, where it unites with a similar plain along the Iowa river. The Cedar has cut a broad and shallow valley along the bluffs which bound it on the east. Its length in Muscatine county is about nineteen miles, and it averages seven miles in width, being more than eight miles wide at the north, and about six miles wide at the south where it unites with the lowlands of the Iowa river. Northward it may be said to have two narrow extensions; one to the northwest, consisting of the bottom lands along the Wapsinonoc, and another to the northeast, a rather ill-defined lowland drained by Mud creek. The west boundary of this plain is an even line of bluffs rising from eighty to one hundred feet above it, and running from section 14 in Wapsinonoc township, southwest to section 30 in Pike township. The bluffs which bound it on the north are somewhat lower, less abrupt, and have a more sinuous course. They extend in a general curve to the south, from south of West Liberty to section 6 in Moscow township. The east boundary consists of a sharp bluff-line, extending from south of Moscow, in a rather direct course, to section 33 in Cedar township. The Cedar river follows this at a varying distance, not exceeding two miles.

The surface of this plain is not entirely without relief. There is a slight general slope to the south of about three feet to the mile. The elevation of its north end is about 663 feet above tide, and of the south end, at the county line, about 615 feet. On its northeast corner there is an island-like highland, covering about two square miles, and occupying parts of sections 7, 8, 17 and 18 in Moscow township. This rises seventy-five feet above the surface of the plain, and has a well-marked bluff line to the north and east, while on the southwest it merges more gradually into the plain around it.

A smaller, lower, and less well-defined elevation is to be seen one mile south of Atalissa. Some low and irregular ridges are occasionally observed on its surface, especially along the water courses traversing it, as near the center of the north line of section 36 in Wapsinonoc township, west of Pike creek in Sec. 8, Tp. 77 N., R. III W., and near the center of the southeast quarter of section 21 in Lake township, where there are elevations twenty feet high. There are, also, shallow pond-like depressions, where the surface goes down from five to ten feet below the general level. Some of these are seen in sections 12 and 13 in Goshen township. The main reliefs on the surface of this extensive plain are the bottom lands of the streams by which it is traversed. The Cedar, which enters the northeast corner from a narrow upland valley, on reaching the plain widens its valley to two and one-half miles, over the bottom of which it meanders from side to side. The bottom lands are from twenty-five to thirty feet below the level of the plain. The east side of the valley coincides with the bluffs bounding the plain for more than half its length, but in Lake and Cedar townships the two diverge as much as a mile, leaving strips of the plain extending like terraces along the upland bluffs. The west boundary of the river valley is characterized by some semicircular curves which have their concavities facing the river. These curves have a radius of about two-thirds of a mile, and they cause the plain to extend in sharp points toward the river. They have evidently been made by encroachments of the bends of the river at different times. The entire bottom land is subject to overflow. The Wapsinonoc has cut an inconspicuous valley in that part of the plain which lies west of the Cedar. It is seldom more than fifteen feet deep, and is usually very flat and open.

The Illinoian Drift Plain.—This comprises the entire east end of the county, from the bluffs of the Mississippi river to Cedar county and the West Liberty plain on the north and west. Its extreme length within the county is thirty-two miles, but to the south, as well as to the east, it is continued into the adjacent counties. The average elevation is about 725 feet above the sea level. Its highest points are found along a line running southwest from Stockton, approaching the bluffs of the Mississippi north and west of the city of Muscatine, and then extending west and south. A sag extends across it from the Mad creek valley, north of Muscatine, northwest to Little Musketo creek. From its very flat crest there is a gentle slope of this upland to either margin. In the east part of the county the slope to the Mississippi is longer than that to the north, and in that part of this plain which is farthest south the slope to the Mississippi is much shorter than the one on the opposite side.

The topographic expression of this plain is not the same over all of its extent within the limits of the county. In Montpelier and Sweetland townships, and in the south tiers of sections in Wilton and Fulton townships, it is extensively dissected by ramifications of creeks and ravines, which seldom have left intact as much as a square mile of the level upland. For about two miles on either side of Fairport several of these ravines have a depth of from 125 to 150 feet below the general level nearest the bluffs of the Mississippi. But these streams become less deep as we follow them north. The upland here hardly has any pitch toward the river. In the east part of Montpelier township, and in the west part of Sweetland, the slope of the upland to the river is greater, and about equal to the gradient of the creeks whose valleys rarely have a depth of 100 feet. Owing to this slope of the upland their apparent depths is maintained for some distance away from the river, and may even increase.

In the vicinity of Muscatine the land is likewise well dissected, and the drainage lines evidently antedate the drift;

but the topography has been somewhat modified by the latter, showing some elevations which are the results of constructive work, rather than destructive. Farther west, in Seventy-Six township, along the edge of the upland fronting the Mississippi, as in sections 1, 2, 10, 11, 15, 22 and 27, the ravines extend generally less than a mile into the plains, and all have a high gradient and comparatively narrow valleys. It seems that along the west of Muscatine Island the excavation by the great river in the soft material, of which this part of the upland consists, has been much more rapid than above Muscatine. The cutting into the bluffs by the river has progressed more rapidly than the recession of the ravines, which have, as it were, been overtaken. In section 15 there is very little left of the east slope of the upland, the line of the bluffs having advanced almost to its crest. That some of this work has been quite recently done is indicated by the fact that the Muscatine slough, which marks an earlier course of the river, when it was undermining the bluff, has not yet had time to become filled.

The northwest slope of the plain is quite different in aspect from that just described. The streams here have seldom cut their valleys more than sixty or seventy feet deep. In Wilton and Stockton townships this cutting mostly falls short of fifty feet. The streams occupy wide, shallow depressions in the upland, and these are separated from each other by low and flat, swells of land. Nearest the divide of the upland these depressions are not so well marked, nor are they conspicuous nearer the margin in the west part of Wilton township, or north of Musketo creek, in Moscow township. But south of this creek they make the dominant feature of the landscape, especially along the bluffs of the Cedar and for one or two miles inside of it. They are most pronounced nearest the Cedar bluffs, where they usually connect with a knolly marginal ridge which follows the bluffs and rises in places as high as twenty or thirty feet above the upland inside. In general their course is from west-northwest to east-southeast. In the north half of section 13, in Cedar township, a narrow ridge of this kind forms the north slope of a creek for some distance, and separates from it a chain of small, undrained ponds. In Secs. 12, 21, 28, 32 and 33, Tp. 77 N., R. III W., the ridges run into dune-like hills, some of which are seen to be now drifting before the wind. Similar conditions exist in Secs. 6, 7 and 12, Tp. 77 N., R. II W., where several small ponds are hemmed in among dune hills. In Moscow and Bloomington townships the area of the ridges encroaches farther on the upland than at any other place, reaching beyond its divide as far as within two miles of Muscatine, following the shallow sag which unites the basin of Mad creek with that of Musketo creek. Some isolated ridges are seen just above the bluffs around Muscatine Island, about four or five miles west from Muscatine.

The Kansan Drift Plain.—Kansan drift, covered by a sheet of sand and loess, forms an upland to the northwest of Muscatine county and extends into it, occupying the two north tiers of sections in Goshen township, the greater part of Wapsinonoc township, and a tract of six or seven square miles in the northwest corner of Pike township; in all about forty-four square miles. The Wapsinonoc creek, coming in from the northwest, divides the plain in the county into an east part, sloping to the south, and a west part which slopes to the southeast. The average elevation of both of these tracts is about 700 feet above the sea level. The bluff line terminating this highland in Wapsinonoc and Pike townships is rather straight, abrupt, and of a uniform height. In Goshen township the terminating bluff is more sinuous, for the most part less abrupt, and more variable in height. Apparently there has been less cutting in this direction by the waters which have filled the lowland than toward either the east or the west. Features are seen here and there which suggest a submerged slope. Some small hills lie out in the plain, that have been detached from the main upland by an erosion which must have long preceded the making of the lowland plain to the south. One instance of this kind is in the southwest quarter of section 1, in Goshen township. Other instances of similar import are the isolated elevations, already noted, south of Atalissa and southwest of Moscow. With the exception of a limited area in the west part of Wapsinonoc township, all of the Kansan drift plain in the county is dissected by streams with wide and open valleys. Along the Big Slough in Wapsinonoc, and also in the vicinity of West Liberty, there are some indications of terraces at elevations varying from thirty to sixty feet above the lowland plain.

Table of Elevations.

Below is given a table of elevations of all the railroad stations in the county, and also of the high water and low water marks in the Mississippi river at Muscatine. The figures are taken from Gannet's Dictionary of Altitudes:

STATION.	Altitude.	AUTHORITY.
Adams	629	B., C R. & N. Ry.
Atalissa	664	C., R. I. & P. Ry.
Conesville	618	B., C. R. & N. Ry.
Fairport	571	C., R. I. & P. Ry.
Fruitland	556	C., R. I. & P. Ry.
Kirk's Siding (Bayfield)	681	B., C. R. & N. Ry.
Montpelier	570	C., R. I. & P. Ry.
Moscow	661	C., R. I. & P. Ry.
Muscatine	562	C., R. I. & P. Ry.
Low water, Mississippi river	531	
High water, Mississippi river	547	
Nichols	615	B., C. R. & N. Ry.
Port Allen	615	B , C. R. & N. Ry.
Stockton	726	C., R. I. & P. Ry.
Summit	726	C., R. I. & P. Ry.
West Liberty	676	C., R. I. & P. Ry.
Wilton	683	C., R. I. & P. Ry.

DRAINAGE.

The Kansan drift plain is, as just stated, everywhere well drained by streams which come down from the north and from the west through wide valleys out on the West Liberty plain. Big Slough, which runs east through the central part of Wapsinonoc township, has a rather wide bottom land, making a slow descent. In some of the lateral slopes down the wide valleys the surface moisture slowly seeps through the somewhat porous surface materials, and the lower part of such a slope is more richly supplied with moisture than the part above, from which the seepage comes. Boggy conditions are occasionally produced in this way. The natural drainage of the West Liberty plain is very defective. Its level expanse occasionally has shallow depressions lacking outlets, where the water stands until it sinks into the ground or dries out. Along the west border of this plain there have been extensive peat bogs, which are now drained by ditches. The natural gradient is so slight and the water drains away so slowly that it has not yet produced natural drainage channels. Farther east, along the bottom lands of the Cedar, there is occasionally a somewhat greater slope toward the river, but even this slope is too low for the formation of natural drainage lines. The soil in this strip of land is coarser than to the west, and it has, to some extent, prevented erosion by allowing the water to descend into the ground. The drainage of the Cedar bottoms is still less efficient, and there are frequent lagoons and swamps. These are most common near the borders of the valley. Such are Pike creek in the east part of Pike township, and Pike run in Orono township.

That marginal part of the Illinoian drift plain which is covered by scattered dunes and paha-like swells has a drainage quite different from that of any other land in the county. Nearly all of it belongs to the basin of the Cedar. As previously stated, the Cedar bluffs on this side of the river, south of Musketo creek, have a crest, through the gaps in which the streams from the upland must pass before emerging on the bottoms. Just inside the crest there are frequently small, undrained ponds, or there is a drainage away from the crest into some lateral tributary of the creeks. Farther away from the river, from points half a mile or less from the bluffs to the head of the streams, the drainage in each little basin is quite efficient, owing to the general slope westward. The land nearest each stream is mostly comparatively low and flat, rising farther away into wide swells, which separate the basins of the different streams. In the north part of Fulton township, some creeks occupy deeper and narrower flat bottoms, which, previous to the tilling of the land, were marshy and which are now meadows. The central sections in Fulton and Wilton townships are more flat than any other part of the drift plains in the county. This land is on the divide between the Mississippi and the Cedar river basins. The ravines are shallow and far between. The early settlers found these lands too wet for tillage. There are a few very low swells, and occasional very shallow, small, undrained basins, otherwise the surface is an even plain. Similar conditions are observed in the adjoining tracts in Moscow, Bloomington and Sweetland townships. Undrained ponds are, perhaps, somewhat more frequent, and part of the surface slightly more uneven. To the south the flat top of the divide is not quite as wide, but it is marked by an interrupted line of very shallow depressions of the surface all the way to the Louisa county line. The drainage of the slope to the Mississippi is almost perfect, the gradient of all the streams being steeper and the modifications of the preglacial valleys by the drift being less. The only exceptions consist of a few very small depressions almost on the brink of the bluffs immediately east, west and southwest of the city of Muscatine. How the bottoms of the Mississippi are drained, has already been made sufficiently evident in the discussion of their topography.

STRATIGRAPHY.

General Relations of Strata.

The rocks which are naturally exposed in Muscatine county belong to the Paleozoic and Cenozoic groups. A conglomerate of unknown age may prove to be Mesozoic. The Paleozoic is represented principally by Devonian limestones and shales, which appear along the Mississippi river and some of its smaller tributaries, east of the city of Muscatine, and also along the Cedar in the vicinity of Moscow. The Carboniferous also belongs to this group, and is represented mainly by conglomerates, sandstones and shales in Muscatine, Bloomington, Sweetland and Montpelier townships. The Cenozoic consists of gravel, sand, silt, bowlders, clay, loess, and alluvium, all usually known as drift. This covers the older rocks everywhere except along the water courses, where it has been carried away by erosion. Over the west end of the county the drift is so deep that the underlying bed-rock never comes into view. No outcrops of the older consolidated rocks are known anywhere west of a straight line running across the county through the town of Atalissa and the southeast corner of Lake township. This great thickness of the drift in the western part of the county is mainly due to deep erosion in the lower rocks before the deposition of the drift. The rock surface is from 200 to 300 feet lower in the western portion of the county than in the east. From this deep excavation, which is filled by the drift, the Carboniferous and much of the Devonian has been wholly removed. Unconformities occur between the lower and the upper series of the Devonian, between the Upper Devonian and the Carboniferous, and between the Carboniferous and the drift.

The general classification of the geological formations in the county is indicated in the following table:

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene or Quarternary	Recent.	Alluvial.
		Glacial.	Illinoian. Kansan Aftonian. Pre-Kansan. Ante-glacial.
			Pine creek conglomerate.
Paleozoic.	Carboniferous.	Upper Carboniferous.	Des Moines.
		Lower Carboniferous.	Kinderhook (?)
	Devonian.	Upper Devonian.	Sweetland creek.
		Middle Devonian or Hamilton.	Cedar valley. Wapsipinicon.
	Silurian.	Niagara.	Gower (?)*

*See significance of the term Gower in report on Scott county, this volume.

UNDERLYING FORMATIONS.

Two deep wells in the north part of the county, one in Wilton and the other in West Liberty, have furnished some information as to the terranes which underlie the outcropping rocks. Mr. M. G. Mills, formerly a resident of Lime City, north of Wilton, gave to the writer some years ago the driller's log of the well at the latter place. This log reads as follows:

ROCKS PENETRATED IN THE WILTON WELL.

(Elevation of the curb of the well, 683 feet above sea level.)

5. Drift, 220 feet, down to 460 feet above sea level.
4. Limestone, 280 feet, down to 180 feet above sea level.
3. Shale, 180 feet, down to sea level.
2 Limestone, 300 feet, down to 300 feet below sea level.
1. Sandstone, 120 feet, down to 420 feet below sea level.

From the records of wells in the adjacent counties it is clear that number 1, in the above table, is the Saint Peter sandstone, number 2 is the Galena-Trenton limestone, number 3 is the Maquoketa shale and number 4 is the Niagara limestone. Number 1 is the water-bearing member, the aquifer, and below this the drilling does not appear to have extended. From the well at West Liberty Prof. W. H. Norton reports a water-bearing sand at about the same level.* From below this several samples of drilling were examined by him from this well at different levels extending down to 1,765 feet below the surface. Some of these samples are referred to the Canadian series and some to the Potsdam, the boundary between the two being placed at 704 feet below the sea level. Combining the records of these two wells and adjusting them slightly to a common level, they indicate a downward succession of the unexposed rocks underlying the county, as given in the following table:

Succession of Rocks Below the Devonian.

FORMATION.	Thickness—feet.	Distance below 650 feet above sea level—feet
Niagara limestone	280	100- 380
Maquoketa shale	180	380- 560
Trenton and Galena limestones	300	560- 860
Saint Peter sandstone	140	860-1050
Canadian shales, dolomites, and sandstones	300	1050-1320
Potsdam sandstones, dolomites and marls	385	1320-1705

It should be remembered that there is a dip to the south of about twenty feet to the mile, and if estimates were to be made from the above table for any particular place, that many feet should be added for each mile the place is south of Wilton, or subtracted for each mile north. There is also a dip to the west. Owing to changes in the dip, local variations in the strata, and possible errors in the known measurements, estimates of this kind are apt to prove more or less incorrect, but for places within the county they are not likely to fail by more than a hundred feet.

*Iowa Geol. Surv., vol. VI, p. 281, Artesian Wells of Iowa.

SILURIAN.

NIAGARA LIMESTONE.

The deep erosion of the bed rock in the north and west part of the county has, without a doubt, cut into the Niagara limestone. This erosion is seen in some wells to have reached to within 400 feet of the sea level and even deeper, while, in the same territory, only a mile or two away, the top of the Niagara limestone comes up 150 feet above this. The drift must rest on the eroded surface of this formation in the north part of Wilton, the south part of Moscow, and very likely a considerable distance farther to the southwest. What there may be under the drift still farther south is more problematic, but erosion is not as likely to have reached the Niagara there. The Niagara is not known to be exposed anywhere in the county. Drift has taken the place of the strata which have been removed from above it. Likewise the Bertram and the Coggan beds, described by Professor Norton, and coming in above the Niagara in places farther north, have no known outcrop, but must underlie the drift, if present.

DEVONIAN.

MIDDLE DEVONIAN.

The Devonian rocks in Muscatine county belong to two main divisions, one corresponding to a part of the Upper Devonian series and the other, at least in part, being equivalent to the Middle Devonian in the eastern states. In counties lying to the northwest the Middle Devonian has been subdivided by Professor Norton into the Wapsipinicon stage below, consisting of the Otis, the Independence, and the Fayette breccia, and the Cedar Valley limestone above. Of the members of the Wapsipinicon stage the Fayette breccia is alone exposed in this county, and that in only a few places. There appears to be no well-defined line of demarkation between it and the Cedar Valley above. This may be due to a lack of good outcrops. For this reason the sections including the two will be treated together, but the dividing line will be indicated, whenever practicable. The Upper Devonian, which consists of the Sweetland creek beds, will be discussed separately.

THE FAYETTE BRECCIA AND THE CEDAR VALLEY LIMESTONE.

On the Cedar.—The lowermost rocks of the Devonian section exposed in the county are seen in the west bank of the Cedar river, from the north county line to within about a mile of the railroad bridge at Moscow. There are about twenty-five feet of sometimes brecciated and sometimes regularly-bedded grayish or white compact limestone, which emits a faint bituminous odor on being struck with the hammer. Where weathered, its upper ledges frequently split into small blocks from half an inch to two inches in thickness. About two or three feet below the upper surface of these beds they exhibit some layers with low, small mound-like elevations three or four inches in diameter and less than an inch high. Where blocks of this limestone have been subjected to the slow solvent action of the river water, a fine lamination is made evident, though no such structure can be detected in the fresh fracture. This rock contains no fossils. It is one of the purest limestones known, and this renders it somewhat more readily soluble by ground water than limestones which contain more of siliceous impurities or a greater percentage of magnesia. In other localities it is frequently cavernous. Indications of caverns at this place are seen in some small sink holes in the bottoms of some of the ravines in the bluffs. Loose blocks of fossil-bearing ledges known to overlie these beds are seen in some of the gullies, indicating their presence in the bluffs. Just north of the county line these ledges are quarried. They contain various corals and brachiopods, the following having been noticed: *Astraeospongia hamiltonensis* (spicules rather coarse), *Fistuliporella constricta* (tubes rather crowded), *Atrypa aspera*, *A. reticularis*, *Spirifer pennatus* Owen, *Capulus* or *Platyceras* sp.

Another exposure of the unfossiliferous limestone breccia occurs in the timber about one-third of a mile north-northwest of the center of section 3, north of Moscow, where it has been quarried. The thickness now exposed is eight feet. This consists of the following:

		FEET.
2.	(*1*)* Coarse limestone breccia, emitting a faint bituminous odor under the hammer	4
1.	(*1*) Evenly-bedded white limestone in thin layers	4

The same brecciated rock has also been observed in making excavations for the piers of a small bridge in the wagon road, near the center of section 8 in Moscow township, and loose blocks of it occur along the west bank of Wresley's lake, in the same section.

At this place, in the east bluff of the small tract of isolated highland on sections 7 and 8, there are some quarries on Mr. Wresley's land which, taken together, include a thickness of about forty feet of rock. These are on both sides of the wagon road, where it approaches the bluffs of the highland. Combining all the exposures, the section is as follows:

		FEET.
3.	(*6*) Hard, gray limestone, in rather irregular ledges, with many fossils, somewhat brecciated and mixed with the rock below, containing *Atrypa reticularis*, *Athyris vittata*, *Spirifer asper*, *S. parryanus*, Stromotopora, *Cystipyllum americanum*, Strombodes, *Acervularia davidsoni*	5
2.	(*3*, *4*, *5*) Softer beds, mostly concealed, with frequent crinoid stems above, blue and fine-grained ledges farther down (seen to the northwest in some old quarries), slightly crushed or brecciated in the lowest part (seen in the quarries east of the road), and containing *Orthis iowensis*, *Atrypa reticularis*, *A. aspera* (far down), *Stropheodonta demissa*, *S. perlana*, *Spirifer pennatus*, *S. asper*, *Cyrtina umbonata*, *Monticulipora monticula*, Retapora	29
1.	(*2*) Strong, gray limestone, in moderately heavy and regular ledges, slightly broken or brecciated in a few places, containing many corals, such as *Favosites placenta*, *F. alpenensis*, *Acervularia davidsoni*,	

*All numbers so set up refer to place in the general section.

Heliophyllum halli, Aulacophyllum, Cyathophyllum, and some brachiopods and mollusks, such as *Atrypa reticularis*, *A. aspera*, *Spirifer pennatus*, *S. subundiferus*, Straparollus.................................. 8

About one mile farther west and a little north the railroad company has worked a quarry quite extensively in the north bluff of the same highland. The section now seen is as follows:

		FEET.
3.	(*4*) Comparatively fragile and somewhat thin-bedded, bluish-gray limestone, with mainly brachiopod fossils..	9
2.	(*3*) Several moderately thick ledges of bluish-gray, fragile limestone, with *Orthis iowensis*, *Stropheodonta demissa*, *Atrypa reticularis*, *A. aspera*, *Spirifer pennatus*..	5
1.	(*2*) Strong, gray limestone, in heavy beds, frequently exhibiting closely set calcite crystals along the joints, and containing fossil corals..................	4

In the south bluff of the Kansan drift plain, one-half mile east of Atalissa, there is an old quarry, now mostly concealed under rubbish. A square yard of gray, weathered limestone is bare. *Cyrtina umbonta* and *Atrypa reticularis* were noticed, and also some fossils belonging to the upper member in Wresley's quarry.

On the Mississippi, East of Pine Creek.—Examining the drainage area of the Mississippi we may begin at the east line of the county along Sulphur branch, which is the name of the creek running south through sections 12, 13 and 24, in Montpelier township. Near the bluffs the section of the Cedar Valley along this creek is as follows:

		FEET.
6.	(*10–11*) Weathered ledges of limestone, with scattered casts of cyathophylloid corals...............	2–4
5.	(*9*) Traces of a carbonaceous black seam of limestone with Stromatopara..................................	¼
4.	(*9*) Thick-bedded, bluish, dolomitic limestone, with casts of *Spirifer parryanus*................................	9
3.	(*8*) Soft, shaly material, with large specimens of *Atrypa reticularis* and other brachiopods......................	1

2. (*8*) Thin ledges of hard limestone, with a small, kidney-shaped or cake-like Stromatopora, *Gomphoceras ajax* Hall (?) and Orthoceras 2
1. (*7*) Ledges of a bluish, finely granular, dolomitic limestone, containing *Cystodictya*, a form near *hamiltonensis* Uhlr. (seen) 4

The base of this section is near low water mark in the river. The top is eroded and has coal-measure shales, filling hollows which extend down into number 4. The layers of this ledge form the bottom in the bed of the creek for some distance, until they are concealed by the coal measures. About a mile from the river the limestone appears again for a short space, exhibiting the following succession in the bed of the creek:

FEET.

4. (*11?*) Red or brownish, moderately coarse, granular, hard and strong dolomitic limestone 2
3. (*11?*) Bluish-gray, fine-grained dolomitic limestone, in layers, mostly about half a foot thick, and containing casts of a Bellerophon and *Atrypa reticularis* 4
2. (*11*) Concealed, probably 2
1. (*11*) Limestone, with large fragments of Stromatopora 2

No more limestone occurs farther up in this creek. Number 3 in the above section is probably identical with a rock observed in Mad creek, northwest of the center of section 24 in Bloomington township. No rock similar to number 4 has been observed elsewhere. It is probably a local change in some of the known ledges.

The creek near Montpelier, just east of the town, exhibits the following section:

FEET.

7. (*10-11*) Yellowish or brownish, finely granular dolomite, in heavy beds, some nearly two feet thick and frequently containing large fragments of Stromatopora 7
6. (*9*) A layer of thinly-bedded, calcareous and dark carbonaceous material, with frequent casts of a Stromatopora of mammillated structure, or traces of stromatoporoid texture in the rock .... ½

5. (9) Grayish, finely granular dolomite of even texture, in ledges from one to two feet in thickness, with casts of *Spirifer parryanus*, *Atrypa reticularis* and corals 8
4. (8) A blue, unctuous clay, changing horizontally into strong material like the ledges above, and containing large specimens of *Atrypa reticularis* and *Orthis iowensis*.. ½
3. (8) Thin-bedded, hard, calcareous rock, with some brachiopods, a few cephalopods, and a reniform or lenticular *Stromatopora* seldom exceeding six inches in longest diameter..............................4-5
2. (7) Bluish-gray limestone, somewhat more calcareous above, and containing *Atrypa reticularis* in abundance, magnesian and more even grained below, containing a *Cystodictya* related to *hamiltonensis* Uhlr. The uppermost ledge is fine grained and bears the marks of a coarse network of vertical plates consisting of the same material as the ledge above 5
1. (6 or 7) Bluish clay with *Athyris vittata*, a thickness of only a few inches seen............................

The ledges forming the upper ten feet in this section have been quarried along the creek in the bluff. The uppermost ledges have been subjected to weathering before the coal measures were deposited, and are yellow and even brownish in color from this weathering.

Close up to the contact with the coal measures some siliceous nodules were seen in the most thoroughly altered ledges, measuring from half an inch to four inches in diameter. This rock is very hard and tough. The ledges of number **5** have been quarried most extensively. They exhibit a uniform grain and break rather easily with a conchoidal, even fracture, with almost equal readiness in all directions. The lowermost ledge is two feet in thickness. The bedding planes are even and well marked; but the ledges frequently exhibit an oblique fracture running in long curves at angles from 10° to 45° from the horizontal, so as to simulate bedding planes for distances of two or three feet. Farthest down the creek, where this number first comes into view, and close by the abandoned tile works, the ledges are seen to have weathered along the joints and bedding planes into a loose, clayey material, so that only the centers in the blocks are sound. It is possible that the green clay, number 4, may be the result of disintegration of the base of the number above. It does not always appear in the same position in other places. *Atrypa reticularis*, which it contains, is like the specimens found above in being of large size, but unlike them in having the calcareous matter of the valves preserved, the fossils above being casts. Number 3, also, exhibits changes due to weathering. Farthest down in the creek, close to the wagon bridge, it lies in thin, straight, floor-like layers, but farther up, under the old storehouse of the tile factory, an excavation shows a hard and tough rock, with only faint and more distant traces of bedding joints. At this junction of numbers 2 and 3 there is a peculiar, crack-like structure, described farther on. The clay containing *Athyris vittata*, below number 2, is not now well exposed. It may possibly, also, be a product of disintegration from the overlying ledges.

An eighth of a mile west of the town of Montpelier a small run shows the following succession of rock, all very much weathered:

		FEET.
6.	(*11*) Fine-grained, yellow limestone (opposite an old farmhouse)	1
5.	(*11*) Disintegrated, rusty limestone, perforated with branching, poorly defined tubes, evidently produced by the leaching out of some such coral as Peronella	2
4.	(*10*) Decayed ledges of yellowish or brownish magnesian limestone with fragments of a large Stromatopora	6
3.	(*9*) A discontinuous seam of carbonaceous limestone	½
2.	Concealed	2-3
1.	(*9*) Yellowish, weathered magnesian limestone of fine texture, like the weathered phases of the Montpelier section in number 5	2

A little more than half a mile west of Montpelier, Robinson creek exposes about twenty-four feet, vertically, of the same horizon.

ROBINSON CREEK SECTION.

		FEET.
10.	(*10*) Somewhat brecciated, much weathered limestone with casts of *Cladopora dichotoma*, about	3
9.	(*10*) Rather less disintegrated limestone, with occasional large fragments of Stromatopora showing concentric wavy rings. The fossil also occurs entire and in situ	4
8.	(*9*) Irregular, interrupted seams of a carbonaceous, black, Stromatopora-bearing limestone	¼
7.	(*9*) Bluish magnesian limestone, in ledges about one foot in thickness, weathering yellow, containing moulds of a coral like *Amplexus yandelli* and also casts of *Spirifer parryanus* and *Atrypa reticularis* of a large size	7
6.	Concealed	2
5.	(*8*) Hard rock charged with fossils such as *Atrypa reticularis* and *Stropheodonta demissa*, and frequently containing a reniform or cake-like, small Stromatopara and *Athyris vittata*	2
4.	(*7*) A reticulated structure of vertical plates extending into a fine grained layer of limestone, about	½
3.	(*7*) A thin seam of clay with occasional fragments of brachiopods	⅙
2.	(*7*) Thin-bedded, fine grained limestone with *Gomphoceras ajax* Hall ? *Atrypa reticularis*, and occasional joints of crinoid stems	1
1.	(*7*) Bluish gray, magnesian limestone, in ledges a little less than a foot in thickness, with a conchoidal oblique fracture; the upper ledges containing numerous fragments of brachiopods, mostly *Orthis iowensis* and *Atrypa reticularis*, and a wide form of *Stropheodonta demissa; Cystodictya* of a form near *hamiltonensis* Uhlr. and *Cyrtina hamiltonensis* var. *recta* were also seen, the former very frequently	5

Nearly a mile west of this place, east of the residence of Mr. Lowry, there is a small creek in which a section occurs comprising some ledges above the uppermost of those found on Robinson's creek. It is seen in the bed of the stream and in the right bank, and runs as below:

		FEET.
3.	(*11*) Somewhat irregular ledges of a disintegrated limestone, with fragments of a large Stromatopora (seen in the right bank of the creek farther south than the following) and some ledges farther down perforated by empty casts of a coral resembling a Peronella	8
2.	(*11*) Weathered, slightly crushed or brecciated limestone ledges containing large fragments of Stromatopora, and with a black, carbonaceous layer near base	4
1.	(*9*) Bluish, dolomitic limestone in even ledges, six inches thick above, and two feet thick below, evidently equivalent to the main quarry rock at Montpelier	6

South of the center of section 21, in Montpelier township, the rock immediately below number 1 in the above section has been quarried at several places in the river bank, and at present a quarry in the creek on Mr. Charles Bar's land has furnished a large amount of rock for the construction of wing-dams farther down the river. The section exposed in this quarry, and near it, is as follows:

		FEET.
7.	(*11*) Hard, brown, weathered limestone, apparently somewhat brecciated, and containing fragments of Stromatopora (exposed 200 paces west of the quarry)	4
6.	Concealed	5+
5.	(*9*) Weathered, apparently brecciated ledges of limestone, with a large Stromatopora, above a dark carbonaceous layer near the base, containing casts of an Amplexus	4
4.	(*9*) Almost white, bluish, finely granular and evenly-bedded dolomitic limestone, in heavy ledges, the lowermost nearly four feet thick, rapidly turning darker blue and yellowish on exposure, oblique curving fracture in some places, casts of *Spirifer parryanus*, *Orthis iowensis* (large), *Atrypa reticularis* (large), Zaphrentis (casts of calyx)	8
3.	(*8*) Hard limestone in thin and rough, but straight layers above, containing Stromatopora (small rounded forms), Gomphocerat (two species) *Atrypa reticularis* (abundant), and joints of crinoid stems	2½
2.	Concealed	3
1.	(*7*) Blue or grayish dolomitic limestone, with Cystodictya	2

The last number is seen lowest down in the creek and also in the river bank several rods to the west, where it disappears under the water.

On Pine Creek.—The west end of the wagon bridge across Pine creek, near the west line of Sec. 21, Tp. 77 N., R. I E., rests on a bank of rock rising about twenty feet above low water. It may be described as below:

		FEET.
4.	(*10*) Somewhat interrupted or broken ledges of limestone, about a foot in thickness, containing Stromatopora	4
3.	(*9*) Bluish-gray, dolomitic, fine-grained limestone, occasionally exhibiting a very oblique, almost horizontal jointing, weathering into shale along the seams separating the ledges, and showing fresh nuclei of rock in the center of the blocks, containing moulds of cyathophylloid corals	10
2.	(*8*) Solid and hard limestones, with many brachiopods, such as *Atrypa reticularis*, *Athyris vittata*, *Strophcodonta demissa*, also crinoid stems and a Stromatopora, of flattened spherical form	3½
1.	(*7*) Bluish, dolomitic limestone, with vertical, cylindric, darker impregnations about one-fourth of an inch in diameter; ledges regular, about eight inches thick, containing Cystodictya	3

A quarter of a mile farther up the creek a limestone corresponding to number 3, in Wresley's quarries southwest of Moscow, is exposed in the bed and left bank of the creek. It contains *Acervularia davidsoni*, *Spirifer parryanus* and *Athyris vittata*, the latter being abundant. Resting on this there is a gray rock of very uniform grain in regular ledges, with a smooth conchoidal fracture. This is an altered phase of number 1 in the foregoing section. It contains a few specimens of the same Cystodictya seen in the latter, and is overlain by number 2 in the same section. The ledges appear to have undergone some peculiar change which gives them an unusual appearance. This change may have consisted of the infiltration of siliceous matter, of which they contain about 6 per cent. Whatever is the nature of the change it has so thoroughly affected the rock that at the line where it ceases, near the south end of the exposure, it suggests an unconformity between the two numbers. At three different places farther up the creek the same phase appears again. The rock is evidently less affected by weathering than other limestone in the region. With its more uniform texture it ought to make a good building stone.

Just below the dam at Pine Creek Mills there is exposed, in the left bank, a hard limestone, which is seen to be crushed and brecciated in the lower part and more regularly bedded above. It is full of the same fossils as occur in number 3, in Wresley's quarries. Among the more common ones are *Favosites emmonsi* (?) *Cystiphyllum americanum*, *Atrypa reticularis* (valves unequally convex), *Spirifer parryanus* and *Athyris vittata*. Mingled with these in the brecciated rock are also forms which are known from the beds below, such as *Cladopora iowensis*, Monticulipora and joints of the stems of Megistocrinus. Large fragments of the rocks from these two horizons are seen side by side, thrown together into a coarse breccia, such as might form along a line of some small dislocation. Higher in the bank there appears a small remnant of the altered ledge described above. It contains the characteristic Cystodictya and a Stropheodonta, and a seam of green clay separates it from the rock below. Ten rods above the dam the following beds are seen in the left bank, almost in a vertical wall:

		FEET.
4.	Traces of blue shale	
3.	(*11*) Eroded ledges of a very hard and rusty red limestone containing Stromatopora	4
2.	(*7, 8, 9*) Highly disintegrated, dolomitic limestone, showing in its lower part some sound centers of blocks of dolomitic limestone of the original bluish color. Stromatopora and a Gomphoceras occur near the middle of the number	12
1.	(*6*) Sound, calcareous rock of the same kind as seen below the dam, extending below the head of the dam	7

Two or three other small outcrops of the Cedar Valley stage appear in the creek above this point and below the junction of its east and west branches, but these are unimportant. In each of the two branches the stream beds have just cut down to the plane of contact between this rock and the overlying Des Moines. This plane rises northward at about the same rate as the beds of the streams which run over coal measure rock and Devonian rock alternately. Near the center of the southeast quarter of section 8 in Montpelier township, a section in the west bank of the east branch of the creek is as follows:

		FEET.
5.	(7, 8) Thin and shelly limestone, full of brachiopods and also containing *Gomphoceras ajax?*.............	4
4.	(7) Disintegrated, fine grained, dolomitic limestone (not well exposed)................................	6½
3.	(6) Soft, very much weathered and crumbling, yellow rock, with *Athyris vittata* in profusion on the slope.	5
2.	(6) Somewhat brecciated, hard, gray, coral-bearing limestone, containing *Alveolites goldfussi*, Strombodes *Acervularia davidsoni*, *Athyris vittata*, *Atrypa reticularis*, *Stropheodonta demissa* ("Small, but identical with one found at Alpena, Mich." Calvin). From the base of the number, scattered, small, vertical plates, ½ inch thick, extend into the fine grained ledge below......................................	5
1.	(5) Compact, fine grained, light-colored limestone, not very rich in fossils, with *Monticulipora monticula*, *Orthis iowensis*, *Spirifer parryanus* (small size, six inches below the top of the number) and *Spirifer pennatus* (farther down)............................	3

The lowest number forms the bed of the creek for a short distance above. It is the uppermost part of number 2 in Wresley's quarries southwest of Moscow. In a tributary of this branch, that comes in from the east through the north part of section 10, there is seen in the northwest quarter of this section a low bank of limestone with Stromatopora. It is overlain by coal measures. More extensive outcrops of the Cedar Valley are found in the next tributary running somewhat diagonally across section 3. In the northeast quarter of the southeast quarter of section 4 in Montpelier township, there is an old quarry in the south bank of this tributary which shows the following succession:

CARPENTER'S QUARRY SECTION.

		FEET.
7.	(*9*, *8*) Shaly, yellow material, or clay, apparently residue from decayed limestone. On the slope of this shale were observed *Atrypa reticularis*, *Orthis iowensis* (one thin variety, also the usual form), *Strophedonta demissa* (of variable size), Platystoma, *Spirifer subvaricosus* (small, short-hinged), *Cyrtina curvilineata*	7
6.	(*8*) Hard, solid ledges, a foot in thickness, in places almost filled with shells, mostly *Atrypa reticularis*. A large form of *Athyris vittata*, with sinus and fold more marked than usual, was also seen	3
5.	(*7*) A layer of fine grained limestone, cut by a network of vertical plates (Fig. 2) made up of material like that in the ledge above	$\frac{3}{4}$
4.	(7) Shaly, dirty, calcareous material, same as number 3 in the Robinson creek section	$\frac{1}{6}$
3.	(*7*) Fine grained, gray limestone, thin-bedded above, more thick-bedded and dolomitic below. Gomphoceras and a reniform Stromatopora in the upper part, Cystodictya below	2
2.	Concealed	5?
1.	(*5*, *6*) Gray limestone, in somewhat irregular ledges, containing many fossils, such as Monticulipora, Ptychophyllum, stem joints of crinoids, Fistulipora, *Acervularia davidsoni*, *Atrypa reticularis*, *Athyris vittata*, *Cyrtina umbonata* exposed in the bed of the creek	3

Number 5 in the above section follows the creek for some distance up, but at last it disappears under the coal measures. In the opposite direction, along the middle branch of Pine creek, this ledge is quite conspicuous for a considerable distance, and it has been quarried in several places in sections 6 and 7, Tp. 77 N., R. I E. In the west half of section 8, the underlying bluish, dolomitic ledges are weathered along the joints, exhibiting blocks with a solid interior surrounded by a two-inch crust of altered rock. The peculiar networks of plates (Fig. 31) is seen on some ledges in a gully southeast

FIG. 31 Network of vertical plates extending into the top of the Cystodictya ledges. Seen from above. Reduced about ¼. Specimen in Carpenter's quarry, on Pine creek. Photograph by W. H. Norton.

from the center of the west line of section 8. Along the west branch of Pine creek, the same ledges (numbers 3-6 in last section) form the south bank of the creek for half a mile in sections 17 and 18, where they have also been quarried. Near the line of the Fifth Principal Meridian, the stream runs over coal measure shale, but the Cedar Valley comes up again in section 12 in Sweetland township. From this section northward, only drift is seen until we come to the old Hanson quarry in section 35, Tp. 78 N., R. I W., now occasionally worked north of the road by Mr. R. J. Vance. The main rock taken out here, on both sides of the stream, is number 3 in Wresley's quarries southwest of Moscow, and lies about ten feet lower down in the section than number 6 in the section at Carpenter's quarry, which is the main quarry limestone along the lower course of this branch. The section at this place is as follows:

FEET.

4. (6) Yellow, marly clay, a residue from disintegrated limestone, with numerous specimens of *Athyris vittata*, *Atrypa reticularis* and *Stropheodonta demissa* (all sizes).. 1
3. (6) Weathered, hard limestone, full of fossils, in beds about eight or ten inches in thickness, stylolitic surfaces frequent near the junction with the number below, and containing Stromatopora, *Favosites alpenensis*, *Cystiphyllum americanum*, *Acervularia davidsoni* (frequent), Strombodes, *Atrypa reticularis* (abundant), *Spirifer parryanus* (frequent), *Spirifer asper*......... 8
2. (5) Yellow limestone in thin, hard layers, somewhat weathered, with frequent joints of crinoid stems and *Striatopora rugosa* (near base), *Spirifer parryanus*, *Spirifer subvaricosus*, *Spirifer asper*, Aulacophyllum, *Chonetes scitulus* (near base), rather continuous with the number below................................. 3
1. (4) Partial exposures of impure, weathered, slightly argillaceous limestone, containing *Monticulipora monticula*, *Stropheodonta demissa*, *Spirifer pennatus*, *Cyrtina hamiltonensis* 6

Some of the fossils listed in number 1 run up into number 2, and *Spirifer asper* in the latter occurs in number 1. At the dividing line, *Megistocrinus latus* is known to occur in other localities, and from there upward joints of crinoid stems are profuse at this place. The thickness of these crinoid-bearing layers is less than it is known to be farther east. One-fourth of a mile farther up the creek the south bank exposes a ledge which belongs a little lower down in the general section. This ledge is almost a shell breccia of *Atrypa aspera*, and is to be correlated with the upper part of number 1 in the Wresley quarries. *Favosites emmonsi*, *Acervularia davidsoni* and *Tentaculites hoyti* were found in the same ledges in a place close by. Occasional outcrops of the ledges of the old Hanson quarry occur in the south bank of the creek above this place, as far up as to the center of section 25, Tp. 78 N., R. I W.

On the Mississippi River, West of Pine Creek.—Returning to the Mississippi river we find small exposures of the Cedar Valley limestone in a few places close to the bank, between the mouth of Pine creek and the town of Fairport. Near the center of Sec. 30, Tp. 77 N., R. I E., the basal part of number 3 in Lowry's run section appears near the mouth of Schmidt's run. At Fairport some ledges which are not well seen in any of the previously described sections come out in the river bank and form the base of a shelf of land on which the town is built. The section is best made out near the west end, close to the kilns of the pottery works.

SECTION AT FAIRPORT.

		FEET.
8.	(*11*) Dolomitic limestone in ledges from 8 to 10 inches, rather hard, with casts of *Stropheodonta demissa* (very high and somewhat wider than the ordinary form), and of the calyx of a Zaphrentis..............	3
7.	(*10*) Thin layers of a hard, fine grained limestone, emitting a bituminous odor when struck with the hammer, containing, near the base, *Cranæna roemingeri*, *Orthothetes chemungensis*, *Stropheodonta demissa* (coarse costae), *Grammysia* (?), *Straparollus cyclostomus*, *Straparollus decewi*, Platystoma, *Pleurotomaria arata*, Gomphoceras, *Nautilus buccinum* (?), *Dipterus calvini*. A seam with frequent stylolitic surfaces separates this number from that below.....................	2¼
6	(*10*) Compact limestone charged with ramifying growths of a Peronella (Idiostroma)........................	1½
5.	(*10*) A thin seam of carbonaceous material.............	$\frac{1}{12}$
4.	(*10*) Limestone, frequently containing some large, laminated Stromatopora with small, dome-like elevations, or with a mammillated surface, also Amplexus (frequently semi-compound), and *Cladopora dichotoma* (?)	1
3.	(*9*) Dark and hard dolomitic limestone, with a Cyathophyllum and occasional Stromatopora...............	1½
2.	(*9*) A dark or black carbonaceous layer filled with a Stromatopora, with concentric wave-like rings......	¾
1.	Soft, bluish, dolomitic limestone, in somewhat heavier ledges than the numbers above, containing casts of *Orthis iowensis* (large forms), *Spirifer parryanus*, *Atrypa reticularis*, and *Stropheodonta demissa*........	2

Number 1 in this section extends down below low water in the river. It is number 5 in the Montpelier creek section. Numbers 3–8 are apparently represented by the uppermost

Stromatopora-bearing beds occurring in several places east of Pine creek.

West from Fairport to west of Wyoming Hill the Cedar valley is mostly hidden by the later rocks which run out almost to the bank of the river. Under Wyoming hill, at its west end, extending up a few feet above low water, is a limestone of a brown or yellow color, with casts of a few Cedar valley fossils. In Sweetland creek, near the center of section 27, eight feet or more of a hard, dolomitic, yellow limestone is seen in the left bank of the creek, under the Sweetland Creek shale. This consists of ledges from six inches to a foot in thickness. Close by it contains large, broken fragments of Stromatopora, and at various points *Spirifer parryanus*, *Stropheodonta perplana*, Zaphrentis (casts of calyx), and *Straparollus cyclostomus*. In the next creek two feet of the same ledges appear in the bank. In Campbel's run, which comes down from the bluffs near the west line of Sec. 21, Tp. 77 N., R. I W., there is a section equivalent in part to the one at Fairport. It is as follows:

		FEET.
6.	(*11*) Dolomitic, rather hard limestone, in regular ledges above, with occasional fragments of Stromatopora, especially frequent below	7
5.	(*10*) Bituminous, black, somewhat calcareous material, containing a large per cent of gas, oil and carbon (in all amounting to 60 per cent of one sample), and with occasional specimens of Stropheodonta with very coarse costæ	½
4.	(*10*) Compact, brittle limestone of a gray or dark gray color, emitting a bituminous odor when struck with the hammer, in ledges from six to ten inches, containing an Amplexus, the upper six inches being highly fossiliferous, and containing among other forms a Monticulipora (with unusually fine tubes), *Dielasma calvini*, *Cranæna romingeri*, *Conocardium altum*, *Athyris vittata* (with sinus and fold well marked), *Leptodesma rodgersi ?*	2
3.	(*10*) Limestone, like the above, containing Amplexus in greater frequency, and also *Straparollus cyclostomus*	1
2.	(*9*) Dark, carbonaceous layers, with imprints of a large Stromatopora	½
1.	(*9*) Blue, somewhat porous dolomitic limestone	1½

Not quite a mile west from here, in Geneva creek, there is a similar succession of ledges, which appears to extend a little higher up in the stratigraphic column. This runs as below:

		FEET.
10.	(*11*) Disintegrated or weathered limestone, with large, white fragments of Stromatopora and *Atrypa reticularis* (large)	3
9.	(*11*) Band of dark, bituminous, calcareous material	½
8.	(*11*) Blue, dolomitic limestone, somewhat porous	3
7.	(*11*) Dark limestone, with occasional lumps of Stromatopora	3
6.	(*10*) Gray limestone, emitting a bituminous odor when struck with the hammer, containing *Cranæna iowensis*, *Athyris vittata* (a flat form) and other fossils	½
5.	(*10*) Seam of black, bituminous material, containing a Stropheodonta with very coarse costæ	1/12
4.	(*10*) Dark, hard, somewhat dolomitic limestone, with occasional moulds of *Amplexus*, highly fossiliferous at top, with *Conocardium altum* and other lamellibranchia	1
3.	Not seen	2½
2.	(*9*) Black, carbonaceous layer, with Stromatopora of wavy, concentric structure	¼
1.	(*9*) Blue, soft, dolomitic, slightly porous limestone, with tubular impregnations of a deeper blue color, in ledges from six to eight inches in thickness, containing casts of *Spirifer parryanus*, *Atrypa reticularis* (a large form), *Orthis iowensis*, Bellerophon and Pleurotomaria	3

On Mad Creek.—The remaining localities where the Cedar Valley may be seen in the county are confined to Mad creek. Near the center of the west line of section 25, in Park Place Addition in north Muscatine, a few feet of an apparently brecciated limestone forms the bed of the creek. It contains occasional specimens of *Straparollus cyclostomus*, Stromatopora and Amplexus, and has in places a bituminous odor, noticeable when the rock is crushed. There are also seams of carbonaceous, dark limestone in some of the ledges. A mile farther north, and northwest of the center of section 24, there is in the bed of the creek a finely granular, dolomitic limestone, dipping at a low angle to the southwest. It consists of ledges some six inches in thickness, with faint traces of darker, cylindrical, fucoid markings, small nodules of pyrites and moulds of the valves of some brachiopods. Ten or fifteen rods farther up, the stream runs over some broken ledges like the highest number in the Geneva creek section.

The General Section.—To correlate the different numbers in the described sections is usually not difficult. Owing to differences in weathering there may be considerable variation in the appearance of the same ledges at different places; but the fossils present in each, the general lithological character of the several ledges, and the presence of peculiar structural features at some horizons enable us readily to recognize the larger divisions. Sometimes we may even recognize each separate ledge or layer at the different exposures, and know its position in the general succession, often to within the limits of a foot, or even an inch. For convenient reference a general section has been prepared, distinguishing eleven divisions into which the series may naturally be grouped, and indicating the horizons of the different fossils. In the local sections above figures are inserted referring each number to its place in this general section. (Plate VI.)

Some peculiar structures have been referred to and mentioned in the descriptions, consisting of vertical plates extending from the bases of some ledges into the rock below. These occur at three different horizons in the section, near or at the base of the Phillipsastrea (*2*) ledges, at the base of the Strombodes (*6*) ledges, and at the base of the Gomphoceras (*8*) ledges. These plates are usually about half an inch in thickness, coming to a blunt, somewhat thinned edge below. At the lowest horizon they are straight and do not extend very deep down the margin, making a gentle curve in the way of a segment of a circle, the vertical width decreasing, first slowly and then more rapidly, toward the two ends. Their length varies from two inches to a foot or more, and they intersect haphazard, no definite pattern being discernible in their arrangement. In the second horizon, at the base of the Strombodes-Athyris ledges, the vertical depth of the plates is often as much as four inches, exceptionally more, and they occur in intersecting radiating clusters, each plate usually terminating endwise in a vertical margin which may extend laterally farther out below than above. In some cases the edges of these plates exhibit small longitudinal flutings that suggest organic markings. At the highest horizon, under the base of the Gomphoceras ledges, there is a continuous network of plates, appearing less straight above and extending down six inches or more (Fig. 31). On some weathered slabs of these ledges the whole structure, superficially, has a slight resemblance to mud cracks. The plates at all three horizons consist of the same material as the rock in the ledges immediately above, from which they extend. In each case this is a limestone, full of fossils, almost a shell and coral breccia, and fragments of these fossils, exceptionally entire valves of brachiopods, make up a part of the substance of the plates. The rock into which the structures extend is at the two upper horizons of a compact limestone with few fossils, or none, in places having a texture reminding one of lithographic stone, and becoming somewhat dolomitic farther down. They seem thus to mark horizons of a twice or thrice repeated sequence of events in a period of Devonian history. In each case they mark a sudden change from conditions of deposition of fine calcareous sediments, in which we find sometimes a few brachiopods, to conditions of accumulation of great numbers of fossils in a sparse, calcareous matrix. Then followed in each case a slow and more gradual return to the previous conditions, which apparently also favored the process of submarine dolomitization, since the fine-grained sediments are found to be more or less dolomitic, especially above. A fourth repetition of the same sedimentary cycle is indicated in the two upper members of the section, and doubtful indications of the plate structure have been noticed near the base of the Stromatopora breccia. But at this level there occurs another change, which consists in the introduction of several lamellibranchia for a short space, indicating a more shallow sea, and this is accompanied by the accumulation of some bituminous material, the presence of which has a similar import. This may be looked upon as an event in a greater cycle, and would naturally modify or obscure the incidents of the smaller one.

Distribution.—The Fayette breccia, consisting of the four lower members of the general section, forms a crescentic belt of unknown width (south of the Otis and Independence, if these occur in the county), entering the county somewhere to the northwest, in Wapsinonoc or in Goshen townships, and extending east under parts of Moscow, Wilton, Fulton, and probably also under some of the northern sections in Pike, Lake, Bloomington and Sweetland townships, where preglacial erosion is deep. The drift over this region is thick, and the only exposures known are in Secs. 3, 5, 6 and 8, in Tp. 78 N., R. II W., in Secs. 23, 27 and 34, Tp. 78 N., R. I W. Bowlders of it occur as the main ingredient in a drift gravel west of Stockton, indicating its presence close by that place.

The Cedar Valley limestone forms a broad belt to the south of this. It most likely underlies the greater part of Wapsinonoc, Pike, Lake and Fruitland townships, and may possibly extend into Orono, Cedar and Seventy-Six. When not overlain by later formations it constitutes the bed rock in Bloomington, Muscatine, Sweetland and Montpelier townships, and the south part of Fulton. In the six first named townships not a single outcrop is known, owing to the deep drift there, and in the five last named townships it is for the most part covered by the Des Moines, coming into view only along the river and farther north in the valleys of Pine creek, Mud creek and Sulphur branch. A narrow strip of it most likely follows the north margin of the area covered by the Des Moines in these townships.

SWEETLAND CREEK BEDS.

In Muscatine, Bloomington, Sweetland and Montpelier townships some argillaceous beds are frequently found overlying the Cedar Valley limestone. These contain a fauna quite different from that of the latter, and are unconformable with this as well as with the coal measures above. For reasons which will presently appear it is proposed to call them the Sweetland Creek beds.

Typical Exposures.—Following the north bluff of the Mississippi westward, the first occurrence of these beds is to be seen in the bank of a creek which comes down from the north, east of the town of Montpelier. About twenty rods north of the bluffs the basal sandstone of the coal measures rests on some olive-gray shale, with green bands, rising about three feet from the bed of the stream in the right bank. This shale is altogether unlike the dark shale of the coal measures in appearance. The layers are more even and uniform. An unconformity between the two is also evident, and the lower formation soon disappears. In the river bluff the same creek is undermining a cliff of coal measure rock, which rests on the Cedar Valley limestone for the greater part of its length, but at the south end the base of the coal measures rises somewhat abruptly, first on an eroded slope of the limestone, and then over some decayed yellow clayey beds which intervene and run up ten or twelve feet above the limestone. The present condition of the bank does not afford an opportunity to study closely the nature of the clay beds, but in all probability they belong to the same strata as the shale above.

To the west of the town, a short distance up Robinson creek, and northwest of Mr. G. W. Robinson's residence, some green clay is seen in the south bank of the creek, apparently resting on the eroded surface of the Cedar Valley limestone. At the base of this clay there is a thin layer of more stony material, and this contains specimens of *Ptyctodus calceolus* and small teeth of other fishes. This is the basal layer of the

Sweetland Creek beds. About one-half mile further up the same creek, near the north line of section 23, Montpelier township, below a small fall in the creek, the following section is seen:

		FEET.
13.	Coal measures.	
12.	Dark bituminous shale with two or three bands of green shale; the dark next the green exhibiting a complex network of thread-like green extensions from ½ to 2mm. in thickness, lying approximately parallel with the bedding. Occasional lingulas found	1
11.	Dark bituminous shale with small spheroidal crystalline nodules of pyrites, occasional lingulas and *Spathiocaris emersoni*	2
10.	Concealed (next number a few rods farther down)	2 ?
9.	Light greenish shale	1
8.	Dark olive-gray shale	2/3
7.	Green shale	3/8
6.	Greenish calcareous shale, almost stony, containing cylindrical or flattened fucoid markings slightly more greenish than the matrix	5/6
5.	Dark gray shale	1
4.	Grayish-green pyritiferous rock with minute fragments of unrecognizable fossils	¼
3.	Dark gray shale	¼
2.	Greenish-gray, somewhat stony shale, exhibiting concretionary conchoidal fractures when weathered	¼
1.	Greenish-gray argillaceous and pyritiferous fine-grained dolomitic rock in layers a few inches in thickness, with fucoid impregnations or markings like those in number 6, ¼ inch in diameter	1 3/8

At the south end of this outcrop there is a small displacement in the ledges, which, dipping at a considerable angle south of it, soon disappear under the coal measures. The displacement is no doubt local and probably due to the falling in of some cavern in the underlying limestone.

Westward for the next three miles these beds do not appear, although the contact between the coal measures and the Cedar Valley limestone frequently comes into view. In the Pine creek basin they must have been removed by erosion previous to the deposition of the coal measures. Their next appearance is in Schmidt's run, about a mile east from the railroad station at Fairport. North of the wagon road, under the bluffs, they may be seen in the left bank of the run. There are several outcrops farther up, and the following section was made out, unconformably overlain by the coal measures:

		FEET.
4.	Dark, almost black shale, with green seams from 1 to 4 inches thick, near which the darker shale exhibits a network of filamentous extensions of green clay...	7
3.	Greenish, light-colored shale..........................	3½
2.	Greenish, stony and hard shale.........................	½
1.	Greenish, gray, soft shale.............................	1½

Just west of the railroad station at Fairport, where a wagon road follows a ravine up the bluff, this ravine exposes the following section:

		FEET.
7.	Coal measures, resting unconformably on the numbers below.	
6.	Weathered shale, of alternate light and dark layers....	5
5.	Dark gray shale..	5
4.	Grayish-green shale, with two bands of darker shale in part perforated by coarse, curving filaments or cylinders of green shale..............................	3
3.	Concealed	2?
2.	Dark gray shale, with curving, cord-like cylinders of green shale, about ⅙ inch in diameter...............	3
1.	Greenish, argillaceous dolomite, in layers about 6 inches in thickness.......................................	1

In a small ravine which comes down from the west side of Wyoming hill there is seen, under and north of the wagon bridge, about eight feet of gray and green shale, with some stony layers. The Cedar Valley limestone comes out in the river bank just below and the coal measures overlie the exposure, rising about 100 feet above it.

Along Sweetland creek the relation of these beds to the formations above and below them is better exhibited than at any other place in the county. About one-third of a mile north from the river bank they come out into view on both sides of the creek, and they are also seen in a small tributary which runs into the creek from the east. Combining all the exposures at this point the following succession of separate layers is evident:

		FEET.
11.	Dark gray bituminous shale, with one or two thin, green bands about 4 feet below the highest exposure. Occasionally small, flat concretions of pyrites are seen. Next the green layer the shale is dark, filled with a maze of fine green filamentous lines. Drift overlies	8
10.	Dark shale, containing lingulas, *Spathiocaris emersoni*, Rhynchodus, and a fossil resembling *Solenocaris strigata*. This number is continuous with No. 11	$1\frac{1}{3}$
9.	Greenish clay, with flat concretions of iron pyrites, frequently having white, stony lamellar extensions from the margin	3
8.	Dark shale	$\frac{2}{3}$
7.	Greenish, stony shale, with a conchoidal concretionary fracture	$\frac{1}{3}$
6.	Hard, light grayish-green shale, with white, flattened, cylindrical fucoid concretions of a concentric structure in horizontal positions	$\frac{1}{4}-\frac{1}{2}$
5.	Greenish, argillaceous or arenaceous, fine grained dolomite, in ledges from 4 to 10 inches in thickness, with occasional lingulas and a fragment of a cast of a gasteropod near the base, frequently exhibiting small, cylindrical, concretionary impregnations of a deeper green, and occasionally impressions of plant-like fibrous structure covered with a thin layer of bituminous material	3
4.	Greenish shale	$1\frac{1}{3}$
3.	A stony seam filled with finely granular pyrites, and occasionally showing larger lumps of the same mineral, in one instance associated with plant like fibrous impressions, frequently containing rounded, worn fragments of fish teeth	$\frac{1}{12}-\frac{1}{4}$
2.	Green, hard shale	$\frac{2}{3}$
1.	Greenish stony layer, with frequent, mostly rounded fragments of teeth of *Ptyctodus calceolus*	$\frac{1}{3}$

Under the lowermost layer containing fish teeth, the uneven surface of the upper ledges of the Cedar Valley limestone is seen, and at least eight feet of this rock is exposed. In some of the shallow depressions in its upper surface a seam of black bituminous material is found. At one point this forms a layer two inches in thickness. Near the south end of the exposure farthest down the creek, the upper beds come down over the uppermost ledge of the limestone, which runs out as if worn away. The surface of the limestone has been partly uncovered. It is brown in color, uneven from erosion and frequently studded with nodules of iron pyrites or covered by a continuous incrustation of the same mineral. In the west bank of the creek the basal sandstone of the coal measures overlies the eroded edges of numbers 6, 7 and 8 in the above section, which rise under it in a hillock (Fig. 1, plate V). In the gully to the east the section is continued higher up and the coal measures do not appear. Some distance farther up Sweetland creek they are again seen unconformably overlying the dark gray shale in the east bank, with erosion contours extending down three feet into the lower formation. At this place the basal conglomerate contains rounded lumps of the dark shale, three or four inches in diameter. Still farther up the creek the darker shale, corresponding to number 11 in the above section, appears at several places in the bed of the stream, rising in one instance about five feet in the bank. The last seen is about 100 paces south from the wagon bridge near the north line of section 27. In each of these places the characteristic green layers with their accompanying network of green threads in the confining dark shale may be seen.

About three-fourths of a mile west of Sweetland creek, near the east line of section 28, in Sweetland township, a smaller stream exposes the following section:

		FEET.
5.	Coal measures.	
4.	Alternate layers of dark and greenish shale...........	4
3.	Fine grained, light yellowish-gray, impure dolomite in thin ledges....................................	2½
2.	Greenish shaly rock with a thin, harder layer below..	2½
1.	Upper ledges of the Cedar Valley limestone, ferruginous and worn superficially............	1-2

In Campbel run, which comes down to the river through the northwest corner of section 21, in the same township, a similar succession of layers is seen at the point where the stream passes the line of the river bluffs (Fig. 2, plate V). The following section appears very clearly:

		FEET.
11.	Base of the coal measures.	
10.	Dark gray shale with lingulas near the base	3
9.	Greenish shale	$3\frac{1}{2}$
8.	A layer of harder, almost stony, shale	$\frac{1}{2}$
7.	Greenish-gray shale weathering with a conchoidal fracture into small spheroidal nodules and chips	$1\pm$
6.	Grayish, fine grained, impure dolomite	$1\frac{1}{2}$
5.	Greenish shale	$1\pm$
4.	A thin and stony, in places highly pyritiferous, seam associated with small selenite crystals when decayed, in places almost filled with rounded fragments of the tritors of *Ptyctodus calceolus*	$\frac{1}{10}-\frac{1}{5}$
3.	Greenish shale	$\frac{1}{2}-1$
2.	Greenish fine grained rock with fish teeth	$\frac{1}{6}-\frac{1}{4}$
1.	Upper ledges of the Cedar Valley limestone with a slightly eroded surface, frequently covered with pyrites.	

Number 10 in the above is seen in two or three places farther up in the creek, but it soon disappears under the base of the coal measures.

Along Geneva creek, in the northwest quarter of section 29, in the same township, the basal layers of the preceding sections are seen in the bed of the stream opposite the Geneva schoolhouse, and below the wagon bridge. The main stony ledge forms the bed of the creek for a distance of ten or twenty rods a quarter of a mile farther up. About half a mile north of the schoolhouse the shale above this ledge rises some six feet in the west bank, and is overlain by the basal conglomerate of the coal measures, from which a small spring issues. Combining these exposures the succession of the layers may be given as in the following section:

		FEET.
13.	Basal conglomerate and sandstone of the coal measures.	
12.	Dark gray and ferruginous, evidently somewhat disintegrated dark shale.	$\frac{4}{5}$
11.	Light greenish-gray shale	$\frac{4}{5}$

		FEET.
10.	Dark lavender colored shale	$1\frac{1}{6}$
9.	Green shaly rock	$\frac{1}{2}$
8.	Concealed	?
7.	Green rock in even thin layers with regular vertical rather equidistant joints	$1\frac{1}{2}$
6.	Concealed	?
5.	Greenish shale (opposite the schoolhouse)	1
4.	Pyritiferous green stony layer with cylindrical straightish fucoid impregnations	$\frac{2}{3}$
3.	Green shale	1
2.	A conglomerate of fish teeth, containing *Ptyctodus calceolus* and Synthetodus frequently in a worn condition and imbedded in a greenish argillaceous fine grained dolomite	$\frac{1}{4}$
1.	Beds of the Cedar Valley limestone containing large fragments of Stromatopora, with the upper surface unevenly eroded.	

From this point westward no more is seen of the beds under consideration until we come to East Hill, in Muscatine. Under the south bluff of this hill the railroad bed has been excavated in the upper dark shale seen in the foregoing sections. These shales rise here about thirty feet above the bed of the road, and they have been so disposed to slip, that piles and a stone wall have for many years been needed to keep the embankment from coming down on the track. These were removed late last fall and the face of the embankment was cut away several feet. This work left the shale well exposed. The section above and below the railroad bed is as follows:

		FEET.
2.	Dark or gray bituminous shale, with three parallel bands of green shale a few inches in thickness and about three or four feet apart, weathering into fine chips of a yellowish light-gray color, containing small flat concretions of pyrites, joints in some of the freshly exposed shale filled with numerous small crystals of selenite disposed in branching patterns, the basal part containing a lingula and exhibiting the peculiar network of green thread-like extensions observed in previous sections near the transitions to green shale	36
1.	Green shale	2

The top of number 2 is unconformably overlain by the coal measures, and has evidently been weathered previous to their deposition. Below number 1 the section is concealed in the river bank. The base of this layer is about ten feet above low water. There is little doubt that it is the equivalent of number 9 in the Sweetland creek section, and the lower layers of these beds may possibly all have been exposed above water at this point before the railroad embankment was made. As these lower layers aggregate about seven feet in thickness at other places, it will be noticed that the extreme thickness of the whole formation at this place is about forty-five feet. This is the greatest thickness that has been seen anywhere in the county.

Just above the wagon bridge which crosses Mad creek near the center of the northwest quarter of section 24 in Bloomington township, some ledges equivalent to numbers 6, 7, 8 and 9, in the Sweetland creek section, appear in the bank of a tributary from the east. Again in the creek running east through the north half of the northwest quarter of section 26 in the same township some thin ledges of rock and some green shale corresponding to numbers 3, 4 and 5 in Sweetland creek come into view from under some coal measure beds.

Geographical Distribution.—So far as known, the above places include all the exposures of the Sweetland creek beds in the county. There is good reason to assume that they underlie the coal measures in most of Muscatine, Bloomington and Sweetland townships, and that scattered outliers occupy the same position in the east half of Montpelier township. In all probability their outcrop in the river bluff is continuous from Wyoming Hill to Muscatine, though mostly concealed by the talus under the bluffs.

General Section.—The separate layers and ledges of the formation have a remarkably uniform development, varying but slightly in different places. The basal layer, though only about three inches in thickness, can always be recognized in its place, and invariably contains the characteristic fish teeth.

FIG. 32. Thread-like extentions of green shale, in the dark layers of number 4, in the general section of the Sweetland Creek Beds.

From six inches to a foot above this layer there is a pyritiferous stony seam from one-half to two inches in thickness, and this is readily identified in all the creeks in Sweetland township, where the lower part of the section appears. The peculiar maze of green threads which extend into the dark shale, where this comes into contact with green layers, have been observed in almost every case where they are due in the section, all the way from Muscatine to Montpelier. It is, therefore, no very difficult task to combine the local outcrops into a general section.

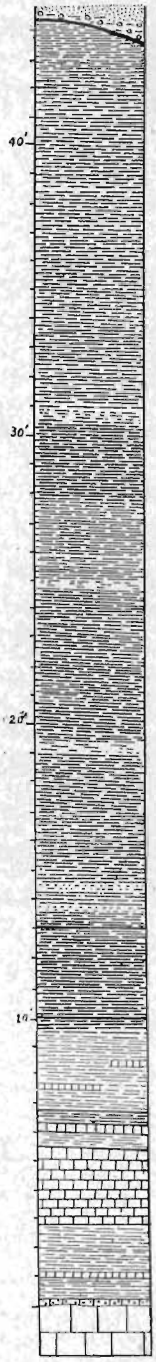


FIG. 33. General section of the Sweetland Creek Beds.

GENERAL SECTION OF THE SWEETLAND CREEK BEDS.

		FEET.
7.	Dark bituminous shale, occasionally containing small flat concretions of iron pyrites, with three thin bands of greenish shales respectively about 5, 9 and 12 feet from the base	33
6.	Dark shale, with thin seams of blue shale, the dark containing two species of lingula. *Spathiocaris emersoni*, Rhynchodus, and a fossil resembling *Solenocaris strigata*	3
5.	Greenish shale, with occasional stony layers, containing flat concretions of pyrites frequently bordered by lamellar marginal extensions of a white dolomitic material	3½
4.	Alternating layers of greenish stone and dark shale, the latter in part containing a network of threadlike extensions (Fig. 32), of the former. The green shale has elongated flattened concretions resembling fucoidgrowths and lying parallel with the bedding. The stony layers are frequently charged with small grains of pyrites and contain minute fragmentsof fossils	2
3.	Greenish fine grained argillaceous magnesian lime stone impregnated with iron pyrites and calcium phosphate, in ledges from 4 to 10 inches in thickness, with cylindrical fucoid impregnations slightly more greenish than the matrix and from 3 to 6 millimeters in diameter, containing two species of lingula, a fragmentary cast of a helicoid gasteropod, and imprints of some fibrous structure like that of some plant stem	3½
2.	Hard greenish-gray shale, with a stony pyritiferous layer that contains fish teeth and impressions of vegetable tissue about 10 inches from base	3
1.	Argillaceous dolomitic stony layer containing *Ptyctodus calceolus* and other forms resembling Synthetodus	¼

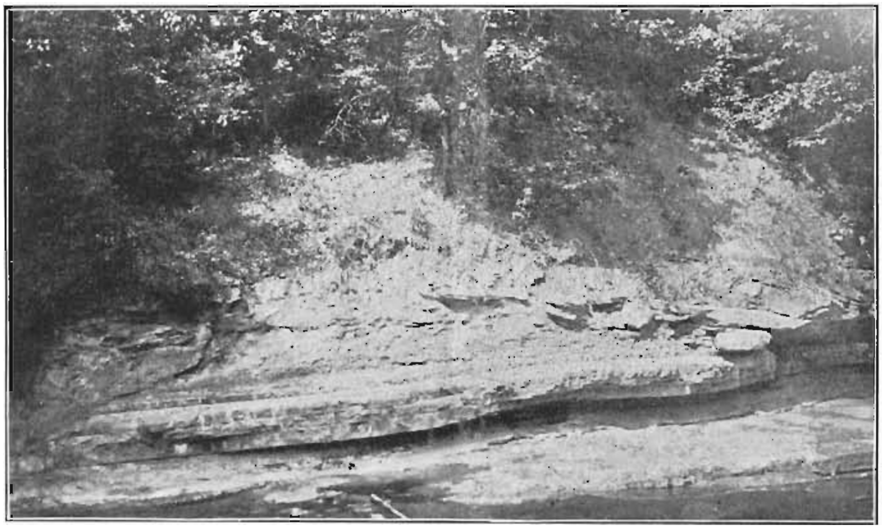


FIG. 1. Sweetland creek beds with coal measure sandstone uncomformably above, and Cedar valley limestone below. *5*, coal measure sandstone; *4*, variable beds of the Sweetland creek shale, No. 4 of the general section; *3*, stony ledge, No. 3 of general section; *2*, greenish-gray shale, No. 2 of general section; *2'*, pyriteferous seam in No. 2; *1*, basal layer, No. 1 of general section, containing fish teeth, and resting on oxidized surface of Cedar valley limestone. Exposure on Sweetland creek, center Sec. 27, Twp. 77 N., R, 1, W.

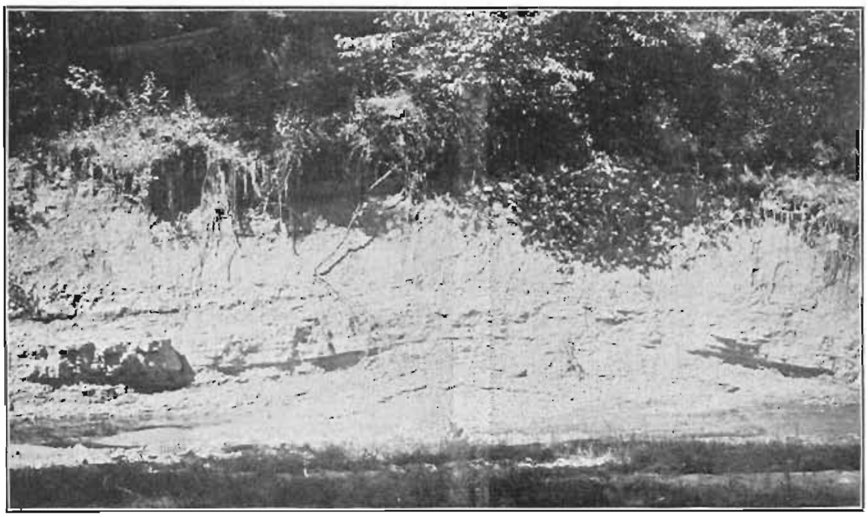


FIG. 2. Sweetland creek beds, unconformable on Cedar valley limestone, Campbell's run, SW. Sec. 21, Twp. 77 N., R. 1., W. *5*, variable beds of the Sweetland creek shale, No. 4 of the general section; *4*, stony ledge in Sweetland creek beds; *3*, greenish-gray shale, No. 2 of general section; *3'*, pyriteferous seam; *2*, basal layer with fish teeth; *1*, eroded surface of Cedar valley limestone.

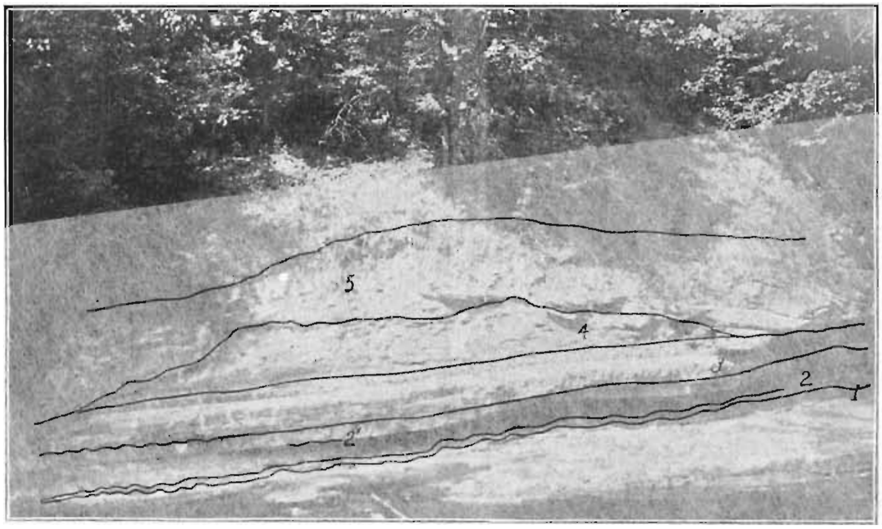


FIG. 1. Sweetland creek beds with coal measure sandstone uncomformably above, and Cedar valley limestone below. *5*, coal measure sandstone; *4*, variable beds of the Sweetland creek shale, No. 4 of the general section; *3*, stony ledge, No. 3 of general section; *2*, greenish-gray shale, No. 2 of general section; 2', pyriteferous seam in No. 2; *1*, basal layer, No. 1 of general section, containing fish teeth, and resting on oxidized surface of Cedar valley limestone. Exposure on Sweetland creek, center Sec. 27, Twp. 77 N., R. 1, W.

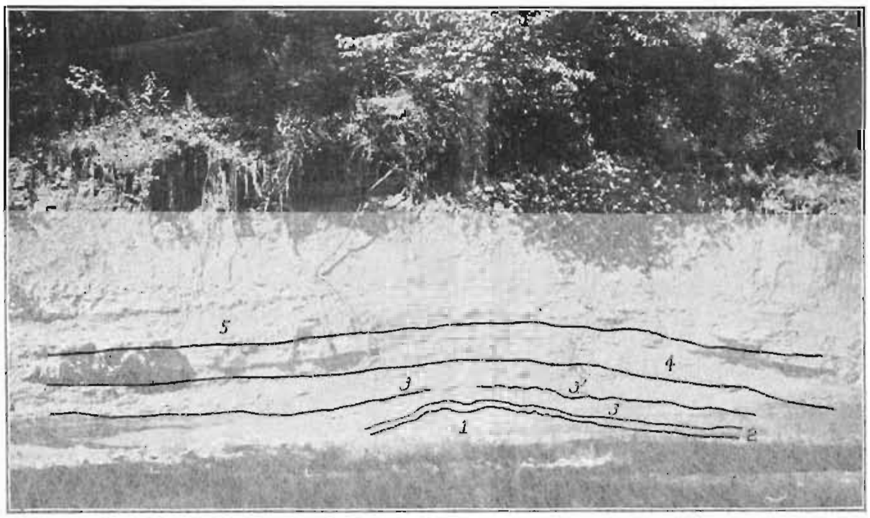


FIG. 2. Sweetland creek beds, unconformable on Cedar valley limestone, Campbell's run, SW. Sec. 21, Twp. 77 N., R. 1., W. *5*, variable beds of the Sweetland creek shale, No. 4 of the general section; *4*, stony ledge in Sweetland creek beds; *3*, greenish-gray shale, No. 2 of general section; *3'*, pyriteferous seam; *2*, basal layer with fish teeth; *1*, eroded surface of Cedar valley limestone.

Lithological Peculiarities.--The greenish ledges turn grayish-yellow on weathering. The main stony ledge, number 3, often protrudes as a shelf over the clay below it, which is more easily removed by erosion. In two instances an efflorescence of epsomite was noticed forming on the face of the clay thus protected from rain by the overhanging rock. The material found in the shells of the lingulas of this ledge was unaltered, but in one instance slightly dissolved away. The tubular impregnations in the stony layers of the formation appear to be marked off from the mass of the rock so as to sometimes weather out like casts of fucoid stems. In other instances they appear like slightly more colored parts of the rock. The thread-like extensions of green clay, which form a network in the dark shale at some horizons where it comes in contact with the lighter shale, vary in coarseness at different places. There is nothing to indicate a structural boundary between the green in the threads and their dark matrix, and there is hardly anything to suggest that they have an organic origin. It seems more likely that they have resulted from some progressive change in the mineral nature of the shale. Excepting the lingulas the fossils which occur in the layer numbered 6 in the general section are all of a black and bituminous substance, which is apt to break and fall out in drying, leaving only a mold. The dark shale in numbers 6 and 7 is fine and very uniform in character. Occasionally it is difficult to distinguish from the coal measure shale, but the latter usually contains small mica scales, which are absent from the former. Where not weathered these beds contain a considerable amount of bituminous material, which on distillation yields inflammable gas and oil. The several layers of the formation have been examined for phosphate by Dr. J. B. Weems, who finds 2.01 per cent of calcium phoshhate in number 7,1.94 per cent in number 6, 2.09 and 2.18 per cent respectively in two analyses of material from number 5, 3.18 per cent in number 4, 6.82 and 5.29 per cent respectively in two analyses of material from number 3, 5.43 per cent in number 2, and 4.86 per cent in number 1.

Structural Relations.—As already shown, a pronounced unconformity separates this formation from the overlying coal measures. The erosion interval preceding the deposition of the latter has left its marks, not only in the reliefs which extend from the top of these beds to a considerable distance below their base into the underlying limestone, but also in the weathering of the Sweetland Creek beds, especially where these rise high. In such places the lamination appears indistinct, and the shales are oxidized and leached. After the deposition of the Sweetland creek beds they were raised and subjected to erosion and sculpturing, which no doubt removed the greater part of them. Only remnants are left. Then, again, the land was submerged, and the topography just sculptured was covered over by the variable shore deposits of the coal measures.

It has also been shown that there is an unconformity with the underlying Cedar Valley limestone. But this unconformity indicates altogether different conditions. The upper formation is, in this case, not a shore deposit. The basal member of the Sweetland Creek beds is a thin layer of argillaceous dolomite, containing no littoral detritus, and it is unusually uniformly developed, though only two or three inches thick. It is a sediment made in the sea at such a slow rate that the teeth of dying fishes accumulated rapidly enough to make at one place as much as one-fourth of its bulk. This layer follows the small inequalities in the surface of the lower rock like a mantle. None of these are very high or deep. On a distance of a few rods none appear to exceed two feet in vertical extent. Near the Geneva school the basal tooth-bearing layer appears to occupy a place eight feet lower than the highest ledge in an abandoned quarry close by. The surface of the limestone is, however, plainly eroded, and apparently to some extent oxidized. In the east bank of Sweetland creek the highest ledges of the limestone run out to the south, and the overlying formation comes down over their beveled edges. An unconformity of this kind is most likely caused by subaqueous erosion, due to marine currents, followed by renewed sedimentation in the same sea. Such events may have been accompanied by an approach of the shore line. This is, perhaps, indicated by the presence of faint traces of vegetation in the later member in this case. But at the very beginning of the second accumulation the shore was not near enough to leave a trace of anything coarser than clay. Even this was scarce at first, when calcareous sediments predominated. The persistence of each thin layer over distances of several miles goes to show that the conditions under which they were laid down were uniform over wide areas, and such conditions are not to be found in the proximity of the shore line. Everything considered, this unconformity was most likely caused by changed conditions in the sea and its currents, in all probability consequent upon some orogenic movements affecting the ocean basin.

Fossils.—The fossils so far found in this formation are few, but they are many enough to indicate that it must be referred to the Upper Devonian or the Chemung. The fibrous plant-like impression from number 3 was found extending over a slab a foot long and about three inches wide. In the pyritous layer in number 2 there was a similar, much smaller, impression. The mold in both instances was covered by a bituminous crust an eighth of an inch in thickness. In this no organic structure could be detected. The lingulas which occur in numbers 3 and 6 have been submitted to Dr. Charles Schuchert, who says that one species is apparently identical with an undescribed species from nodules in the "Black Shale," or the Genesee; one is related to *L. melie* Hall, from the Cuyahoga shale, and another to *L. nuda* Hall, from the Hamilton. The author has also observed one lingula in number 6, which resembled *L. subspatulata* M. and W. Some small bilobate fossils from the same number in the general section have been examined by Dr. J. M. Clarke, who has reported that they are identical with *Spathiocaris emersoni* Clarke. This fossil occurs in the Portage group, in New York, and has not previously been reported from the west. In the same layer the author found one fossil which resembled *Solenocaris strigata* Meek. This form is known to occur in the "Black Shale" of the Ohio valley. The cast of a gasteropod found in the stony ledge, number 3, was too fragmentary for more exact determination. Dr. C. R. Eastman has examined all the fish remains found, and states that the greater number of the teeth from numbers 1 and 2 are *Ptyctodus calceolus* M. and W. He finds them on the average smaller than usual, but in other respects perfectly like the type. He also reports that there are several other forms of flat, crushing teeth, which are allied to Synthetodus from the State Quarry fish bed in Johnson county. From the bituminous, dark shale, number 6, he identifies a Rhynchodus, related to *R. excavatus* Newb., from the Hamilton in Wisconsin.

LIST OF FOSSILS IN THE SWEETLAND CREEK BEDS.

Lingula, sp. undet.	Identical with one from the Black Shale
L. cf. melie Hall	Cuyahoga Shale
Lingula, cf. nuda Hall	Hamilton
Lingula subspatulata M. and W. (?)	Black Shale
Spathiocaris emersoni Clarke	Portage Shale
Solenocaris strigata Meek (?)	Black Shale
Ptyctodus calceolus N. and W.	Hamilton and State Quarry Beds
Rhynchodus, cf. excavatus Newb.	Hamilton
IMPRESSION OF PLANTS.	
Synthetodus	State Quarry Beds
Gasteropod.	

Additions will no doubt be made to this list. As it is, it indicates a correlation with the Upper Devonian of New York, and more particularly with the Devonian Black Shale of the interior, which also is regarded as a part of the Upper Devonian. To this shale it shows another resemblance in having the basal layers stony and containing a comparatively high per cent of calcium phosphate, while the upper part is a black shale. It will be remembered that in Perry and Hickman

A GENERAL SECTION
OF THE
CEDAR VALLEY AND THE WAPSIPINICON STAGES IN MUSCATINE COUNTY, IOWA,
WITH A
TABLE OF FOSSILS, REFERRED TO HORIZONS WHERE THEY HAVE BEEN OBSERVED.

11 *Stromatopora breccia.* Hard, gray limestone, in part blue and dolomitic, with occasional hollow molds of corals and sometimes large fragments of stromatoporas, ledges from 6 inches to 1 foot in thickness, 8 feet.

10 *Straparollus ledges.* Fine-grained limestone, in part dolomitic, ledges from 3 inches to 1 foot, carbonaceous or bituminous black seams above and below, where it is rich in fossils, occasional stromatoporas, 5 feet.

9 *Main Dolomite.* Blue dolomite, weathering yellow, of an even texture and with a conchoidal easy fracture, frequent molds of fossils, lower ledges over 2 feet thick, 9 or 10 feet.

8 *Gomphoceras ledges.* Tough calcareous gray limestone in heavy ledges which split on weathering, full of fossils, with a network of vertical plates extending into the rock below, 5 feet.

7 *Cystodictya ledges.* Somewhat dolomitic (at least below), blue or light gray limestone of a uniform texture becoming calcareous and fine grained above, fossils usually not removed by solution, occasional joints of crinoid stems above, 6 feet.

6 *Strombodes ledges.* Hard calcareous rock full of corals and brachiopods, sometimes weathering into a marl-in irregular ledges which split on weathering, occasionally brecciated and mingled with the beds below, branching vertical plates of the material in the lower ledge extending down into the next member, 8 feet.

5 *Megistocrinus bed.* Calcareous, somewhat shelly or brittle rock, without definite ledges, containing numerous joints, of crinoid stems, 5 feet.

4 *Spirophyton–Scitulus beds.* Somewhat brittle and slightly argillaceous blue limestone with oblique joints, occasionally slightly brecciated, usually with many brachiopods in a fine-grained matrix, weathering rather rapidly, 17 feet.*

3 *Vanuxemii beds.* Alternate ledges of limestone and marly or clayey ledges, with more corals than the beds above, 5 feet.

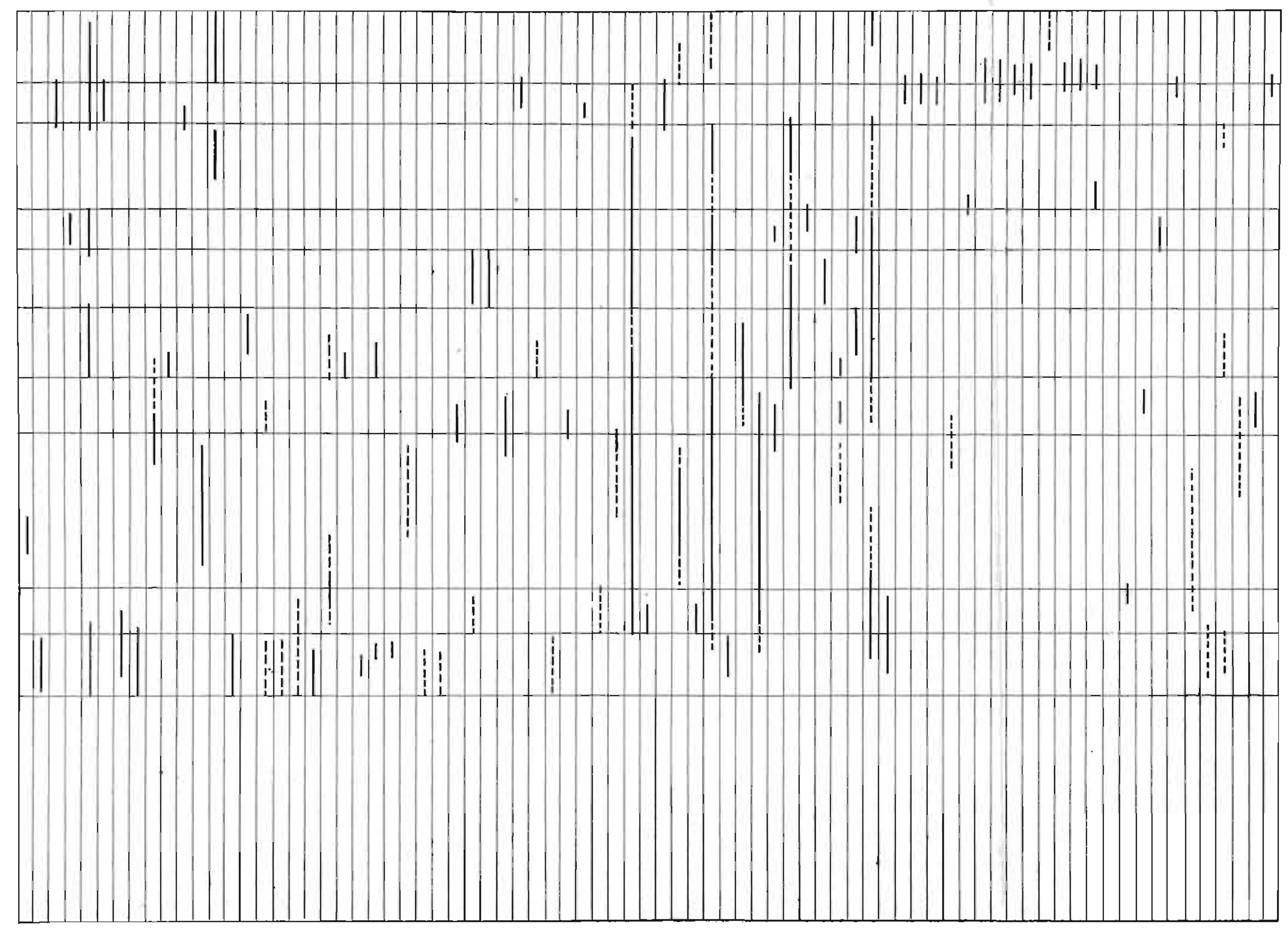
2 *Phillipsastra beds.* Tough, gray limestone in heavy ledges, full of corals and brachiopods, vertical lamellar extensions from the lower surface of some ledges at or near the base, 7 feet. It is at the base of this bed that Calvin draws the line between the Wapsipinicon and Cedar Valley stages.†

1 *Basal breccia.* Fine-grained, compact, very pure limestone, frequently brecciated, destitute of fossils, emitting a faint bituminous smell when struck with the hammer, exposed in the county 25 feet.

* Nos. 3 and 4 are the *megistocrinus farnsworthi* beds of Johnson county. The *spirifer pennatus* beds of Calvin, Geology of Buchanan county, are stratigraphically equivalent to No. 1 of this section. S. C.

† The beds immediately below the *Phillipsastræa* horizon are very rich in fossils in Buchanan county, and constitute the *spirifer pennatus* beds of Calvin. See report on Buchanan county, Iowa Geol. Survey. Vol. VIII. S. C.

Shirophyton structures.
Astræospongea hamiltonensis W. and W.
Stromatopora (concentrica goldf.?)
Stromatopora (reniform).
Stromatopora (all kinds).
Idiostroma (Peronella)
Favosites alpenensis Winch.
Favosites placenta Rom.
Favosites emmonsi Rom ?
Alveolites goldfussi Billings.
Amplexus
[Streptelasma rectum Hall.]*
Zaphrentis (casts of calyx).
[Chonophyllum magnificum Billings.]
Ptychophyllum.
Aulacophyllum.
Cyathophyllum.
Heliophyllum halli E. and H.
[Diphyphyllum archiaci Bill.]
Acervularia davidsoni E and H.
Strombodes.
Phillipsastræa billingsi Calvin.
Cystiphyllum americanum E. and H.
[Cystiphyllum sulcatum Billings.]
[Elæacrinus elegans Conrad.]
[Stereocrinus triangulatus Barris.]
[Dolatocrinus.]
[Megistocrinus latus Hall.]
Spirorbis.
Cystodictya (near hamiltonensis Uhlr.).
Monticulipora monticula White.
Monticulipora (very fine cells).
Fistulipora.
Fistuliporella.
Cladopora iowensis.
Cladopora dichotoma Hall.
[Orbiculodea.]
Chonetes scitulus Hall.
Orthis iowensis Hall.
[Orthis vanuxemi Hall.]
Orthothetes chemungensis.
Stropheodonta perplana Conrad.
[Pholidostrophia nacrea Hall.]
Stropheodonta demissa Conrad.
Spirifer subundiferus M and W.
Spirifer asper Hall
Spirifer pennatus Owen.
Spirifer subvaricosus Hall and W.
Spirifer parryanus Hall.
Cyrtina curvilineata White.
Cyrtina hamiltonensis var. recta Hall.
Cyrtina umbonata Hall.
Athyris vittata Hall.
Atrypa reticularis L.
Atrypa aspera Schlotheim.
Cranæna romingeri Hall.
Dielasma calvini Hall?
Cranæna iowensis Calvin.
[Avicula.]
Paracyclas lyrata Conrad.
Conocardium altum Keys.
Grammysia.
Leptodesma rodgersi Hall.
Pleurotomaria arata Hall.
Bellerophon.
Straparollus decewi?
Straparollus cyclostomus Hall.
Platystoma.
Platyceras rectum,
[Tentaculites hoyti White]
[Gomphoceras abruptum Hall?]
Gomphoceras ajax Hall?
Nautilus buccinum Hall?
[Goniatites]
[Phacops bufo Green]
Ptyctodus calceolus M. and W.
[Heteracanthus uddeni Lindahl]
[Dinichthys pustulosus Eastman.]
Dipterus calvini Eastman.



* Species in brackets have not been observed in Muscatine county, but are known to occur at the indicated horizons not far beyond its limits.

counties, in Tennessee, the Black Shale changes downward into the phosphate rock.*

This comparison may be better shown in tabular form.

RELATION OF DARK SHALE TO PHOSPHATE-BEARING ROCK IN IOWA AND IN TENNESSEE.

IOWA.		TENNESSEE.
Bed No. 7 contains 2.01% of phosphate	Dark Shale.	Black Shale, containing little or no phosphate.
" " 6 " 1.94% " "		
" " 5 " 2.13% " "		
" " 4 " 3.18% " "	Variable Beds. Greenish-gray pyritiferous rock and shale.	Light gray to bluish-black phosphate rock, with disseminated pyrites.
" " 3 " 6.05% " "		
" " 2 " 5.43% " "		
" " 1 " 4.86% " "		

The indicated correlation appears all the more probable, as there exists under the phosphate-bearing rock in Tennessee an unconformity, which is believed to be due "not to the existence of a land area and subaerial erosion, but rather to non-deposition, by reason of strong marine currents."† The renewal of the conditions of sedimentation in the Paleozoic sea in the late Devonian age may not have been quite simultaneous in the two localities, though nothing is known to indicate the contrary, but there seems to have been at any rate a parallel in the sequence of events.

CARBONIFEROUS.

During the time of the deposition of the rocks of the Lower Carboniferous series farther south, Muscatine county was above water, at least for a time which was long enough wholly to remove any materials that might have been laid down in the first stages of the period. The earliest rocks which appear after the Upper Devonian are those of the Des Moines stage of the Upper Carboniferous.

DES MOINES.

In the south half of the east end of the county there is a part of an outlier of the Upper Carboniferous, which is cut

*See the Tennessee Phosphates, by C. W. Hayes. Seventeenth Ann. Rep. U. S. Geol. Surv., Part II.

†Loc. cit., p. 534.

off from the north margin of the Illinois coal field by the valley of the Mississippi river, and extends into Scott county on the east. The materials of which it is composed are very variable, consisting of conglomerate, sandstone, shale, fire clay, coal, and limestone. These change in short distances, and local sections present great differences.

The point farthest west where these rocks have been observed is in Lowe's run, in the Ne. qr. of Sec. 32, Tp. 77 N., R. II W. Beginning farthest up in the west branch of this stream the section exposed is as follows:

		FEET.
4.	Light colored shale, disturbed by glacial action and worked into the till	4+
3.	White or ferruginous and yellow or brown sandstone, in beds of varying thickness, sometimes with oblique bedding	10
2.	Laminated, black, carbonaceous, very soft sandstone, with frequent impressions of plants	4
1.	Sandstone, mostly dusky yellow or brown, following the bed of the creek some distance down	(?)

Number 3 has been quite extensively quarried, and is used mostly for foundations and retaining walls. Under the bluff two miles west of Muscatine there is an abandoned quarry in a sandstone which rises about fifteen feet in the bluff. This is possibly a continuation of number 1, in the Lowe's run section. Along the branches of Pappoose creek, in the city of Muscatine, sandstone, shale or coal is always seen, wherever the creek has cut down below the drift. In the northwest part of the city, near the adjoining corners of sections 26, 27, 34 and 35, a sandstone fifteen feet thick lies at an elevation of at least 125 feet above the river. In places it is directly overlain by loess, no bowlder clay being present. Under this sandstone there is a small seam of coal, which appears in a creek southeast of the crossing of Logan and Cedar streets. In going up the main branch of Pappoose creek the coal measures make their first appearance a short distance above the junction of Star and Cedar streets. Combining the rock exposures seen in the south bank of the stream at this place with some exposures in a gully from the same side, where some rock has been quarried, the following section is apparent:

		FEET.
5.	Shelly, yellow or gray sandstone	9
4.	Somewhat ferruginous sandstone, in ledges about a foot in thickness, with occasional impressions of Lepidodendrons	8
3.	Irregularly-bedded, fragile, ferruginous sandstone, with frequent concretions of iron pyrites and impressions of Lepidodendrons	6
2.	A seam of impure coal	1
1.	Fire clay (in the bed and in the bank of the creek)	4

This same vein of coal is found at a higher level to the north on the other side of the creek, where it has lately been worked on a small scale. A little farther up in the creek all the visible rock is like the upper member in the above section. There is a ravine in which fifty feet of it is seen, rising to within thirty feet of the general upland level.

The escarpment in West Hill, fronting the river, has been examined by several geologists, and we may quote here the account given by Hall more than thirty-nine years ago, which is as follows:

		FEET.
8.	Thin-bedded sandstone, with shaly layers	19
7.	Massive sandstone, with large concretions	10
6.	Seam of coal or shaly coal, with under clay	4
5.	Shaly sandstone, with shaly partings, more shaly in the lower part	8½
4.	Thin-bedded sandstone, with shaly partings	5
3.	Heavily-bedded sandstone	6
2.	Green shale	3
1.	Distance to level of river (covered)	20

The coal seam (number 6) of the section is, as originally described by Whitney, not very regular, but is divided into several smaller and somewhat irregular areas toward the river. To the west a short distance it becomes more regular, and attains a thickness of two and one-half to three feet. A little farther westward it appears to thin out entirely, allowing the sandstones above and beneath to come together. There are, perhaps, several coal seams in this outlier. The thickness of the one worked varies from an inch to more than three feet.* It may be added that of the large spherical concretions mentioned in Hall's section, and figured in the earlier reports, none are now in sight. A large specimen, which is seen as a beautiful ornament in front of a residence in the central part of the city, has been brought from across the river in Illinois. Working of the coal vein in this section long ago ceased. Some of the entries on the old Smally property extended back from the bluff more than 1,000 feet.

In that branch of Mad creek which runs through the northern part of sections 26 and 27, in Bloomington township, shale and sandstone come into view in several places. Such is also the case in the branch opposite to this, from the east. A small quarry has furnished some sandstone in the east bank of Mad creek, near the center of the east line of the northeast quarter of section 13. But at no place in the basin of this creek does the Des Moines formation have any considerable thickness, owing, as it appears, to preglacial erosion along the course of the stream.

In East Hill, fronting the river, some coal has been mined high up in the slope. Under this coal there is about four feet of fire clay and then a basal sandstone of variable thickness, from four to six feet. This rests on the uneven surface of the upper bituminous shale of the Sweetland Creek beds. From this point to the east line of the county the coal measures are always present in the bluffs of the Mississippi, or at a short distance back, occupying a position under the drift and above the Devonian rocks. In section 30 in Sweetland township most of the exposures consist of shale. In the east half of this section is the old Hoor coal bank, no longer operated. Doctor Keyes has reported that the floor in this mine was a soft, gray fire clay, and the roof was a sandstone,

*Keyes. Iowa Geol. Surv., vol. II, p. 477. Des Moines, 1894.

quite firm and rather compact, and he gives the general section as follows:

		FEET.
5.	Shale, bluish, argillaceous	10
4.	Sandstone	2
3.	Coal	3
2.	Fire clay	4
1.	Hidden to river level	30

East of Geneva creek in section 29, Sweetland township, there is more sandstone. This has a thickness of twenty-five feet in the quarries on Mr. Stark's farm. At this place it is seen to have a joint or fissure which is filled with plates of fibrous or columnar white calcite from half an inch to two inches in thickness. From here to Pine creek the prevailing rock of the formation is sandstone, which reaches its greatest development in the county between Wyoming Hill and the west arm of Pine creek. Over this tract preglacial erosion has been less effective than over any other part of the county. The character of the Carboniferous in this region can be best shown by giving some local sections.

In the east bluff of Sweetland creek, east from Mr. Nettlebush's coal mine, in section 27, Sweetland township, the succession is as follows:

		FEET.
4.	Rather hard and strong sandstone in ledges frequently several feet in thickness	30
3.	Seam of coal and black shale	3
2.	Soft, arenaceous shale, with a coaly seam near middle.	70
1.	Sandstone, conglomeratic at base, extending below the bed of the creek	10

The coal mines referred to are on the northeast quarter of section 27. The coal there is the equivalent of number 3 in the above section.

The different beds which are to be seen at Wyoming Hill, in the face of the bluff are somewhat like those given above, but there is less shale and more sandy material.

WYOMING HILL SECTION.

		FEET.
9.	Drift and loess, mainly loess	30
8.	Sandstone of uniform texture in beds several feet thick, soft and disintegrated above	30
7.	A seam of coal and fire clay	3 (?)
6.	Dark shale with frequent small ferruginous concretions	12
5.	Sandstone, partly thin-bedded and partly in beds two feet in thickness	17
4.	Seam of coal	½
3.	Shaly sandstone in irregular slanting layers interbedded with dark seams of sandy shale. Very variable	45
2.	Sweetland creek beds	8
1.	Cedar Valley limestone to low water	5

In a gully which comes down at the west side of the hill, the base of number 3 is seen to be a conglomerate about a foot in thickness. Farther up the same gully what appears to be an equivalent of number 6, is seen to contain impressions of fern leaves in profusion. The numbers 3 and 5 have yielded impressions of Lepidodendron and Calamites, sometimes of large size.

A somewhat generalized section of the Des Moines constructed from observations around Fairport and in the run next east of this village is as follows:

		FEET.
4.	Disintegrated fine sandstone with oblique lamination, in places shaly	40
3.	Shale, in part light, in part dark	10
2.	Finely laminated, hard or fragile sandstone, with fine, long slanting lamination	20
1.	Dark shale and sandstone, variable and usually with a thin conglomerate at base	10

Back of the bluffs, in a ravine not quite two miles east of Fairport, a sandstone occurs at an elevation of about fifty feet above the river. This stone is literally filled with black and carbonaceous impressions of plants. Much of it is ripple-bedded and under it there is a seam of coal resting on fire clay.

South of the center of section 20 on the last high spur of the bluffs west of Pine creek there is an old abandoned coal mine at an elevation of about 110 feet above the river. It has furnished considerable quantities of coal in former years. The seam is overlain by a black limestone, in part concretionary and in part bedded. The latter contains quite a number of fossils, among which Dr. Calvin has recognized the following species:

Chonetes mesoloba N. & P.
Chonetes parvus Shum.
Spirifer cameratus Morton.
Derbya crassa M. & H.
Productus muricatus N. & P. (?)
Aviculopecten occidentalis Shum. (?)

This limestone is interesting as being the only member in the coal measures known in the county containing marine fossils. It is easily recognized both lithologically and by its fossils as being the equivalent of the limestone overlying Dr. Worthen's coal number 1 in Rock Island county, in Illinois.

East of Pine creek the coal measures are more shaly, and cliffs of sandstones are seldom seen along the streams. These have wide valleys with comparatively long slopes, on which evidences of small landslides now and then appear. Seams of impure coal are included in the shales and sometimes crop out in the bed of the streams. Near the east line of the county at Montpelier and in the creek next east of this, a sandstone rises in vertical walls about thirty feet high. It is white and thin-bedded, and of more variable composition at the base. In the bed of Montpelier creek the thin-bedded stone is seen to have beautiful ripple marks. In the other creek the base is coaly and shaly, an interrupted vein following the contact of the coal measures and the Cedar Valley limestone for about a mile up the stream. More or less pronounced indications of a carbonaceous or coaly deposit at this horizon are found in Montpelier creek, Robinson creek, Lowry's run, and in the east and middle branches of Pine creek in sections 4, 7 and 8, of Montpelier township.

The west bluff of Pine creek, all the way from Pine Creek Mills to near the junction of its two main branches near the center of section 17 in Montpelier township, consists of a high and frequently vertical escarpment of solid sandstone, from fifty to a hundred feet high. This sandstone rests on softer shaly beds, into which the creek has cut its valley. The sandstone has been partly undermined by the stream; furthermore it is cut by vertical joints; and for these causes blocks of the rock break off and fall down, forming a talus below. Near the north end of the escarpment some large blocks of

FIG. 34. Devil's Lane, from the south; Wild Cat Den. Photo by Calvin.

the whole formation of the sandstone have begun to creep out and down on the underlying shale and have left a deep fissure ten feet wide between the detached blocks and face of the main ledge. This fissure is known as Devil's Lane (Fig. 34). A remnant of another block lies still farther out, having advanced farther down toward the creek. This must have been detached first from the parent ledge. A third block is just in the process of being detached and is ready to join the procession in the rear, (Fig. 35). On the surface of the ground above, there are three sunken pits in a row over the forming crevice. This is open below, at the south end, and is known as the Niche. North of the Lane there is a recess in the wall which has been called the Bake Oven. Some distance to the north of this, close up to the brink of the wall, another small recess in the sandstone has been formed. This received the name of Wild Cat Den from the Nimrods among the early settlers in the region. The beautiful scenery along this mural escarpment, is enhanced by some native pines that rise in sombre grandeur from the brink of the wall. During the warm season it attracts from the cities and from the surrounding country, many visitors, who find comfort in the cool shade of the bluff and enjoy refreshing drinks from the chalybeate springs that issue from under the base of the sandstone. Some years ago a cast of the curving, tapering, radical end of a calamites tree was found in one of the blocks of the talus below this cliff.

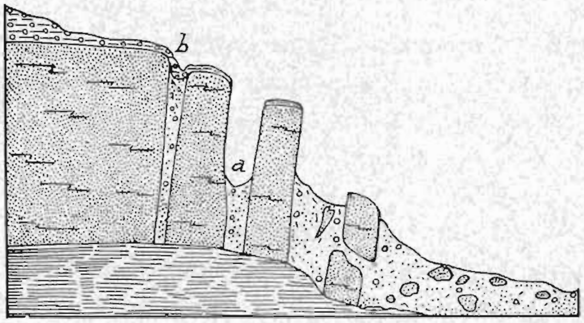


FIG. 35. Detached blocks of coal measure sandstone creeping on a foundation of shale, near Wild Cat Den. *a*, Devil's Lane. *b*, Settling of the ground above a widening joint.

Northward from the river the Des Moines rapidly thins out. Near the east line of the county it is last seen in the south half of section 1, in Montpelier township. Along the east branch of Pine creek it disappears in the northern portions of sections 3 and 4. Near the center of the south line of the latter section there is about thirty feet of sandstone, mostly disintegrated to an incoherent sand, with here and there some hard, thin, ferruginous layers. At Atteneder's old quarry, near the north line of Sec. 18, Tp. 77 N., R. I E., the sandstone is sixty feet high in the quarry wall. A small amount of shale separates it from the Cedar Valley limestone below. But in two miles farther up the creek the whole formation gives out. In Sweetland creek it is last seen near the south line of Sec. 10, Tp. 77 N., R. I W. Away from the creeks, and under the upland drift, it no doubt reaches somewhat farther north. A well at Pleasant Prairie has penetrated thirty-two feet of dark shale and sandy material, which must belong to the coal measures. Beds of this kind are also reported from a deep well near Summit.

In the west bluff of Cedar river, northwest of Moscow, small blocks of Des Moines sandstone were observed. These were of such a character as to lead to a suspicion that there was an outlier of this rock under the drift close by. This supposition was verified in examining some drillings from a well on the farm of Mr. Frank Barnes. These contained Carboniferous shale with pyrites that had come from below the drift. The same shale has been reported by drillers from some wells just east of Atalissa. Very small pockets of coal measure shale lie on the limestone at one place in Gatton's quarries, south of the Chicago, Rock Island & Pacific railroad, in the northwest quarter of section 8 in the same township.

General Section.—If a general succession in the Des Moines beds were to be indicated the following appears to the writer as representing the nearest approximation at present possible:

		FEET.
6.	Black limestone, arenaceous, and with marine fossils	2- 4
5.	Coal and fire clay.	
4.	Sandstone, sometimes replacing the number below	30-100
3.	Coal or carbonaceous shale	0- 50
2.	Argillaceous and arenaceous, very variable beds, with frequent impressions of plants and occasional seams of coal near base	10- 40
1.	Basal conglomerate, very variable, in places replaced by sandstone, black shale or coal	0- 10

Unconformity with the Devonian.—Some time before the Des Moines was deposited in this region the Devonian sea had retreated, and the land thus uncovered had been subjected to extensive denudation. One result of this denudation was the development of a peneplain, which cut the Devonian rocks some fifty feet deeper down near the north end of the county than along the Mississippi farther to the south. Hence the uplift was most likely accompanied by a slight tilting of the land toward the south. In the area under consideration the greatest inequalities in the ancient Carboniferous land surface which are evident do not exceed forty or fifty feet, but they are frequently abrupt and well marked. (Fig. 36.)

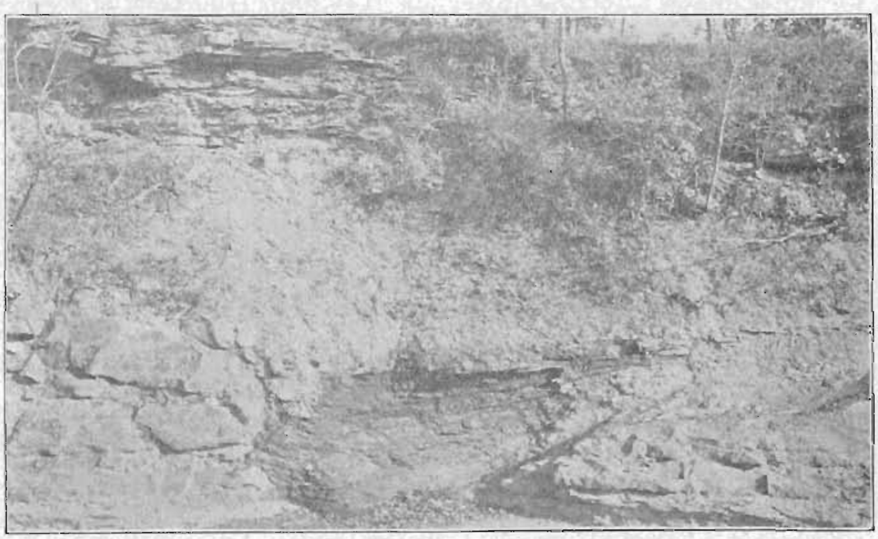


FIG. 36. Unconformity between the Des Moines and the Cedar Valley limestone in the east bank of Sulphur branch, in Montpelier township. Photo by Calvin.

Wide crevices filled with coal measure clay sometimes follow the joints down from the old surface in the limestone. These filled caverns are occasionally such as to suggest that the ancient land had at some time an underground cavernous drainage. Farther east stalactitic matter and travertine may still be found on the bottom of some caverns which are otherwise filled by coal measure shale.

The character and distribution of the basal conglomerate sheds some light on the nature of the old land. The conglomerate is usually best developed in the low depressions in the older rocks, as if made along the courses of the land streams. Sometimes the large fragments are quite angular. These seldom make up the greater part of the rock, but lie imbedded in a sandy matrix. In the east bank of Lowry's run, in section 22 of Montpelier township, a conglomerate of this kind is seen. At the south end it is cut by an unconformity at an angle of about thirty-five degrees from the horizontal, and is directly overlain by a coal seam dipping north with this angle. This marks a local incident in the advance of the Carboniferous sea. It indicates that the conglomerate is rather to be regarded as a product of the work of land streams on a sinking coast than as a residue from beach erosion. The materials which are represented in the larger fragments of the conglomerate show that it was brought mainly from the north and northeast. The average size of these fragments is from one to two inches in diameter. A list of the more commonly represented rocks in the conglomerate is here appended.

MATERIALS IN THE BASAL CONGLOMERATE.

1. *Niagara chert.*
2. *Niagara dolomite.*

These two contain recognizable Niagara fossils, such as joints of crinoids, brachiopods and favosites. The Niagara dolomite is frequently silicified.

3. *Fayette breccia* (silicified blocks, seen in Montpelier creek at the contact of the coal measures with the Sweetland creek shales, occurring singly in four or five places, a foot in diameter, one having a small pocket filled with zinc blende unchanged, having the superficial appearance of blocks subjected to the solvent action of water).

4. *Quartz nodule from the Fayette breccia* (known from its texture and peculiar pitting of the surface).

5. *Sweetland Creek shale* (near local outliers of the same formation).

6. *Red chert* (source not known).

The Carboniferous Record.—The general succession in the Des Moines of this county shows that the coast of the advancing sea was low, allowing only a small quantity of coarse materials to be brought down by the land streams. (Fig. 37.) As the sea advanced there was at first shallow

FIG. 37. Basal conglomerate of the Des Moines, in the left bank of Montpelier creek near the bluff of the Mississippi. Photo by Calvin.

water, where the surface waves produced ripples in the heaping sand. Then beaches and sandpits were formed, hemming in coastal marshes, where mud accumulated and vegetation flourished and became imbedded. The sandstone in Sweetland township is frequently bedded in a way suggesting that the beach sand at this stage was blown about by the wind, which may have aided in the making of isolated marshy places. After some time the sea had so far gained the ascendancy that calcareous deposits were laid down in waters with a brachiopod fauna. The advance was in all probability continued with interruptions for some time, but at this point our record ceases, having been obliterated by erosion during later eras.

CRETACEOUS ? ?

THE PINE CREEK CONGLOMERATE.

On the right bank of the west side of Pine creek, a short distance north from where it leaves section 34, Tp. 77 N., R. I W., there is a pebbly sandstone, unlike the coal measure conglomerate in the surrounding country. This sandstone is mostly brown in color, changing to yellow. It has a rather coarse texture, compared with the coal measure rocks, and is somewhat more variable in this respect. The best exposure appears in a small gully, which comes down the hill from the west, some twenty rods north of the south line of the section. In all a thickness of about sixteen feet is seen. Springs issue from the base of this rock, along the slope to the creek, indicating finer impervious underlying beds. The lower part of the section has one ledge which is two feet in thickness. But the bedding is irregular and the layers vary much in thickness in short distances. Some of the ledges are strong enough to be used for building stone, while one or two are loose sand. Even the hardest layers break easily under the hammer. In these the sand and gravel is cemented by a black matrix of peroxide of iron. The uppermost ledges are somewhat finer than the lower. Two sets of quite regular joints here cut the rock. One set bears west of north and the other north of east. Along these joints the ferruginous material is most profusely deposited. Some of the ledges are cut up into rhomboidal blocks about a foot in length and from eight to ten inches in width. These have a shining black hard crust, half an inch or more in thickness, which on some of the blocks has separated from the lighter and softer rock within, forming thin, straight and smooth plates. Above this brown sandstone there is a yellow loose sand containing small bowlders of greenstone and granite. On top of this sand there is bowlder clay and loess. Small exposures of the conglomerate occur for a distance of a quarter of a mile along the west side of the creek to the south of this place.

The degree of induration, in the pronounced jointing, and the general ancient aspect of this conglomerate render it reasonably certain that it is not a part of the drift which overlies it. But it has pebbles of Archæan rock, and one of these is nearly six inches in diameter. None of them were observed to be scored, though quite a number were examined. The average size of the pebbles is from one-fourth to two inches in diameter. On the other hand, it is not believed that it can belong to the coal measures. Some of the pebbles appear to be pieces of coal measure concretions and lumps of coal measure clay, and the aggregation of rocks represented in the pebbles is unlike anything observed in the coal measure conglomerate. For comparison, a collection of fifty pebbles was made, representing the average sizes. The proportion of specimens of different rocks in this lot was as follows:

	PER CENT.
Yellow chert	32
Greenstone	26
Granite (mostly red)	10
White quartz (some of a faint, pink color)	8
Fragments of coal measure rock	4
Light red orthoclase	2
Black felsite	2
Porous Niagara chert	2
Chalcedony	2
Orthoclase-biotite rock	2

The only conclusion which can at present be drawn as to the age of this conglomerate, is that it is post-Carboniferous and preglacial. Dr. Calvin, who has seen it recently, pronounces it identical in nature with the Rockville conglomerate described by McGee. It also somewhat resembles the Cretaceous conglomerate found in Guthrie county by Mr. Bain. Possibly it may be an outlier of the Lafayette formation, observed farther south by McGee and by Salisbury.

In the south bluff of West Hill in Muscatine, just east of Broadway street, there lies on top of the coal measures and under the drift a small remnant of a conglomerate somewhat resembling that above described. It is seen for a distance of only three or four rods and its greatest thickness is three feet. It is plainly uncomformable with the beds below. The base is a very pebbly sand, held in a dark ferruginous matrix, which, in some places, does not wholly fill the interstices between the pebbles. The upper surface is a brown ferruginous, moderately fine sandstone of about the same hardness and aspect as the middle ledges in the Pine creek conglomerate. It is seen to contain three rounded bowlders from eight inches to one foot in diameter. One of these consists of gneiss, one of mica schist and one of quartzite. In a collection of 100 pebbles from this ledge, different rocks were represented by the number of pebbles indicated in the following list:

	PER CENT.
Greenstone	26
White quartz	26
Yellow chert	18
Granite (mostly red)	7
Light red orthoclase	5
Coal measure rock	4
Black felsite	3
Quartz-biotite schist	3
Faintly pinkish white quartz	2
Quartz speckled with jasper	2
Red quartzite	1
Hornblende rock	1
Milky quartz	1
Gneiss	1

The author is inclined to the opinion that this conglomerate in Muscatine and that exposed on Pine creek are both outliers of the same formation.

As to the age of this conglomerate the author has no opinion to offer except as indicated above. The complexity and uncertainty of the problem is fully stated in a letter recently received from McGee, in which he says: "The greater part of the brown sandstones in that region are of course

Carboniferous, and outliers of that age occur at intervals northward through Scott and Clinton counties, and I believe also in Jackson and Linn, within suggestively few miles of the Rockville conglomerate. Several of these outliers have come to light since I left the state; and, as you will remember, it was chiefly the evidence of the Cretaceous outliers northward and of the Cretaceous fossils in the drift that led me to correlate the Rockville deposit with the Mesozoic. Subsequently I have worked on the Lafayette formation, and found it to form the record of a wonderfully extensive continental subsidence, followed by an impressive continental uplift. I have traced the Lafayette deposits well up into southern Illinois, while Salisbury and others have found outliers of what appears to be the same formation still farther northward; and I am convinced that remnants of this formation ought to exist in the Mississippi valley, at least as far northward as Keokuk, and probably as far as Davenport or even Clinton. Finally, I long ago observed in Dubuque and Delaware counties peculiar sub-drift or basal-drift deposits unconformably underlying what we now call the Kansan drift-sheet; they are made up of ferruginated liviviated loam (probably what Bain would call ferretto) containing quartz pebbles and, as I remember, a few granitoid pebbles. On first examining this deposit, I was disposed to consider it glacial in origin, though much older than the lower till, the Kansan of to-day, and I described it, with these ideas in mind, in a paper published in the Geological Magazine of London about 1879 or 1880. Subsequently, being unable to trace the deposit over any considerable area, I rather neglected it, and, in the preparation of a report on northeastern Iowa, I assumed it to be a subaerial accumulation containing some detritus from the Rockville conglomerate, and perhaps other formations intervening between the Paleozoic and the Pleistocene—the assumption being, I believe, implicit, since I do not recall referring to the matter specifically. Accordingly there appear to be four distinct series of deposits to which local accumulations of brown sandstone might be assigned, the criteria for comparison and correlation being sadly vague."

PREGLACIAL EROSION.

Nature of the Data.—The number of deep wells, which the farmers have found it necessary to make on the uplands, give us some information concerning the nature of the old land surface that is buried under the drift in the west end of the county. In the course of the survey records of a number of such wells have been obtained, mostly from well makers. A table is given below, in which these wells are enumerated by sections and townships. The second column in the table gives the location of each well, and the name of the owner when known. The third column describes the situation with regard to topographic features. The fourth gives the elevation of the top of the well, with regard to sea level. This has been obtained from railroad levels, and from the topographic sheets of the United States Geological Survey in the north tier of townships. For the other part of the county the elevations given are mostly either aneroid measurements or estimates. The fifth column gives the depth of the well from the surface. The sixth column describes the materials which have been penetrated. The information obtained on this subject is the least satisfactory, except as to the elevation of the bed rock. Well makers generally fail to distinguish between the pebbleless yellow loess and pebbly, yellow bowlder clay. Both are usually reported as "yellow clay." In the same way a blue silt or soil-bed is not always reported separately from blue bowlder clay. But the records are given for what they are worth, in the hope that in the light of future explorations some of them may prove useful. The depths to the bed rock are given with greater confidence, as depth is of the greatest practical importance to the well makers, who have more than one way of knowing when rock is encountered. The last column gives the elevation of the top of the bed rock in feet above sea level, in which case the figures are in *italics*, or it gives the level at which the well stopped in drift, in which case the figures are in ordinary type. It will be noticed that the wells are quite uniformly distributed over the uplands, while the lowlands are represented by only a few borings. The data on the bed rock levels seem quite sufficient for the construction of fifty-foot contours over all except the south tier of townships. A map giving the contours is presented in plate vii. It is believed fairly to represent present explorations, and may be used with some confidence in making estimates on the construction of new wells.

WELL RECORDS IN MUSCATINE COUNTY.

BLOOMINGTON TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
1	G. Parks, Sec. 5, Tp. 77 N., R. II W.	Upland	720+	115	Loess and blue clay, 10 ft of sand at bottom	605
2	J. Greiner, Sec. 3, Tp. 77 N., R. II W.	Upland	740+	200	No rock	540
3	County farm, Sec. 33, Tp. 77 N., R. II W.	Upland	720+	208	Clay 100 ft, sand 20 ft, clay 60 ft, limestone 28 ft	*540*

CEDAR TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
4	William Verink, Sec. 14, Tp. 76 N., R. IV W.	Low upland	690	85	Loess 15 ft, yellow sand 40 ft, blue clay without pebbles 10 ft, white sand with gas 15 ft	605
5	C. Carpenter, Sec. 33, Tp. 76 N., R. IV W.	Upland	730+	125	Loess and yellow sand, blue clay, sand below	605
6	Louis Eliason, Sec. 36, Tp. 76 N., R. IV W.	Upland	720+	154+	Mainly till, gravel at bottom	566
7	A. Cone, Sec. 24, Tp. 76 N., R. IV W.	Low upland	660+	200+	Soft till 130 ft, hard blue till 60 ft	460
8	C. Hadley, Sec. 36, Tp. 76 N., R. IV W.	Low upland	680	158+	Gas at 126 ft	522
9	J. Fanning, Sec. 15, Tp. 76 N., R. IV W.	Low upland	670	130+	No rock	540
10	S. Littrell, Sec. 35, Tp. 76 N., R. IV W.	Low upland	680	205+	Loess and yellow sand 20 ft, blue clay, sand and gravel	475
11	T. M. Brown, Sec. 34, Tp. 76 N., R. IV W.	Low upland	680	150	Loess 15 ft, yellow sand 8 ft, blue clay 100 ft, muck at 130 ft, gravel at bottom	530

WELL RECORDS IN MUSCATINE COUNTY—CONTINUED.

FRUITLAND TOWNSHIP.

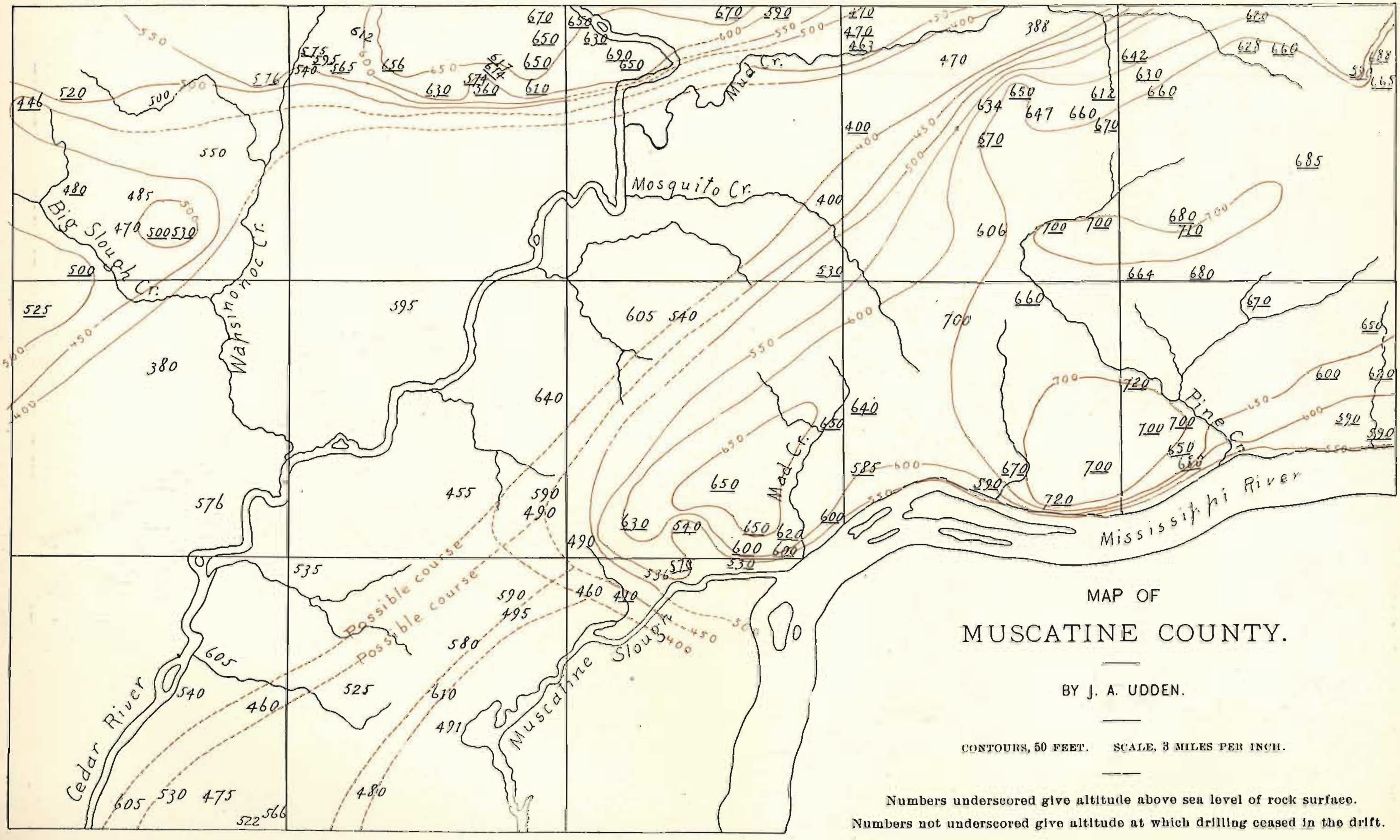
Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
12	Charles S. Miller	Below bluff	570+	110	No rock	460
13	Hershey Creamery Sec. 4, Tp. 76 N., R. II W.	Base of bluff	580	44	No rock	536
14	G. W. Kincaid Sec. 5, Tp. 76 N., R. II W.	Below bluff	570	160	Three wells entered rock at this depth	410

FULTON TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
15	Sedo Hayden Sec. 7, Tp. 78 N., R. I E.	High upland	780+	120	Gas from near the bottom of drift.	660
16	Sec. 23, Tp. 78 N., R. I E.	Upland	760+	75	Rock at bottom	685
17	Town of Stockton	Upland	720+	110	Drift 100 ft deep	620
18	B. Otto Sec. 7, Tp. 78 N., R. I E.	Upland	750+	105	Rock at 98 ft	642
19	George Deming Sec. 7, Tp. 78 N., R. I E.	Upland	760+	130	Yellow and blue clay 60 ft, brown sticky clay 12 ft, blue clay 58 ft	630
20	J. Reimers Pleasant Prairie.	Upland	740+	92	Drift 60 ft, black shale 32 ft	680
21	C. Wolfe Sec. 33, Tp. 78 N., R. I E.	Upland	738+	144	Yellow clay 30 ft, blue clay 40 ft, quicksand 7 ft, blue dirt (probably in part shale) 38 ft, rock to 144 feet	600
22	J. H. Broders Sec. 3, Tp. 78 N., R. I E.	Upland	740+	106	Yellow and blue clay, 70 ft, sand 8 ft, limestone 28 ft	660
23	Sec. 31, Tp. 78 N., R. I E.	Upland	780+	121	Drift 116 ft, rock 5 ft	664
24	Sec. 12, Tp. 78 N., R. I E.	Upland	748+	158+	Yellow clay and sand 20 ft, blue clay 120 ft, rock at 158 ft, timber at 140 ft	590
52	Hans Brookman Sec. 12, Tp. 78 N., R. I E.	Upland	720+	32	Drift with gravel and bowlders at base; solid rock at bottom	688
26	H. Stoltenburg Sec. 12, Tp. 78 N., R. I E.	Upland	730	105	Drift to near 70 ft, then soft white limestone	665
27	Ernest Muller Stockton	Upland	715	150	Drift to 47 ft, soft limestone to bottom	666
28	Pleasant Prairie		750+	90	Drift 40 ft, shale and sandstone	710

GOSHEN TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
29	West Liberty Plain, southwest of Atalissa	Lowland	650	?	Loess 6 to 10 ft, fine sand a few ft, coarse sand, below 25 ft; depth unknown.	?
30	Cyrus Overman Sec. 10, Tp. 78 N., R. III W.	Near bluffs	670+	40	Disintegrated rock in bottom	630
31	In the bluff in the east part of Atalissa	In slope of bluff	684	90	Drift 80 ft, coal measure shale 10 ft	604



MAP OF MUSCATINE COUNTY.

BY J. A. UDDEN.

CONTOURS, 50 FEET. SCALE, 3 MILES PER INCH.

Numbers underscored give altitude above sea level of rock surface.
Numbers not underscored give altitude at which drilling ceased in the drift.

WELL RECORDS IN MUSCATINE COUNTY—CONTINUED.

GOSHEN TOWNSHIP—CONTINUED.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
32	W. Lundy... Atalissa (north part).	On the bluff.	690+	43	Drift 43 ft, then rock...	647
33	Frank Barnes... Sec. 1, Tp. 78 N., R. III W.	Upland...	700+	156	Drift 50 ft, coal measures 100 ft, limestone 6 ft...	650
34	Atalissa...	Bottom land at base of bluff...	664+	.....	Loess 10 ft, sand +, blue clay to 35 ft, sand +...	....
35	W. A Howell... Sec. 5, Tp. 78 N., R. III W.	Upland...	670+	......	Yellow clay 15 ft, blue clay 35 ft, sand 8 ft...	612
36	Isaac Dickinson... Sec. 9, Tp. 78 N., R. III W.	Upland...	720+	78	Yellow clay 15 ft, blue clay 25 ft, dark sand 4 ft, hardpan 20 ft, soft yellow sandstone (came up in small lumps) 14 ft...	656
37	Atalissa (Markham)...	Base of bluff	670+	110	Yellow clay and sand 38 ft, blue clay 71 ft, sand and limestone...	560
38	Atalissa (Overman)...	Base of bluff	670+	136	Yellow clay and sand 42 ft, blue clay 44 ft, blue limestone 44 ft, porous brown limestone 6 ft, wood 40 ft from top...	574

LAKE TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
39	Southeast sections in Lake township, general section...	Upland...	740	250	No rock in several wells ranging in depth from 150 ft to 250 ft. A general section of the drift is as follows: Loess and sand 20 ft, blue clay 100 ft, water sand 10 ft, blue clay...	490
40	F. D. Wood... Sec. 27, Tp. 77 N., R. III W.	Upland...	720	265	No rock...	455
41	C. Humphries... Sec. 13, Tp. 77 N., R. III W.	Upland...	740+	100	Bottom in sand...	640
42	Isaac Sager... Sec. 25 Tp. 77 N., R. III W.	Upland...	740+	150	No rock...	590

MONTPELIER TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
43	C. Howard... Sec. 19, Tp. 77 N., R. I E.	Upland...	730+	100	Drift 20 ft, sandrock 80 ft, limestone under this...	710
44	Daniel Grimm, Jr... Sec. 6, Tp. 77 N., R. I E.	Upland...	730+	20	Loess a few feet, an old soil, with dark, winding, vertical cylinders resembling filled gopher holes, extending down into the underlying pebbly clay, some 5 ft thick. Below this a sticky silt and then a reddish clay...	....

MOSCOW TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
45	Near north line Sec. 2, Tp. 78 N., R. II W...	Slope...	680	......	Rock at a depth of about 90 ft...	590
46	Summit Sec. 26, Tp. 78 N., R. II W...	Upland...	730	200	Rock in bottom...	530

WELL RECORDS IN MUSCATINE COUNTY—CONTINUED.

MUSCATINE TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
47	Cemetery, west of city	On bluff	720+	424	Yellow clay 40 ft, blue clay 100 ft, dark sand 40 ft, blue clay 10 ft, limestone, varying in hardness, 234 ft	530
48	Gunserhauser's well	On terrace	695	75	Drift 60 ft, then coal measures	620

SEVENTY-SIX TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
51	J. Venatta Sec. 2, Tp. 76 N., R. III W.	Upland	740+	150	No rock	590
52	Patrick O'Brian Sec. 17, Tp. 76 N., R III W.	Upland	700	175	No rock	525
53	Daniel McCabe Sec. 11, Tp. 76 N , R. III W.	Base of Mississippi bl'ff	575	80	Sand, blue clay, and gravel	490
54	H. J. Jeffries Sec. 22, Tp. 76 N., R. III W.	Base of bluff	585+	94	Yellow clay above, red sand 60 ft, white sand and gravel	491
55	I. Reed Sec. 15, Tp. 76 N., R. III W.	Upland	730+	100	No rock, gas at bottom	610
57	Bluff of the Mississippi river Sec. 10, Tp. 76 N., R. III W.	In bluff	715+	115	Loess 12 ft, black gumbo or soil 2 to 3 ft, mainly blue till 100 ft	600
58	A. Migim Sec. 10, Tp. 76 N., R. III W.	On a drift ridge	750+	170	Loess 12 ft, yellow till 38 ft, gravelly sand 25 ft, blue till, 25 ft, yellow cemented gravel 10 ft, blue till, very hard and stony, 60 ft	580
59	Isaac Eperly Sec. 32, Tp 76 N., R. III W.	Upland	720+	240+	Loess 10 ft, yellow sand 10 ft, blue clay down	480

SWEETLAND TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
60	Frank Nettlebush Sec. 27, Tp. 77 N., R. I W.	Upland	730+	340	Loess 20 ft, clay, sand, and gravel 40 ft, soft sand rock 40 ft, "soapstone," coal measures 57 ft, limestone 185 ft	670
61	John Monsen Sec. 20, Tp. 77 N., R. I E.	Upland	740+	304	Drift 90 ft, coal measures 120 ft, limestone 94 ft	650
62	Muscatine Terra Cotta Lumber Co Sec. 30, Tp. 77 N., R. I W.	Under bluff	585+	205	Shale 18 ft, loose rock 2 ft; solid rock 1·5 ft, slight escape of gas was noticed	585
63	Daniel Roberts Sec. 18, Tp. 77 N., R. I W.	Upland	720+	80	Yellow clay 3 ft, sand and clay 77 ft.	640
64	J. Newman Sec. 4, Tp. 77 N., R. I W.	Upland	760+	60	Soil and yellow clay 5 ft, blue pebbly clay 25 ft, forest bed 10 ft, ash, clay changing to sand 20 ft	700
65	S. Wintermirte Sec. 36, Tp. 78 N., R. I W.	Upland	780+	65	Yellow clay 8 ft, stony clay 40 ft, creek gravel 4 ft (with snails and bivalves), yellow clay and blue, with pebbles, 10 ft, ash clay 5 ft, sand	715
66	P. Brossart Sec. 26, Tp. 77 N., R. I W.	Upland	765+	200	Drift 130 ft, sandstone and shale 65 ft, then limestone 5 ft	635

WELL RECORDS IN MUSCATINE COUNTY—CONTINUED.

PIKE TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
49	G. N. Aylesworth........... Sec. 26, Tp. 77 N., R. IV W.	West Liberty plain.......	635	59	Sand 30 ft, clay 10 ft, gravel 19 ft...	576
50	Nichols..........	West Liberty plain.......	638	250	No rock, all clay, sand and gravel. The well was tubed over 250 ft...	388

WAPSINONOC TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation.	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
67	Christian Wolfe............ Sec. 28, Tp. 78 N., R. IV W.	Upland.......	725+	240	Unknown 40 ft, blue clay 60 ft, sand 6 ft, yellow clay 25 ft, blue clay with muck, wood and sand 107 ft, sand 8 ft...........................	485
68	West Liberty artesian well.	Upland slope	696	1768	Depth of drift 120 ft; this consists of yellow clay 25 ft, quicksand 2 ft, blue clay 38 ft, sand and gravel 55 ft; bed rock 1,648 ft...	576
69	Brooks' farm............ .. Sec. 7, Tp. 78 N., R. III W.	Upland slope	640+	100+	Drift 100 ft, hard rock 40 ft, softer rock with water	540
70	John Venatta............... Sec. 8, Tp. 78 N., R. III W.	Upland slope	665+	245	Drift 100 ft, limestone 145 ft........	565
71	Frank Hunter............... Sec. 23, Tp. 78 N., R. IV W.	Upland slope	670+	120	Bottom of well in sand.............	550
72	Louis Watson...... .... Sec. 7, Tp. 78 N., R. III W.	Upland slope	690+	138	Loess 15 ft, blue clay 50 ft, rusty yellow clay with many boulders 30 ft, soft brown limestone 43 ft..	595
73	George Venatta............ Sec. 9, Tp. 78 N., R. III W.	Upland slope	670+	220	Yellow clay with some boulders 20 ft, blue clay 60 ft, brown clay with many boulders 15 ft, blue limestone 80 ft, soft brown material 8 ft, hard limestone 29 ft, soft limestone 8 ft...............	575
74	Adolf Vogle............ .... Sec. 27, Tp. 78 N., R. IV W.	Upland.......	730+	200+	Rock in bottom...	530
75	T. W Stoops................. Sec 8, Tp. 78 N., R. IV W.	Upland.......	740+	220	Loess 6 ft, yellow clay 20 ft, sand 2 ft, blue clay 160 ft, sand 28 ft, rock at 220 ft, of cream color..........	520
76	Pliny Nicholls.............. Sec 20, Tp. 78 N., R. IV W.	Upland.......	700+	367	White limestone from 220 ft to 350 ft, below this a porous brownish rock......	480
77	John Gibson .... Sec. 18, Tp. 78 N., R. IV W.	Upland.......	730+	284	Loess, yellow clay, blue clay with a layer of sand, 12 ft of "river sand" with shells and a tooth of "an animal," drill stopped on rock..........	446
78	Robert Wagner...... ...... Sec. 15, Tp. 78 N., R. IV W	Upland.......	675+	175	Mostly drift.........................	500
79	Fred Kirchner...... .... Sec. 32, Tp. 78 N., R. IV W.	Upland.......	700+	398	About 200 ft to rock which was white and hard above, reddish and porous below.................	500

WELL RECORDS IN MUSCATINE COUNTY—CONTINUED.

WILTON TOWNSHIP.

Number.	LOCATION AND OWNER.	SITUATION.	Elevation	Depth.	MATERIALS PENETRATED.	Bed rock above sea level.
80	William Boot................. Sec. 9, Tp 78 N., R. I W.	Plain	710+	240	Sand 90 ft, blue clay 100 ft, sand and gravel 10 ft.....................	470
81	Three miles south of Wilton	Plain.........	700+	300	Drillers report going down 300 ft and finding no rock (Teeple).....	400
82	Wilton (north part of town)	Upland.......	700+	230	General section, sand and clay 100 ft, sand fine above, coarse below, 130 ft, then there is rock; driftwood occurs at a depth of 100 ft..	470
83	Charles Norton.................. Sec 13, Tp. 78 N., R. I W.	Upland	725+	113	Soil and yellow clay 14 ft, blue clay with pebbles 24 ft, sand 2 ft, limestone 23 ft...........................	612
84	W. Felthorn.................. Sec. 13, Tp. 78 N., R. I W.	Upland.......	760+	100	Yellow and blue dirt 14 ft, brown sand 7 ft, blue clay 68 ft, sand 10 ft	....
85	C. W. Colliers.............. Sec. 14, Tp. 78 N., R. I W.	Upland.......	760+	113	Yellow clay 8 ft, blue clay 32 ft, black hard pan 68 ft, gravel 5 ft..	647
86	Hans Kai...................... Sec. 10, Tp. 78 N., R. I W.	Upland.......	740+	101	11 ft rock in bottom.................	650
87	Fred Nolte.................... Sec. 15, Tp. 78 N., R. I W.	Upland.......	730+	96	No rock................................	634
88	Smith.......................... Sec. 15, Tp. 78 N, R. I. W.	Upland.......	770+	134	Brown sand 10 ft, blue clay 20 ft, sand 30 ft, blue clay 40 ft, rock 35 ft	670
89	M. A. Roy.................... Sec. 27, Tp. 78 N., R. I W.	Upland.	741+	135	Yellow clay and sand 20 ft, blue clay 108 feet, sand 6 ft, then rock.	606
90	E Reimers.................... Sec. 2, Tp. 78 N., R. I W.	Upland.......	700+	312	Yellow clay, sand, and gravel 60 ft, blue dirt 80 ft, quicksand 60 ft, blue clay 90 feet, coarse river sand 22 feet, no rock...............	388
91	Wilton artesian well........	Low upland.	690	1480	Drift 220 ft, limestone 280 ft, shale 180 feet, limestone 300 ft, sandstone 120 ft...........................	470
92	George Wildasin............. Sec. 12, Tp 78 N., R II W.	Low upland.	710+	......	Yellow clay 6 ft, sand 4 ft, "swamp clay" with vegetation 4 ft, gray stony clay 5 ft, ashy clay and sand..............................	....

Preglacial Topography.—(Plate viii.) A comparison of the contours of the preglacial land with the present topography shows a partial correspondence between the two. The lowlands of the West Liberty plain occupy a low tract on the preglacial land surface. Wapsinonoc creek, Mud creek, Mad creek, and Pine creek lie in preglacial valleys. But that part of the course of the Cedar which runs from northwest to southeast, in the north part of the county, comes down from an old upland, and that part of the Mississippi which is above

Muscatine crosses the north end of an old divide. These positions of the two great rivers are evidently due to changes in drainage brought about by the deposition of the drift. An old upland crest extends north and a little east from Wyoming Hill. It is continued to the south and east in Illinois. The bed of the river is rock-bound for more than forty miles above Muscatine, and the valley is comparatively narrow and practically without bottom lands. This part of the valley is of much more recent making than the buried low lands under the West Liberty plain. The deep northeast extension of this lowland under Mud creek may have been occupied by some great stream in preglacial times, but our present knowledge neither warrants nor disproves the supposition that it marks an earlier course of the Mississippi. But it is quite evident that no such great stream flowed in the present channel of the Mississippi previous to the deposition of the drift. The drainage from either side of the valley at this place is not yet fully adjusted to the present conditions, as is evident from the fact that much of the land nearest the river drains into the great stream by circuitous routes through smaller valleys of evident preglacial existence. The main cause of the change is probably to be sought in some obstruction outside the limits of the county, but the selection of the particular course here is most likely due to overflow following the line of an earlier, smaller and local stream. The minor preglacial contours in the region have a decided east and west trend.

It is evident that on the whole the glacial work in the region has resulted in the reduction of reliefs by partial filling of the low tracts. These were the result of long continued and effective erosion, compared with which the destructive work performed after the making of the first drift is insignificant.

THE PLEISTOCENE.

The era of extensive erosion during which the ancient reliefs just described were carved out came to an end at the advent of the glacial period, during which the country was overrun by extensive ice fields at, it seems, three different times. The eroded terranes appear to have suffered but slightly from the ice incursions in this region. The old topography has not been much changed. There was hardly any planing of the surface. No scorings have as yet been observed on the bed rock in Muscatine county. On the contrary there is evidence that even the less coherent surface accumulations in the region were not always disturbed, being rather simply buried under the glacial detritus accumulated.

ANTE-GLACIAL SILT.

Occurrence.—On top of the bed rock, and under the lowermost member of the drift, a silt sometimes appears, associated with scant soil beds and loess-like deposits. The best instances are seen along that branch of Mud creek which is followed by the Muscatine division of the Burlington, Cedar Rapids & Northern railroad, in the north part of Muscatine township. The outcrops occur in the bank of the stream not far from the north line of the Nw. qr. Nw. ¼ Sec. 26, and also in the Ne. qr. Ne ¼ Sec. 27, Tp. 77 N., R. II W. At the former place it is blue, rather coarse laminated calcareous silt, with lentils of finer silt and pockets of rusty sand imbedded, weathering to yellow or rusty-gray. It appears to be slightly disturbed and is overlain by cross-bedded sand and gravel, over which there is dark blue till. At the latter place the following section was seen in the low north bank of the creek.

		FEET.
4.	Blue silt with ferruginous blotches and oxidized spots and streaks, slightly calcareous below	1½
3.	Dark, loess-like, non-calcareous silt containing flattened roots or branches of woody plants, and *Succinea lineata* and *Pyramidula strigosa iowensis*	½
2.	Very fine, blue, calcareous laminated silt	½
1.	Coarser, calcareous, laminated, blue silt, like that seen farther up the creek	1

The wood in number 3 is gymnospermous. The coal measures appear in the bed of the creek immediately below this place. Near the junction of this branch with Mad creek some silt, similar to number 1 in the above section is, together with some peat, worked into the base of a dark blue till, and some distance farther up the stream this dark till gradually changes downward into a similar blue silt. In Mud creek the same silt is occasionally seen in the same situations under a dark bowlder clay in the bed of the creek. The first instance noticed is under a high bank on the east side of the creek, near the west end of Polk street, in Park Place addition. Here it is much contorted, evidently from being overridden by the ice which deposited the drift. A few rods farther up it appears again in the opposite bank and is partly worked into the till and partly graduates into it. Similar exposures of it appear in the left bank of the creek near the north line of section 24, in Bloomington township, and in the tributary coming from the west in the northwest quarter of the same section. At the latter place it has plainly been tilted and worked by the ice. In that branch of Pappoose creek which is crossed by the old Butlerville road, now Russell avenue, just east of the center of the east line of section 34, in the west part of Muscatine, a thickness of eight feet of the same silt appears in the bank of the ravine below the street bridge. The surface of the material is of a rusty, gray color, which changes to dark blue farther in where the weathering has not reached. The coal measures come out close by, south of the creek, at a higher level, being there overlain by bowlder clay. This indicates that the silt is confined to the lower part of the gully.

In the valley of Sweetland creek this silt is found at a place about 100 paces north from the center of the south line of section 15, in Sweetland township. In the west bank of the stream at this point the following section was exposed.

	FEET.
4. Ferruginous, stratified, yellow, pebbly clay resembling a terrace deposit	3
3. Yellow calcareous till (running into No. 2)	5
2. Very calcareous bluish till with fragments of wood in the lower part, kneaded into No. 1 below	2
1. Finely laminated, calcareous blue silt	4

Close by, to the north from this place, the silt rises twelve feet in the bank above the creek. A few feet below its upper surface it gradually becomes coarser and at the same time blotched, as if weathered, and farthest down, more like a till or reddish clay, and containing some pebbles. The bed rock rises above the level of the uppermost part of the section close to the north.

A similar deposit is seen under the wagon road bridge, and north of it near the mouth of the small creek which comes down to the river on the east of Wyoming hill, a mile and a half west of Fairport. At this place some of the layers are almost black, and it is cut by conspicuous straight joints.

In the northeast corner of section 34, in Sweetland township, below the old Hanson quarry, in the west bank of the creek, there is a section of blue silt and loess-like material so like the one seen in the lower west branch of Mad creek that there can be no doubt that the two represent identical conditions. It is as follows:

	FEET.
6. Bowlder clay, pebbly and somewhat stratified	2
5. Stratified sand	1½
4. Fine, unctuous silt	1½
3. Blue, loess-like material with vertical, cylindrical, ferruginous impregnations, three inches in diameter and less, resembling the "pipes" common in some phases of loess	3
2. Dark, mucky, slightly effervescing silt, with imbedded, flattened roots and twigs of gymnospermous woody plants and with thin and very fragile shells of pulmonates resembling those seen in No. 3 in the section north of Muscatine	½
1. Blue, mottled, laminated silt like that seen on Sweetland creek, extending below the bed of the creek	2(?)

Still another instance of this silt occurs in Sulphur branch, just above the last outcrops of coal measure shale north of the south line of section 1 in Montpelier township. It is dark blue, with a few scattered sand grains, and contains vertical, cylindric impregnations of iron oxide. Over it there is a dark, mucky layer with fragments of wood, and this is overlain by bowlder clay. In one place it was seen to be cut by a nearly vertical vein, four inches wide, of a sandy till connected with the till above.

Probable origin.—It will be noticed that in each one of the above described localities the bed rock appears close by, usually not more than two or three rods away. In all but two places the formation lies in preglacial valleys now partially filled with drift. In four cases it is seen to be overlain by the lowermost drift known in the region presently to be described. For the most part it is calcareous and frequently it is plainly water bedded. Sometimes it graduates into drift. At other times it is disturbed by glacial action and partly worked into the bowlder-bearing drift. In four places it contains a layer that resembles a marshy soil, with plants, snail shells and some peaty material. Of the snails, which have been examined and identified by Professor Shimek, *Pyramidula strigosa iowensis* Pilsbry is regarded as a form now extinct and *Succinea lineata* W. G. B. is noted as "very common in dry regions to-day from Upper Missouri to the highlands below Natchez, in Mississippi." Both are well known species from the loess. The imbedded plants are flattened roots or branches, a half inch and less in diameter. All that have been examined show the pitted tracheid tissue of gymnosperms. North of Muscatine, and in the west branch of Pine creek, the shell and the plant remains lie imbedded in a thin layer resting on laminated silt and succeeded above by loess-like material. On Pine creek this is again capped by water-bedded silt.

It seems most likely that this silt and loess accumulated in front of the margin of the first ice field. The prevailing calcareous nature of the thin-bedded silts indicates such a source. The plainly marked lamination of these shows that their deposition was comparatively rapid. In a region of deep reliefs, such as this was at the advent of the first ice, the drainage must have been frequently ponded up against the ice in many of the preglacial valleys. The drainage from the margins of the ice must have brought large quantities of calcareous silt into these ponds, and this would be confined to the valleys alone. Mud flats might form in this way, on which plants and snails may have found a temporary *habitat.* Occasionally loess-like wind drift might also accumulate in such situations. The advancing ice may later have overrun and disturbed such deposits, plowing them up and mixing them with drift in some places, and at other places leaving them undisturbed in the positions in which they are now found. The presence of gymnospermous vegetation indicates at any rate that boreal climatic conditions were not far off when these deposits were formed. Possibly a part of them may be preglacial loess.

GLACIAL DEPOSITS.

General observations.—The main deposit of the drift is the glacial bowlder clay. In Muscatine county this occurs in three different phases which are known as pre-Kansan, Kansan and Illinoian, the two former being separated by the Aftonian gravel (forest and soil beds?), and the two latter by the Buchanan gravel and the Yarmouth soil and leached horizon. The field relations of these members of the drift can be best set forth in describing some typical sections from the border of the region of the deep drift.

In the bluff in the west part of the city of Muscatine, at the crossing of Main and Third streets, some excavations have lately been made that expose a nearly vertical wall of drift, not far from seventy feet high. The section is about as follows:

		FEET.
6.	Loess (in the slope above)	2-10
5.	Yellow till with white powdery, disintegrated, calcareous concretions in the upper part (Illinoian).	15
4.	Yellow sand with some gravel (Buchanan?).........	
3.	Blue till, apparently somewhat disturbed, with a network of wide, oxidized joints, and with some pockets of sand extending down from above (Kansan)......................................	10
2.	Sand and gravel, mostly rusty red, occasionally with layers standing at angles considerably exceeding 40° from the horizontal, contorted and faulted (Aftonian)......................................	14
1.	A dark blue till with bits of gymnospermous wood, changing downward into a dark silt and associated with peaty material (pre-Kansan)................	3-20

Number 5, in the above, appears again on the grounds opposite the Catholic church farther up in the bluff, where its calcareous concretions occasionally contain gravel and sand, appearing like mortar rock. At the present stage in the excavation below it is seen to run out as a lens in the west end of the hill. Number 3 is the most conspicuous part of the wall in the excavation. Number 1 is not well exposed at present and can only be seen when the rubbish below is cleared away. A well just below this place is reported to have penetrated twenty feet of "dark clay and muck." The top of this well is on a level with the floor of the excavation.

At the place where Lowe's run leaves the uplands in the Ne. qr. Sec. 8, Tp. 77 N., R. II W., Fruitland township, this stream is at present cutting under a bluff in the right bank and has laid bare the following section:

		FEET.
6.	Yellow and blue till cut by vertical oxidized joints, with a ferretto zone and decayed granite bowlders above and with a horizontal sharply defined base (Kansan)..	30
5.	Fine ferruginous sand (Aftonian?)..................	½
4.	Alternating bands of yellow and white cross-bedded sand (Aftonian?)......	8

		FEET.
3.	Pebbly, light gray or yellow, cross-bedded sand and gravel (Aftonian?)	$3\frac{1}{2}$
2.	Fine ferruginous silt (Aftonian?)	$\frac{1}{2}$
1.	Dark, almost black, homogeneous bowlder clay, with bits of gymnospermous wood, limestone and greenstone pebbles and occasional pockets of yellow sand (pre-Kansan)	7

The top of number 1 in this section is a horizontal plane, except at certain places where numbers 2 and 3 make some abrupt and pocket-like detours down into it. Its lower part is almost a pebbleless silt at one point. Numbers 2, 3, 4 and 5, though some of them are very thin, remain, nevertheless, persistent for the whole exposure. Number 6 is in one place almost as dark as the lowermost member and quite like it in texture. In the slope above the top of number 5 there is some more till rather more sandy. This may possibly represent the Illinoian. The same drifts are seen at the bluff in the left bank of Kincaid's run, two-thirds of a mile farther west.

SECTION IN KINCAID'S RUN.

		FEET.
5.	Yellow, sandy till (Illinoian?)	12
4.	Stratified ferruginous gravel and till (Buchanan or Yarmouth?)	3
3.	Yellow and light blue bowlder clay with white chert, leached for two feet at top (Kansan)	18
2.	Ferruginous sand and silty material	3 (?)
1.	Dark, almost black till, weathering rapidly to brown, silt-like at one point, with straight joints and some pockets of sand and gravel extending down from the number above, otherwise having a straight plane for its upper surface (pre-Kansan)	2

Farther up in this creek there is an excavation in the right bluff where a bowlder clay, which is equivalent to number 3 in the above section, terminates above in a leached gray zone two feet high, on which there rests a calcareous and more sandy till twelve feet thick. Just above this place a gravel, which appears to be equivalent to number 2 above, is more than twelve feet thick and is changed into a mortar rock by the infiltration of a calcareous matrix. The section last given is almost exactly duplicated in the south bank of the stream, something more than a mile above this place, near the crossroads in the Se. qr. of Sec. 36 Tp. 77 N., R. III W.

In the margin of the deep drift, where it runs up on the higher bed rock, there thus appear, nearly complete at four places, the same successive phases of drift, viz.:

6. Loess.
5. Yellow till, somewhat sandy....................Illinoian.
4. Sand, stratified till, or a leached horizon........ .... Buchanan and Yarmouth.
3. Yellow and blue till, the main bowlder clay.....Kansan.
2. Sand and gravel, sometimes cemented..........Aftonian.
1. Dark till....................................pre-Kansan.

The exposure on Main street in Muscatine has been examined by Calvin, Leverett and Bain, who have identified the several drifts as indicated. In the study of the drifts in the ravines farther west the author has had the advice of Dr. Calvin, with whom he had the privilege of examining these places a second time. It seems that the nature of these sections, as well as the general features of the drift throughout the county, are in full accord with the theory of a multiple drift, even if this region cannot be regarded as furnishing any important part of the general evidence on which the divisions of the drift have been established, and these divisions are here adopted as furnishing the most satisfactory point of view in a description of the drift in the county.

Drift pebbles.—It will be perceived that the locality offers good opportunities for comparative observations on the character of the three bowlder clays. In course of the work a study of the pebbles in each has been made, which may be worth recording. One hundred pebbles, ranging in size from one-fourth to one-half an inch in diameter, were collected at two points from each drift, care being taken that no selection of any kind should be made except as to size. Notes were taken as to the nature of the rock from which the pebbles were derived, and as to the extent to which they were rounded, scored and polished. These observations were tabulated and the results expressed in percentages for each of the drifts as below:

Percentages of Different Rocks among the Pebbles in the Three Bowlder Clays o Muscatine County.

KINDS OF ROCKS.	PRE-KANSAN.		KANSAN.		ILLINOIAN.	
	From Lowe's run.	From Kincaid's run.	From Main street, Muscatine.	From half mile east of Lowe's run.	From East hill, Muscatine.	From Main street, Muscatine.
Limestone (not dolomitic)	38	39	28	29	3	7
Chert	11	17	12	5	9	8
Limestone (red, decayed)	......	......	1	......	1	4
Chert (Oolitic)	......	1	......	......	......	......
Dolomite (Niagara)	3	7	3	16	60	56
Sandstone (coal measures)	......	1	3	1	......	1
Clay-ironstone (coal measures)	......	......	2	......	1	2
Sand (in paste of limonite, Pine creek conglomerate?)	......	......	......	......	1	3
Pyrites (coal measures)	1	1	......	......	......	......
Coal	......	......	1	......	......	......
Quartz (white)	8	8	12	8	6	5
Greenstone	15	10	10	8	4	5
Quartzite	4	4	6	13	1	4
Granite (red)	......	2	3	5	2	1
Granite (white)	4	3	4	2	3	2
Diabase	1	3	1	12	4	2
Felsite (black)	5	......	5	1	......	......
Schist (micaceous)	4	2	4	1	......	1
Chalcedony	2	1	2	......	......	......
Hornblende rock	3	......	......	......	......	......
Slate (black)	1	......	1	......	......	......
Jasper	......	......	......	......	1	......

Mechanical Character of Pebbles from the Three Bowlder Clays in Muscatine County.

	Pre-Kansan till.	Kansan till.	Illinoian till.
Per cent of rounded pebbles	38	42	29
Per cent of scored pebbles	17	11	8
Per cent of polished pebbles	13	10	2

It will be noticed that as to kinds of rocks represented the Illlinoian drift differs most markedly from the other two, which are in this regard quite alike. Dolomitic limestone is much more frequent in the uppermost drift than in the other two. This dolomite is mostly Niagara limestone. In the two lower bowlder clays the limestone pebbles are nearly all non-magnesian, of a dull white appearance. The rock does not resemble the Cedar Valley limestone. Chert and greenstone are more frequent in the two lower drifts. As to mechanical characters it will be observed that scored, well-rounded and polished pebbles are least common in the upper drift. Rounded pebbles are most frequent in the middle drift, and the scored and polished ones in the lower. The great number of dolomitic white pebbles in the Illinoian is apt to give the impression that scored pebbles are particularly frequent in this drift, but this does not appear to be corroborated by a crucial examination of fragments of the size used in this case. For evident reasons different kinds of rock have not been affected to the same extent by these mechanical processes. This is well illustrated in the table below, and from the same observations as the previous one. It seems that the difference as to scoring may be partly accounted for by the variations of the proportions of the frequency of different rocks:

Mechanical Character of Drift Pebbles of Different Kinds of Rocks.

PER CENT OF WELL-ROUNDED PEBBLES OF—		PER CENT OF SCORED PEBBLES OF—		PER CENT OF POLISHED PEBBLES OF—	
*Black felsite	71	Greenstone	25	*Black felsite	55
Greenstone	49	Limestone	18	White quartz	22
White quartz	48	Dolomitic limestone	6	Limestone	18
Limestone	44	Diabase	5	Chert	15
Quartzite	28	Quartz (all kinds)	2	Greenstone	4
Dolomitic limestone	27	Granite	1		
Chert	20				

*The persistent rounding and polishing of the black felsite pebbles, as well as the absence of scorings on them, suggests that these are derived from some water-laid gravel or conglomerate.

The pre-Kansan Till.—This is the designation given by Bain to a bowlder clay which lies under the Kansan near Afton, in Union county. It is separated from the latter by the Aftonian gravel. There can hardly be any doubt that this drift in Union county and the lowermost dark drift in this county are identical. Their general appearance and their relation to the overlying beds are alike and the same. In this county the pre-Kansan drift is compact and rather tough when not weathered, not particularly hard, but rather floury when dry, almost black, but somewhat rapidly changing color on exposure to the air, usually without conspicuous joints, and containing frequent fragments of gymnospermous wood. In Union county, as well as here, it is associated with silt and loess-like deposits, and there are indications of peaty deposits above it. Besides occurring west of Muscatine, it has been noticed in some places along Mad creek, and perhaps in one place on Sweetland, and at one point on Sulphur branch. If it represents the product of a separate ice period it is quite natural that it should be found sparingly in low places in a region where the abrasive work of the Kansan ice was slight. Such seems to be its situation in this county. It is represented by number 1, in each of the preceding typical sections.

Aftonian Gravel.—This formation was first described by Professor Chamberlin. In the sections given above it is represented by number 2 on Main street, in Muscatine, by numbers 2, 3, 4 and 5 in Lowe's run, and by number 2 in Kincaid's run. It is believed to be the main water sand in the wells in Lake township, lying most commonly about a hundred feet below the surface, and frequently coming out in the base of the bluff west of Muscatine for a distance of four or five miles, where it gives rise to numerous and copious springs. In the east half of section 6, in Fruitland township, it is at one place about twelve feet deep and consists of sand, gravel and some bowlders. In Kincaid's run it is at one place cemented by a strong calcareous matrix. At the center of the west line of section 34, in Sweetland township (Tp. 77 N., R. I W.), and close by a small bridge, there is a fine sand or loose sandstone of a peculiar twisted structure. This Calvin is inclined to regard as Aftonian. It lies under Kansan drift, being exposed for only about a rod square. Part of it is fine and part of it coarse and gravelly. Mica scales are common in the finer layers. It is cut by rather conspicuous straight joints. In three lots of pebbles from these Aftonian gravels, yellow chert, greenstone, white quartz and red granite were the prevailing rocks. These sands and gravels may represent an interglacial interval. They are quite well worn and sorted.

Kansan Till.—This drift sometimes changes downward by gradual transition into the pre-Kansan, but more often it is separated from the latter by the Aftonian. Most commonly it rests on bed rock, ranging in the east part of the county from nothing to 100 feet in thickness and changing from a blue color below to yellow above, where it is frequently leached to a depth of six feet and has a ferretto zone or soil layer. Usually it is cut by irregular joints, which are made more conspicuous by weathering. When dry it is usually very hard where unweathered. Frequent greenstone bowlders are regarded as one of its characteristic features, as also a species of decayed granite bowlders in weathered exposures. In such places fragments of yellow chert are usually conspicuous. This till is represented by number 3 in the Muscatine section on Main street, by number 6 in Lowe's run, and by number 3 in Kincaid's run. In the Muscatine bluff, west of these places, it is believed to rise from fifty to 100 feet above the Aftonian gravel, frequently underlying the loess. It is the main till, nearly everywhere the principal, exceptions being found in southern Cedar township and at East hill in Muscatine. West and north of the West Liberty plain it underlies the loess everywhere, but east of the Cedar it is frequently separated from the loess by the much thinner till of the Illinoian stage. This drift has so frequently been described that a further account of it in this place seems unnecessary.

Buchanan gravel and Yarmouth soil.—Calvin has described some gravels in Buchanan county which were formed in connection with the disappearance of the Kansan ice, and Leverett has discovered a leached horizon with an ancient soil underlying the Illinoian in Des Moines county. Both formations may be said to belong to the interval between these two drifts. The Buchanan represents the gravel-forming period marking the close of the Kansan, and is accordingly but a phase of the latter. The Yarmouth represents the interval between the close of the Kansan and the oncoming of the Illinoian. The gravels seen to be rare in this county. Number 4, in the Main street section, is one of the few instances of its presence. Some gravel underlying a calcareous till in a railroad cut near the county line, about three miles west of Stockton, may belong here. A leached horizon, the Yarmouth, at the top of the Kansan is more frequently in evidence, as will be remembered from the drift sections given. In the road which runs up on the bluff near the center of section 6, in Fruitland township, a similar dividing zone is found in connection with some sand and gravel as indicated below:

SUCCESSION OF DRIFT DEPOSITS NEAR CENTER OF SECTION 6, IN FRUITLAND TOWNSHIP.

		FEET.
7.	Loess, somewhat calcareous, rising with the slope above	10
6.	Yellow, very calcareous till with mostly dolomitic pebbles (Illinoian)	4
5.	Leached, dark sandy clay (Yarmouth?)	2
4.	Gray leached sand (Buchanan?)	3
3.	Yellow ferruginous sand (Buchanan?)	5
2.	Blue and yellow till with well marked ferruginous joints, chert fragments and greenstone pebbles (Kansan)	95
1.	Concealed (springs from Aftonian gravel not far off)	

Illinoian Till.—After the interval which is recorded in the deposition of the Buchanan gravel and in the formation of the Yarmouth soil and leached surface there was an ice incursion from the east, depositing drift material in Scott, Muscatine, Louisa, Des Moines and Lee counties in this state, and over the greater part of the state of Illinois. It was first recognized as a distinct drift by Leverett, who has called it the Illinoian, and who has traced its boundary through Illinois, Iowa and Missouri. It differs from the Kansan in being somewhat less leached, and in having a topography not quite as old, in presenting a fresher appearance, in containing a larger proportion of bowlders of Keweenawan rock and in having (in this county) many dolomitic limestone pebbles. It is believed to have occasional erratics of a conglomerate known to occur on the east shore of Lake Huron, and copper nuggets are also supposed to be more frequent in this drift than in the Kansan.

In Muscatine county the Illinoian drift has not reached any great development. It seems to occur only in separate areas on the Illinoian drift plain, where undoubted exposures of Kansan till underlying the loess are very common. The terminal moraine which should cross the county from northeast to southwest is nowhere well marked, unless it be in the south part of Cedar township. From indications of the topography the principal marginal accumulations of this ice field have been made out to follow in the main the divide between the Cedar river drainage and the drainage of the Mississippi, excepting in Cedar township, where it comes out to the southwest approaching the Cedar river. Along the course of the divide there are occasionally low and wide swells of land rising slightly above the general level, and also some small, undrained ponds, usually covering a fraction of an acre of ground. Such ponds are seen in sections 33, 34 and 35 in Cedar township, 2, 3, 15 and 22 in Seventy-Six township, in 29 and 32 in East Lake township, in 10, 11, 13, 15 and 16 in Bloomington township, and in section 4 in Sweetland. The topography indicates, however, that the Illinoian drift does not terminate with this limit, but that there are small extra-marginal accumulations as far out as to the bluffs of the Cedar river and to the Mud creek valley. The presence of loess and sand renders a definite determination of the locus of the Illinoian border very unsatisfactory, if not quite impossible.

Some occurrences of this till have already been described in the typical sections west of Muscatine, and these may be passed by here. It is well exposed in East Hill, where several streets are graded down into it. The greatest thickness is seen in the clay pits of the brickyards on either side of Second street. Farther down in the face of these excavations there is a calcareous blue silt with alternating layers of fine sand. This silt is taken out for the manufacture of brick, and a thickness of ten feet is often exposed in the bank. It is calcareous and for the most part finely laminated. Some of the coarser layers are ripple-bedded. In one place its upper surface appeared as if worked into the till above. This till varies from eight to fifteen feet in thickness and is all Illinoian. It is grayish-blue in color below and yellow above, and contains numerous pebbles of dolomitic limestone and bowlders of Keweenawan eruptives. The upper unleached surface of this till is covered by a sand of apparently the same age, for it contains occasional striated pebbles and bowlders of the same rocks and of the same general appearance as those in the bowlder clay. In two feet this sand changes upward into coarse and stratified loess which, in its turn, is succeeded by typical yellow floury loess of a finer grain. The author believes that the lower calcareous silt at this place is a deposit formed in some marginal glacial water, subsequently overrun by the ice containing the bowlder clay which now lies above it, and that the bowlder bearing sand which rests on this till was a contemporaneous deposit, either on the till or on the ice itself, at some stage of its disappearance from this region.

Some twenty rods east of the center of section 24 in Bloomington township, in the south bank of the railroad cut, a fresh looking till appears, which is calcareous to within two feet of its upper surface, where there is a slight ferretto zone under the base of the loess. To the south of the creek, which is here followed by the railroad, the land rises in a low and broad loess-covered ridge running parallel with the creek and suggesting an underlying deposit of the same till. The Illinoian already noticed in the bluff near the center of section 6, in Fruitland township, is connected with a similar topographic feature, for close by to the west there is a ridge running a little west of south. Superficially this ridge consists of loess, below which there is sand with some pebbles and bowlders. This ridge is certainly built by some constructive agency and not a result of erosion.

In the southwest quarter of section 32, in Cedar township, the river cuts into the east bluff, which is here made up of the swell supposed to represent the terminal moraine of the Illinoian ice lobe. The till is dark and blue below, cut by somewhat weathered joints of a peculiar clustered arrangement and appearing quite unlike the weathered joints in the Kansan. The entire bluff, a hundred feet in height, consists of this till, capped by loess. The bowlders which it contains are frequently planed and more fresh in appearance than those of the Kansan till. Chert is somewhat scarce and there is a greater proportion of Keweenawan material, such as agate nodules, diabase, red slaty sandstone and gabbro. Bowlders and pebbles of limestone are common. On approaching the county line this till somewhat suddenly becomes sandy, which fact perhaps may be looked upon as corroborating the topographic evidence of the existence of a drainage course on the Illinoian ice from the east, following a depression across the upland from the Mississippi to the Cedar, just south of the county line.

A yellow till, leached for about three feet down from its upper surface, is seen under the loess in a road grading near the center of the south line of the southeast quarter of section 28, in Bloomington township. Judging by its appearance and its pebbles it is probably to be referred to the Illinoian.

The places enumerated here are not supposed to be all the localities of exposures of this till, but they appear to be the most important ones. In the region of Pine creek this till seems to be absent, as also in Sweetland creek valley, leaving the Kansan topography unmodified.

The small development of the Illinoian till and the absence of a well defined terminal moraine in this county seems to be due to two causes. Coming from the southeast, as the ice must have done if its motion was normal to a perpendicular to its margin, there was a tract of high land present to obstruct its progress in the west end of Rock Island county, in Illinois, and in the southeast part of Sweetland township on this side of the river. In the basin of Pine creek there is, as just stated, a total absence of Illinoian drift. The high land to the south may have retarded the flow in this direction and prevented it from bringing in much of its drift. Another circumstance which may have contributed in reducing the quantity of the drift from this ice is to be inferred from the conditions indicated for an efficient marginal drainage and ready ablation of this segment of the ice lobe. Mr. Leverett has shown that at the time of the maximum development of the Illinoian ice the waters of the Mississippi most probably followed the Mud creek swale from the Wapsipinicon south of Dixon, past Durant and Wilton, to Moscow, at which place it emerged on the low lands of West Liberty plain. The great river thus followed closely the margin of the ice, rendering the removal of drift uncovered by ablation of the marginal ice easy and prompt. Part of what might, under different circumstances, have formed a marked terminal moraine may therefore be deposited under the West Liberty plain.

Evidence of such ablation is not wanting. In an excavation made by the Chicago, Rock Island & Pacific railroad, near the west line of section 5, in Fulton township, the loess rests on sand and gravel, associated with what appears to be some Illinoian till. This gravel consists of more than 80 per cent of Devonian limestone, the lower fossil-bearing beds being represented as well as the unfossiliferous brecciated beds. It is a crush gravel, formed most likely in the ice or under it. Some pebbles were left in situ in the process of breaking, other stronger fragments being forced into them. This gravel cannot have been transported any great distance. In such case it would be found mixed with a greater quantity of other drift material from other localities. The only place from which it seems likely that Devonian rock of this kind can have come is to the southeast (see chart on preglacial topography), where ledges of the kind represented come up to an unusual height. In all probability transportation by the ice was to the northwest. The presence of the gravel indicates a removal of finer material of the drift, and this would naturally be taken in the same direction. A mile and a half east of Stockton, on the same road, another excavation, newly made at the time of observation, exhibited highly tilted beds of silt and sand and gravel ten feet high under loess. These materials constitute apparently the central body of a long, low and flat ridge running northwest-southeast, indicating a drainage line on the ice having the same direction as in the previous instance.

Near the center of Sec. 8, Tp. 77 N., R. II W., where a branch of Chicken creek crosses the road running east and west, there is seen under the loess on the east side of the bridge, a deposit of coarse, stratified ferruginous sand several feet deep. This may possibly belong here, for it appears to be replaced on the west side of the ravine by a sandy till somewhat stratified, and not unlike the Illinoian.

A yellow sand is very generally present under the loess over the outer slope of the Illinoian drift plain. It varies in thickness from a mere streak to ten feet and more. In the southern part of Moscow township, south of Little Musketo creek, in the northwest part of Bloomington township, in Lake township, in the northwest part of Seventy-Six township, and in Cedar township a similar sand frequently forms a large part of low, flat, loess-covered ridges which extend out radially to the margin of the drift plain as previously described. Superficially some resemble the paha described by McGee, but the genesis and structure are wholly different. A few of these ridges have been lately modified by wind action. It is believed that some, if not most of them, may have been produced by drainage lines on the Illinoian ice, which very likely at some time extended out of the bordering low lands. Such an explanation of them is suggested not only by the topography, but also by the fact that the sand occasionally contains pebbles and small bowlders, as has been observed on section 1, in Seventy-Six, and on section 12, in Lake township. Occasionally they consist of clay and sand, so placed that an open well may have one wall in the coarse and the other in the fine material. In fact they appear to have a structure akin to that seen in the ridge east of Stockton. The high slope of the silt beds in that ridge plainly indicates tilting after deposition. To account for such tilting we may regard the ridges as accumulations along drainage lines on the surface of the ice. They may have been augmented by wind action at the time of making or afterward. As the ice melted away the beds settled down to their present altitude, forming disconnected low ridges trending in the direction of the drainage lines. One of these ridges follows, like a typical osar, the present course of a stream. It is the one already referred to in the description of the topography as having been observed near the north line of section 14, in Cedar township, following a creek on its north side. It is about twenty feet high and ten rods wide, with a chain of small undrained ponds on the north side, and consists of sand, occasionally mixed with clay. Between these ridges or wide swells there are flat and low stretches of land from one-fourth to one-half a mile wide. In the absence of exposures it cannot be made out whether all these swells consist of Illinoian drift or whether some represent old Kansan divides, and the intervening flat lands are in old valleys between, which have been filled with overwash from the Illinoian ice. In either case the topography here at times indicates the presence of some drift which is later than the Kansan, and most likely produced by drainage from the outer margin of the Illinoian ice. Attention has already been called to the fact that this drift was not sufficient in quantity to fill the inequalities of the topography of the Kansan and impress the land with a topography of its own. At the vanishing of the ice itself the old valleys naturally determined the new drainage. Along the course of the Pine creek, Sweetland creek and Mad creek, which had deeper valleys than the other streams, there seems to have taken place at this time a deposition of various materials such as gravel, stratified, sandy bowlder clay, sand and fine laminated silt that deserve special notice. It may be that part of them were formed earlier and really represent the Illinoian drift, and it is possible that some have a later date than this and should not be referred to this stage at all.

An instance of this kind is the stratified bowlder clay mentioned in describing the ante-glacial silt as occurring near the south line of section 19, in Sweetland township. It forms an ill-defined terrace on the west side of the creek. In Sec. 26, Tp. 78 N., R. I W., there is a well-defined terrace from fifteen to twenty feet higher than the bottom land of the creek. It follows the west branch of Pine creek for nearly a mile, varying in width up to at least twenty rods. In some places the material of this terrace is yellow stratified sand, and in other places it consists of fresh looking calcareous till, faintly stratified. This till, as well as the yellow sand, runs upward into loess which forms a capping from three to five feet thick over most of the whole terrace. Similar imperfectly defined terraces appear in section 2, in Sweetland township, along the same creek. In the lower valley of Pine creek there are several remnants of a terrace rising generally twenty-five or thirty feet above the bed of the creek. Near Pine Creek mills, on the east side of the stream, the upper part of this terrace consists of fine laminated, purplish-brown silt, which contains calcareous nodules. It is overlain by loess and the separation between the two is trenchantly marked. Farther down the whole terrace is well exposed in the right banks of the creek. In the bed of the stream at this point the coal measures appear, rising some twelve feet from the creek bed. On top of this there is five feet of clayey gravel, then a foot of yellow silt, and above this about seven feet of alternating layers of yellow and red silt. Part of the latter is exceedingly fine and unctuous. Some rods to the west this fine silt is overlain by porous loess. The same silt occurs in the same relation to the loess half a mile to the south. At each point these materials contain pebbles of the Niagara dolomite, in that respect resembling the Illinoian drift, which otherwise is conspicuously absent. It is also highly calcareous.

Along Mad creek, in Muscatine, there is a terrace of similar structure. A spur of it is cut across by the Burlington, Cedar Rapids & Northern railroad, close by Eighth street, at which place its upper part consists of a finely laminated, highly calcareous, red or blue silt, with numerous calcareous nodules. Eight feet from its upper surface there are some coarse seams which contain pebbles of Niagara limestone. In the east bluff of the creek, on Ninth street, a thin sheet of loess rests on a laminated sand twelve feet deep. In the upper part of this sand there are several pebbly seams containing material mostly from the Niagara limestone. This sand apparently replaces the Illinoian drift, which is seen associated with a little of the fine silt on the opposite side of the creek. In Park Place addition the same fine dark silt of the terrace occurs on both sides of the creek. Where not covered by loess it forms a tough, impervious soil. It has recently been exposed by grading just east of the Muscatine Pickle works. Another most interesting occurrence of it is in a small ravine opposite Fourth street in East Hill. At this place it changes downward into Illinoian till, which is slightly stratified, and it is abruptly succeeded on the brow of the hill by typical porous loess. On the opposite side of the ravine there is more till and less silt, but otherwise the succession is the same.

The gravel which has been worked on Mr. Samuel Sinnett's farm, near the southeast corner of section 23, in Bloomington township, probably also belongs to the stage of ablation of the Illinoian ice. It overlies a till which resembles that of other exposures referred to this stage, and the two are in fact interbedded. It contains much Archæan material, but there is also a considerable amount of Niagara dolomite.

The Sangamon Soil and Leached Horizon.—After the disappearance of the Illinoian ice no more bowlder clay was deposited in this county. The water of the Mississippi found a lower overflow along its present channel, and ceased to come down by way of Mud creek channel. Some patches of loess and sand appear to have covered the Illinoian deposits from the first, but for the most part the surface of the land at this time consisted of Kansan and Illinoian till. This surface was for a long time being leached and oxidized by atmospheric agencies, and a soil was formed in the same way as soils are formed to-day. On low grounds sand and peaty accumulations were laid down. Deposits of atmospheric dust were, perhaps, also made in favorable situations. This stage has been called the Sangamon soil and leached horizon by Leverett, who finds it particularly common in the valley of the Sangamon river, in Illinois. It is frequently seen in Muscatine county. Near the southwest corner of section 14, in Bloomington township, a ravine has cut under the loess and some yellow sand. Beneath this there is a dark, peaty, muck, with imbedded wood. In the country to the northeast from here, in Wilton, and especially in Sweetland township, a mucky soil with wood is reported by well makers as very frequent at this level. West of the center of section 6, in Montpelier township, on Mr. Daniel Grimm's farm, Mr. Charles Alteneder found under the loess a buried soil on a bowlder clay which was perforated by what appeared to be filled gopher holes.* In a ravine on the east part of section 1, in Montpelier township, the ash-colored base of the loess over-

*Professor Witter reports having seen wood from this muck, at another place, on which there were marks of a beaver's teeth.

lies a thin seam of black muck filled with decayed vegetation, and this in turn rests on a sticky, blue, leached soil, which forms the upper surface of the underlying bowlder clay. A deep peat which, probably, also is to be referred to this formation, occurs in a ravine at the northwest corner of the southwest quarter of section 34, in Sweetland, at a point where this leaves the loess and begins to cut down in the bowlder clay below. Near the center of the southwest quarter of section 12 there is a peat which contains large pieces of gymnospermous wood, and from which were taken some elephant bones, now in Mr. Charles Weir's museum in Muscatine. Traces of peaty material are seen in the base of the loess in the old clay pit near the corner of Eighth and Chestnut streets in Muscatine. One-eighth of a mile southwest of the center of section 19, in Pike township, there is a spring in the bluff of the Kansan drift plain. Right above this spring there is ten feet of loess, which rests on a black soil of bowlder clay. Near the center of the southwest quarter of the same section the same soil is seen higher up under six feet of loess. In this township the old soil rests on Kansan till. On the highest uplands the surface of the till under the loess, as a rule, presents a leached and oxidized zone in all parts of the county.

Lake Calvin.—During the time these soils and leached horizons were forming on the higher ground the lowlands along the Cedar were covered by a lake-like expanse of the Cedar river, and were being filled with gravel and sand. An important instance of evidence to this effect was found near the north line of the northwest quarter of section 23, in Cedar township, on the land belonging to Mr. W. B. Verink. At this place a stream runs down from the upland to the Cedar bottoms. In the cut of the road on the west section line the following drift section was noted:

		FEET.
3.	Loess, slightly sandy in places and running into laminated silt below, which appears slightly disturbed	10
2.	Peat, in irregular pockets and lumps	2
1.	Grayish-white, leached sand, with a weak incipient calcareous matrix	6

On the north side of the creek the same succession appears, but here the peat and sand have been cut away toward the creek, and the loess comes down over their eroded edges. Not far from the center of the north line of the same section the creek has exposed the peaty material again. The section here is as follows:

		FEET.
6.	Sandy loess, in places irregularly stratified	7
5.	Sand	1
4.	Stratified, yellow sand, with some fine, bluish silt	5
3.	Peaty layer, with black fragments of plants, partly disturbed	1
2.	Pinkish or yellow diatomaceous mud	½
1.	White, stratified sand to below the bed of the stream	12

The bed of this creek is about on a level with the West Liberty plain. Samples of the diatomaceous mud which lies under the peat have been examined by Mr. P. C. Myers, of the University of Iowa, and he has identified fourteen different forms of diatoms, a list of which he has published in the Proceedings of Iowa Academy of Sciences, vol. vi, pp. 52–3, giving the habitat of each species.

LIST OF DIATOMS FROM THE DRIFT IN CEDAR TOWNSHIP.

SPECIES AND HABITAT.

1. *Navicula abaujensis* Pant. Fossil in fresh-water deposits, Hungary.
2. *Navicula borealis* (Ehr.) Kuetz. Fresh water, cataracts, rivers and wet moss, all over Europe and America.
3. *Navicula gibba* (Ehr.) Kuetz. Found everywhere in fresh water.
4. *Navicula major* Kuetz. A cosmopolitan species in fresh water.
5. *Navicula nobilis* (Ehr.) Kuetz. Var *dactylus* (Ehr.) V. H. In bogs; also found fossil.
6. *Navicula rupestris* (Prinn.) Hantz. On wet rocks.
7. *Navicula placentula* (Ehr.) Kuetz. In rivers in Europe and America, also marine, sometimes fossil.

8. *Eunotia diodon* (Ehr.) In rivers, on wet rocks, sometimes fossil; found also in springs and rapids.

9. *Eunotia gracilis* (Ehr) Rabenh. In boggy, swampy places.

10. *Eunotia major* (Wm. Sm.) Rabenh. In fresh water everywhere.

11. *Stauroneis phœnicenteron* (Nitz.) Ehr. Cosmopolitan.

12. *Cystopleura gibba* (Ehr.) Kunze. Common in fresh water, also fossil and marine.

13. *Cymbella cymbiformis* (Kuetz.) Breb. Var. *parva* (Wm. Sm) V. H. Common everywhere in fresh water.

14. *Hantzschia amphioxys* (Ehr.) Grun. Common everywhere in fresh water.

From this list and from the comparative number of individuals of each species Mr. Myers infers that the conditions attending the deposition of this mud were probably such as are found in shallow bogs subject to gentle overflows from some creek or river. This view is in accord with the evidence from the containing beds. These consist of sand and silt and occupy a level at which such materials could not have been laid down in any quantity except in slack water. The sand under the peat is very pure and much more like a littoral lacustrine sand than sand deposited by a creek. In all probability the sand was a deposit in the lake near its margin. As the filling proceeded marshy conditions were produced and at this stage the diatomaceous mud and peat were made. Later on these were covered by a few feet of variable layers of silt and sand, such as are now forming over bottom lands.

Sandy water-bedded deposits of a similar nature occur under the loess on Mud creek, near Wilton, and have yielded the remains of a mastodon or elephant. Dr. Calvin investigated this locality for the University of Iowa, at the time of the discovery of the bones in 1874, and gave an account of the fossils and the containing beds to President Thatcher. The main facts presented in this report are summarized below:

The bones were found in the south bank of the creek about half a mile south of Wilton, at a point where the stream coming from the north bends abruptly to the west. Measured from the water, the bank at the time rose nearly thirty feet high. The several bones lay at about the same level in the bank. The skeleton had evidently arrived entire at the place but it was dismembered and scattered before it became finally imbedded. The deposits containing the skeleton were modified drift, consisting of alternating strata of very fine sand and clay. The fineness of this material, the regular stratification and absence of organic matter, indicated that at the time of the imbedding of the skeleton, the locality was covered with comparatively deep, clear and still water, "having nothing of the character of a marsh but rather resembling the bottom of some wide lake or some large, slowly moving river." The topography of the surrounding country and the nature of the drift itself, favored the idea that a lake at one time covered the territory of the West Liberty plain and reached up to Wilton, and that sediments from some in-flowing river had aided in filling this lake. "*Occasionally larger bodies carried by some more powerful agency, found their way out to the deeper parts and became covered up by the accumulating sediment.*" The evidence was conclusive that the sediments containing the bones were laid down after the ice had disappeared from the region. In the excavated skeleton the cranium and the cervical vertebra were missing, but of the vertebræ there were exhumed nine of the dorsal, two sacral, and one caudal; besides thirteen ribs, one segment of the sternum, parts of both of the innominate bones, one femur, the right tibia, a number of the tarsal, metatarsal and phalangeal bones, one patella, the right scapula, the lower end of the humerus and some carpal and metacarpal bones. The right scapula was in a particularly perfect condition. Measurements were taken as follows:

	INCHES.
Scapula—	
Length, from margin of glenoid cavity to superior angle	39
Width from posterior angle to opposite border	28
Glenoid cavity, diameters	9½, 5½
Circumference of head	32½
Weight, 51½ pounds.	
Longest rib, on outer curve	52
Widest rib, across	4
Vertebra (first dorsal)—	
Width and depth of centrum	5½
Across lateral process	11½
Length of dorsal process	10
Height of neural arch	2¼
Width of neural arch	2½
Right tibia—	
Length	35
Circumference at top	22½
Circumference at middle	10¾
Humerus, circumference at lower end	37

The water in the lake in which these deposits were laid down appears to have stood highest at the time of the disappearance of the Illinoian ice. Over the north and west slope of the Illinoian drift plain the loess is often underlain by a yellow sand. In one or two places this sand has been observed to be water-bedded.

It will be remembered that the Illinoian drift on East Hill in Muscatine appears to be continuous with sand that changes upward into loess. Less than half a mile from this place to the northeast several Archæan bowlders come up above the surface of the loess, eight having been counted on an area of a few acres. The largest one is at least four feet in diameter and the smallest one a little less than one foot. One is seen in the cut of the road going down the bluff along the south line of section 25. The loess at this place is only about five feet deep and the bowlder comes up to within six inches of its surface. In section 23, in Bloomington township, bowlders are sometimes seen on top of a sand under the loess and extending up into the latter, which in such places, usually, is thin. In section 35, in Moscow township, wells are reported to enter a sand which is twenty feet deep, under four or five feet of surface loess. Some bowlders have also been found on the surface of low lands in this section. Along Musketo creek in section 23, sand and loess frequently interchange and replace each other. One bowlder was seen resting on loess near the south line of section 8, in Wilton township, one in the southwest quarter of section 11, and one near the center of the west line of section 2, in Moscow.

At none of these localities where bowlders have been found is the loess more than a few feet deep, nor does it have the appearance of the typical upland loess. It is at the same time more clayey and more sandy, resembling certain phases of alluvial deposits. The bowlders lie on comparatively low upland, not exceeding 700 feet above the sea level. The two first mentioned localities are in a wide, shallow depression of the Illinoian drift plain, which extends from the valley of Mad creek northwestward. The bowlders were, in all probability, transported by floating ice on the surface of the lake at an early stage, when its waters stood high, and were probably stranded on the shore. Before the disappearance of all the inert remnants of the ice farther to the south, where the flow had been stronger than here, there may have been a temporary drainage across the land from below Moscow to the Mississippi near Muscatine. The high stage of the lake must, however, have been of short duration, for the bowlders are few and not associated with any indications of a shoreline. It may indeed have been of the nature of a periodic or an accidental overflow. For most of the time of its subsequent existence it must have been a wide expansion of the Cedar river, somewhat like Lake Pepin in the Mississippi of to-day, with its water level but slightly higher than the present surface of the West Liberty plain. At this level there has been some cutting, and it seems to have been maintained until the basin was filled. This probably occurred near the advent of the Iowan ice to the north. The sand ridge which frequently crests the bluffs on the east border of the plain is most likely a wind drift formed on the lee side of the lake a this stage.

With regard to the nature of the filling, not very much is known. Over the whole lake plain, excepting the Cedar bottoms and a strip of varying width following these on the west, there is usually a superficial deposit very much like a loess, ranging from five to fifteen feet in depth. This must have been deposited latest and probably after the river began to meander on the old lake bottom. Downward it changes gradually in a few feet to a yellow sand, and this in turn rests on gravel and sand. At Nichols the filling has been explored to a depth of 250 feet (some reports make it 300 feet). Near Atalissa it is known to reach down 100 feet. At the old ford in section 36, in Goshen township, riffles of bowlders appear in the bed of the river and the greater number consist of greenstone, yellow chert, granite and white quartzite. The fragments are noticeably angular and are probably derived from the Kansan drift. On section 32, in Orono township, the river cuts into the gravel of the plain bed. Some of the bowlders are from two to four feet in diameter, and some were seen to have plain glacial scorings. The most frequent rocks among the bowlders are diabase, granite, greenstone

Trenton limestone, Niagara limestone, and Sub-Carboniferous limestone resembling the Burlington. The latter must have been brought from the south or west. To sum up, part of the filling in the preglacial basin was most likely furnished by the Kansan drift. In the deposition of the uppermost gravel floating ice seems to have aided in bringing some of the bowlders.

The topographic features of the lake plain have already been described in a previous chapter. The full history of the lake can not be made out, since none of its shore lines appear above the level to which it has been filled. The occurrence of diatoms and mastodon remains in some of its sediments is in itself significant of the age of some of the upper part of its filling, for diatoms and mastodon remains have both been taken from the Sangamon soil resting on Illinoian till in the west part of Davenport, in Scott county.* The correlation

*The diatom-bearing mud in this place has been examined by Dr. Astrid Cleve, of Upsala, Sweden. She reports the following forms:

Cymbella gastroides Kuetz. Rare.
Eunotia monodon Ehr. Common.
Eunotia prærupta Ehr. Common.
Eunotia prærupta var. *bidens* Grun. Common.
Hantzschia amphioxys (Ehr.) Grun.
Navicula amphibola Cl. Common.
Navicula semen Ehr. Common.
Pinnularia commutata Grun.
Pinnularia streptoraphe var. *minor* Cl.
Pinnularia streptoraphe var. *styliformis* Grun.
Stauroneis phœnicenteron var. *amphilepta* Ehr. Rare.
Stauroneis javanica Grun. Very rare.

From other samples taken later Mr. P. C. Myers has added the following to the list of identified diatoms from the same place.

Eunotia gracilis (Ehr.) Rabenh. (Not common.) Bogs and stagnant ponds.
Eunotia diodon Ehr. (Common.) Springs, rivers, cataracts.
Encyonema cæspitosum Kuetz. (Very rare.) Stagnant water, lakes, rivers.
Gomphonema subtile Ehr. (Very rare.) Quiet water, fossil in Europe.
Gomphonema dichotomum Kuetz. (Very rare.) On algae in quiet, fresh water in Europe and America. Fossil in Silesia.
Meridion constrictum Ralfs. (Very rare.) Living and fossil all over Europe and America.
Navicula borealis (Ehr.) Kuetz. (Not rare.) In rivers, cataracts, wet moss; Europe and America. Also alpine.
Navicula elliptica Kuetz. (Not rare.) Fresh water, brackish water, in lakes, and fossil.
Navicula dicephala Ehr. (Common.) Everywhere in fresh water.
Navicula placentula (Ehr.) Kuetz. (Common.) Rare in fresh water, common in brackish, also common as fossil.
Navicula mutica Kuetz. (Not rare.) Common in brackish water, rare in fresh water ponds and lakes. Fossil in Prussia.
Navicula hilseana Janish. (Common.) Fresh water lakes.

☞ Continuation of notes on following page.

with the Sangamon rests, however, on better evidence, which must be sufficiently clear from the account given.

In conformity with precedents this fossil lake should properly be known by the name of its discoverer, whose distinguished service to science since the time of his observations in this region, twenty-five years ago, has so greatly advanced our knowledge of American geology.

The Loess.—Excepting the bottom lands and some sandy tracts on West Liberty plain, and on the west slope of the Illinoian drift plain, loess invariably covers the drift throughout the county. It is best developed along the bluffs of the Mississippi river, where its usual depth is from fifteen to twenty-five feet. Opposite Broadway, on West Hill, in Muscatine it is nearly forty feet deep, and this is its maximum thickness as far as known in the county. On the outer slope of the Illinoian drift plain it averages about ten feet, and on the Kansan drift plain it has about the same depth. On long and low slopes to lowlands and ravines it frequently is no more than five feet deep, but where there has been considerable cutting back on such slopes, producing abrupt bluffs, it is apt to be deeper. This circumstance, together with well records from the higher flats of the upland, indicates a greater development on the undissected flat uplands. On some terraces, and on the West Liberty plain, the loess-like superficial material is usually only a few feet in thickness. The formation occurs at levels, usually following the gentler slopes on the drift surface, and sometimes also the steeper slopes.

Four different phases of loess may be mentioned. A sticky and sandy phase has already been referred to as possibly con-

---

Navicula bacilliformis Grun. (Not common.) Rare in fresh water lakes.

Navicula viridis Kuetz. (Common) Widely distributed, preferring quiet, shallow ponds and bogs fed by springs.

Navicula iridis Ehr. var. *affinis* (Ehr.) V. H. (Very rare.) Fresh water everywhere.

Navicula gibba (Ehr.) Kuetz. (Not rare.) Fresh water all over North and South America and Europe.

Navicula viridis (Nitzsch) Kuetz. (Not common.) Fresh water everywhere.

Nitzschia palea (Kuetz.) Wm. Smith. (Very rare.) Frequent in creeks, rivers and ponds.

Pleurostauron autum (W. Sm.) Rab. (Rare.) Common in fresh water.

Suriraya ovalis Breb. var. *minuta* Breb. (Rare.) Rivers, cataracts and mountain streams

Tabellaria fenestrata (Syngb.) Kuetz. (Very rare.) Everywhere in fresh water

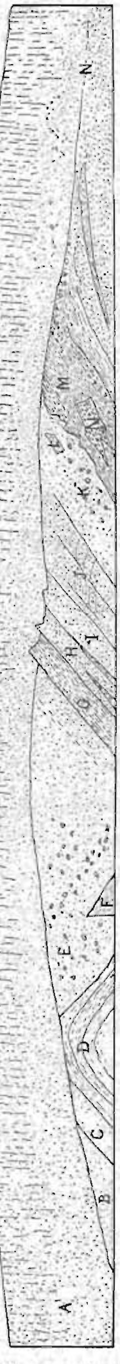


FIG. 38. Section of drift exposed in a railroad cut, in a low ridge, one and one-half miles east of Stockton. A, loess; B, gray sand; C, ferruginous sand; D, faintly bedded silt; E, red sand and gravel; F, silt; G, yellow silt; H, red sand; I, yellow sand; J, cross-bedded sand and gravel; K and L, square blocks of fine silt imbedded in sand; M, fine silt, sand and gravel; N, sand changing upward into loess.

nected with fluviatile conditions attendant upon the early stages of Lake Calvin. It differs from the other phases in being thin and in having, at a few places, a small number of bowlders imbedded. Another phase is interbedded with the upper part of the Illinoian drift, and contains frequent snailshells. It seems to have formed on or near the Illinoian ice in its vanishing stage. One exposure of this kind is seen in the bluff along Hershey avenue, about two blocks west of Maine street, in Muscatine. It contains some pebbles in its lower part.* Another was seen in a fresh railroad cut across a low swell east of Stockton. Here there is, strictly speaking, no interbedding with the bowlder clay, but some highly tilted beds of silt, on the edges of which it rests, were observed to run up into the base of the loess with sharp, projecting edges, in such a manner that it appeared inconceivable that they should have been so imbedded unless the layers of silt were frozen at the time. The tilting of the underlying bedded materials suggests settled superglacial or englacial accumulations (Fig. 38). Still another phase of loess is coarser than the usual, and contains seams of fine sand and, in one instance, coarse sand and small pebbles. It is always evenly laminated, and at the same time free from clay or fine material. It is seen in the basal part of the loess,

* For fossils in this formation, see page 388.

and occurs along present or former large waterways. This is usually cut by slanting, straight joints into slightly faulted blocks, and changes upward into fossil-bearing, structureless loess. Typical exposures are seen near the crossing of Eighth and Pine streets, in Muscatine, and in the railroad cut in a small isolated hill, near the northwest corner of section 6, in Fulton township. At the latter place it rests on ferruginous gravel, into which some bent, vein-like protrusions of the base of the loess extend in a way that suggests extensive settling after deposition (Fig. 39). A little higher up it contains fossils, among which have been identified by Professor Shimek *Helicodiscus lineatus* (Say) Morse, *Pupa muscorum* L., *Bifidaria pentodon* (Say) Sterki, and *Succinea avara* Say. This phase seems also to be related to the Illinoian drift. Finally there is the floury loess without lamination, and uniform in composition. This is by far the most common phase, and into it all the other phases grade vertically or horizontally. It constitutes the usual upland veneer. It is occasionally fossil-bearing. In the city of Muscatine Professor Witter has collected from it the following mollusks:*

Helix striatella.
Helix fulva.
Helix pulchella.

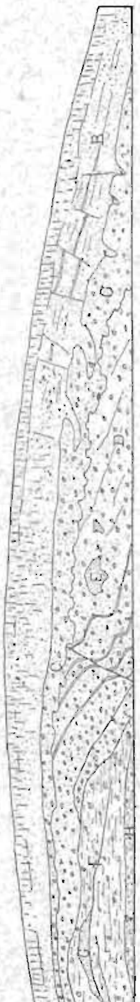


FIG. 39. Section of drift exposed in a railroad cut in a low hill three quarters of a mile west of Stockton. A, loess of somewhat compact texture; B, loess, with fossils above and coarse streaks below, cut by slanting straight joints; C, pebbly sand; D, stratified gravel; E, blocks of silt; F, till; G, silt, resting on some ferruginous sand; H, blue till.

*Proc. Iowa Acad. Sci., vol. I, pt. i, p. 16. 1880.

Helix lineata.
*Pupa blandi.**
Pupa corticaria.
Pupa muscorum.
Pupa simplex.
Succinea avara.
Succinea obliqua.
Helicina occulta.
Limnæa humilis.

Besides these mollusks he has also discovered teeth, bones and antlers of a species of caribou or deer, and a tusk and teeth of a mammoth or mastodon.

Opinions differ as to the origin of the loess. The usual view has been that it is an aqueous sediment, laid down at a time when the land was submerged. Chamberlin has lately advanced the hypothesis that it is in part an atmospheric sediment and in part a surface wash. Some of the features presented by the loess in this county seem to sustain such a view.

The greater part of the loess in this county was no doubt formed subsequent to the Sangamon stage, at the time when the Iowan drift was being deposited to the north of this region, as Calvin has shown. But some loess seems to be older than this, as where it is found interbedded with the Illinoian drift. Some may also be more recent. Professor Witter has reported the finding of chipped flints in the upper part of the loess exposed in a clay pit on Eighth street, in Muscatine. The author has found a river unio two feet from the surface of the loess on the bluff overlooking the Mississippi, in section 29, in Sweetland township. It was associated with chips of flint, and must have been brought there by human agency. Near the center of section 8, in Lake township, he accidentally found a nest of stones of a size suitable for hand hammers, lying one foot under the sod in

*The fossils from eastern Iowa usually identified as *Pupa blandi* are *Pupa pentodon*. *Pupa blandi* seems to be restricted, so far as the loess fossils of Iowa are now known, to the western part of the state. B. S.

the loess. There is no doubt that they had been placed there by human hands. It may be that at all of these places these relics of human work were purposely buried, but nothing has been observed to indicate that such was the case. An alternative view is that they were simply left on the surface of the ground and have been covered later by secular accumulation of atmospheric dust. If this be the correct view the surface loess in these places must be quite recent.

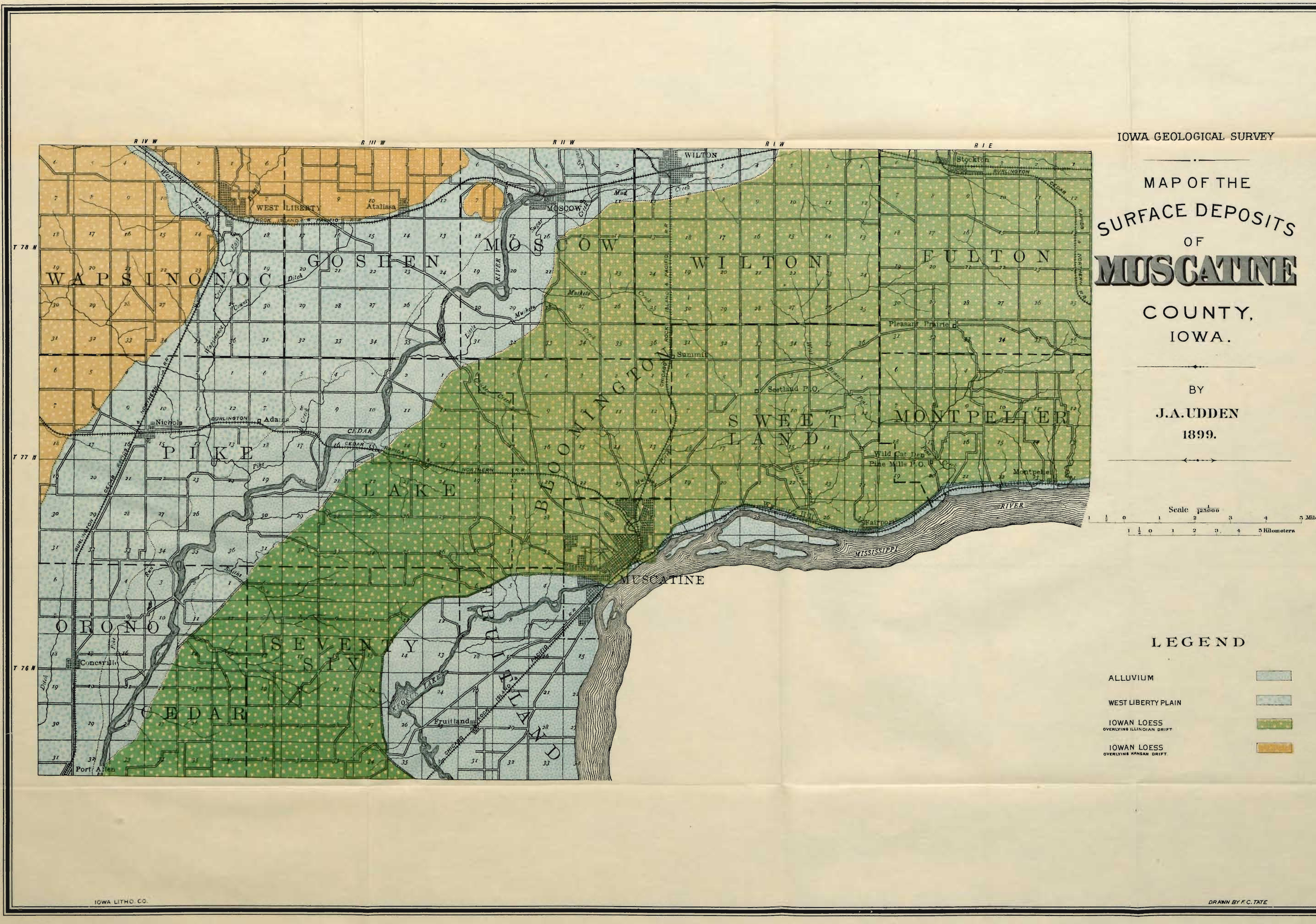
Terrace and Alluvium.—The deposits on the Cedar bottom are usually not very sandy. This bottom forms a belt about two or three miles in width, except near the north and south boundaries of the county where the valley of the river is narrow. At Moscow the town is situated on a terrace which appears more recent than the West Liberty plain. East of the railroad depot an excavation in this terrace, twenty feet deep, shows a structureless, yellowish, surface sand two feet deep, resting on a white or gray sand rather free from gravel. The Mississippi bottom land above Muscatine is narrow, and only a small strip next the river is subject to overflow. Above this the ground is a low slope up to the bluffs, in part at least formed by wash from the latter. This slope is never sandy. Below Muscatine, alluvium covers most of the island, and also the slope between the Muscatine slough and the bluffs. This slope largely consists of confluent fans of deposits from the creeks and ravines draining the uplands, and these fans are usually proportionate to the streams in size. Muscatine island is mostly covered by a rusty sand which in some places, as in sections 16 and 21, in Fruitland township, contains a large amount of gravel. On the south half of sections 33 and 34 there is a remnant of a terrace, known as the Sand Mound, rising from thirty to forty feet above the level of the island. It consists of rather fine, white sand, with very few pebbles. Some of the surface material on the island may have been derived from this terrace. Small alluvial tracts of land occur along the larger creeks in the county, especially along the Wapsinonoc, Mud creek and

Pine creek. From an alluvium which occurs in a small run just below Fairport, some snail shells have been collected. Part of the exposure is somewhat like a loess. Prof. B. Shimek has identified the following forms in the collection made:

Polygyra multilineata (Say) P. & J.
Zonitoides minusculus (Bin.) P. & J.
Succinea obliqua Say. ?
Pomatopsis lapidaria (Say) Try.
Limnæa humilis Say. (?)
Pisidium abditum Hald. (?)

DEFORMATIONS.

The bed rock is slightly tilted to the south and west. The dip to the west is small. Near the east county line the top of the main dolomite, number 9 of the general Devonian section, is thirty feet above low water. Near the center of section 29, in Sweetland township, the top of the same ledge is about eight feet above low water. The two places are eleven miles apart from east to west. The fall of the river in the same distance is less than three feet. The total dip to the west in eleven miles is thus twenty-five feet, which is only a little more than two feet to the mile. The dip to the south is much greater. It has been made out along two lines. The elevation of the top of the Basal breccia (general section, No. 1), near the county line northwest of Moscow, is about 660 feet above sea level. The top of the Stromatopora breccia in Mad creek, in north Muscatine, lies at a level of about 560 feet. The former is seventy feet below the latter in the Devonian section. Hence there is a total descent of 170 feet in eleven miles, which is the north-and-south distance between these two places. This makes a dip of about sixteen feet to the mile. Near the north line of section 34, in Tp. 78 N., R. I W., the elevation of the base of the Strombodes ledges is 690 feet above sea level. The elevation of the top of the Stromatopora breccia west of Fairport and near Wyoming


IOWA GEOLOGICAL SURVEY
MAP OF THE
SURFACE DEPOSITS
OF
MUSCATINE
COUNTY,
IOWA.
BY
J.A.UDDEN
1899.
Scale
LEGEND
ALLUVIUM
WEST LIBERTY PLAIN
IOWAN LOESS
OVERLYING ILLINOIAN DRIFT
IOWAN LOESS
OVERLYING KANSAN DRIFT
R IV W
R III W
R II W
R I W
R I E
T 78 N
T 77 N
T 76 N
WAPSINONOC
GOSHEN
MOSCOW
WILTON
FULTON
PIKE
LAKE
BLOOMINGTON
SWEETLAND
MONTPELIER
ORONO
SEVENTY SIX
CEDAR
FRUITLAND
WEST LIBERTY
Atalissa
MOSCOW
WILTON
Stockton
Nichols
Adair
Summit
Scotland P.O.
Pleasant Prairie
Wild Cat Den
Pine Mills P.O.
Montpelier
Fairport
MUSCATINE
Conesville
Fruitland
Port Allen
MISSISSIPPI
RIVER
CEDAR
IOWA LITHO. CO.
DRAWN BY F.C. TATE

Hill is about 550 feet above sea level. The vertical distance between the two horizons in the section is forty-two feet, the Strombodes ledge being the lower. The north-and-south distance between the two places is nearly six miles, in which there is a total descent of 140 feet, or twenty-three feet per mile. Averaging these two measurements there is a dip to the south of about twenty feet to the mile. This would bring the top of the Cedar Valley limestone down to about 400 feet above sea level along the south boundary of the county, near the Mississippi river. Local variations and small folds are evident at some places. The south dip of the coal measures seems to be about four feet per mile less than that of the Cedar Valley limestone, indicating that the earth movements which produced this tilting had already commenced before the coal measures were deposited. That such was the case is known from evidence elsewhere in the state. No general faults or folds appear anywhere in the county.

JOINTS.

In most exposures of the bed rock two or three systems of joints can be observed. In the Des Moines sandstone all of these joints are generally nearly vertical. This is also the case in the most compact ledges of the Devonian limestone. In the softer ledges of the latter rock the joints are more apt to run at a considerable angle from the vertical, sometimes diverging as much as forty-five degrees, or even more. Some observations have been made on the bearings of these joints, and are given in the table below. It will be noticed that the joints cluster about two directions which intersect at right angles, one having an average trend about N. thirty-five degrees E., and the other of about N. fifty-five degrees W. (Fig. 40.) These directions coincide with the tilting of the rock, which is to the southwest, but more to the south than to the west, as already shown. The dip joints appear to be more frequent and more uniform in development than the

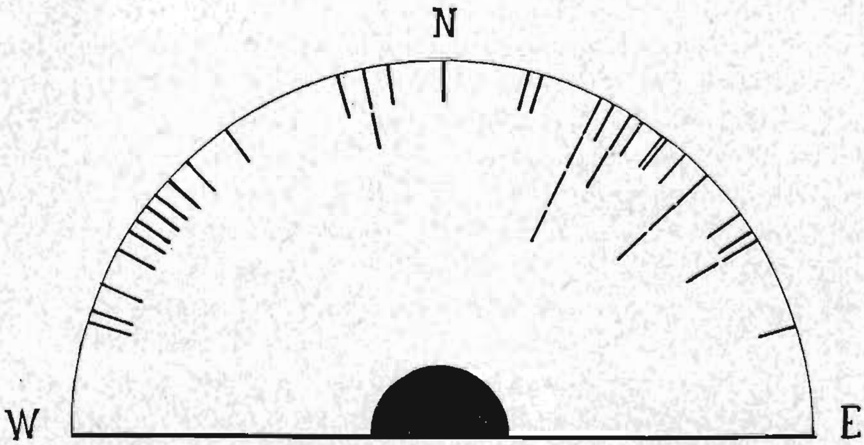


FIG. 40. Diagram showing the position of joint planes in the bed rock.

strike joints. The observations are too few to indicate any difference in the general direction of the joints for the different formations, if such difference should exist. The measurements were made with a small hand compass and were corrected for declination.

TABLE SHOWING DIRECTIONS OF JOINTS IN THE COUNTRY ROCK IN MUSCATINE COUNTY.

In the Des Moines Sandstone.

Montpelier creek	N. 27° E.			
Wild Cat Den	N. S.	N. 25° E.		
West Hill, Muscatine	N. 25° E.	N. 42° W.	N. 72° E.	N. 16° W.
Pappoose creek, Muscatine	N. 55° W.	N. 25° E.		
Branch of Pappoose creek	N. 70° W.	N. 40° E.		
Lowe's run	N. 50° W.	N. 8° W.	N. 30° E.	

In the Cedar Valley Limestone.

Montpelier creek	N. 45° E.	N. 53° E.	N. 57° W.	
Robinson's creek	N. 45° E.	N. 15° E	N. 12° W.	
Alteneder's quarry	N. 45° E.	N. 72° W.		
Fairport (landing)	N. 32° E.	N. 58° E	N. 12° W.	N. 25° E.
Sweetland creek	N. 37° E.	N. 43° W.		
Mad creek	N. 36° E.	N. 60° W.		
Gatton's quarry	N. 52° W.	N. 13° E.		
Pine creek	N. 32° E.	N. 35° W.		

In the Sweetland Creek Beds.

Robinson's creek	N. 58° E.	N. 66° W.

EARTH TEMPERATURES.

From a few observations made on the temperatures of well water, it seems that the underground temperature increases downward in this county at a rate somewhat near 1° Fahrenheit for 100 feet. This corresponds to the observed rate of increase at other places in this region. The data from Muscatine county are as follows:

Underground Temperatures.

	Depth in feet.	Temperature Fahr.
Average of several surface wells and springs...	50	51°
Frank Nettlebush's well	347	54°
Wilton artesian well	1,360	64°
West Liberty artesian well	1,768	65°

MINERALS.

Among the minerals found in the country rock *calcite* is the most common. It frequently occurs as Iceland spar, lining small crevices in the Cedar Valley limestone. Joints in this rock are sometimes filled with plates of a columnar structure. A white incrustation of this kind, an inch thick, was found lining a crevice in the Des Moines sandstone in Stark's quarry, in section 29, in Sweetland township. In Robinson's creek, in the uppermost weathered ledges of the Cedar Valley limestone underlying the coal measures, there are some small cavities which have been filled by a radiating variety of cone-in-cone, the bases of the cones next to the surface of the cavity occasionally consisting of pure transparent calcite. *Pyrites* is common in the Des Moines shales. It forms spherical concretions in the sandstone in the west part of Muscatine. It fills joints, sometimes an inch wide, in the eroded surface of the Cedar Valley limestone, under the coal measures in Sulphur creek. In similar situations it occasionally almost covers the surface of the lower rock. About a foot above the base of the Sweetland Creek beds it forms a seam from half an inch to two inches in thickness. Higher up in this rock it forms spherical and lenticular concretions. A yellow effervescence of *copperas* is often seen on the black carbonaceous shale of the Des Moines. *Sphalerite* is sometimes found in small crevices in the Cedar Valley limestone, and has been observed near Montpelier. It was also seen in a silicified Devonian bowlder belonging to the basal conglomerate of the Des Moines at that place. *Gypsum*, or *selenite*, occurs as a disintegration product from pyrites in the Sweetland Creek beds, sometimes in dendritic forms in joints in the black shale. An incrustation of *epsomite* is now and then formed on exposures of the basal ledges of the same formation. A calcareous *limonite* forms the matrix of a conglomerate under the drift on West Hill in Muscatine. Concretions of impure *siderite* are quite frequent in the coal measures. *Bog manganese* forms a considerable ingredient in a black, mucky substance on top of the limestone in Wresley's quarry southwest of Moscow. A peculiar occurrence was noticed in a railroad embankment west of Stockton, near the county line. A Devonian bowlder lodged in fresh clayey drift had a powdery coating of this mineral measuring one-fourth of an inch in thickness. Large lumps of impure *hematite*, altered from Cedar Valley limestone, lie under the coal measures in the right bank of Pine creek about one-half mile from its mouth. Among the rare minerals of the drift *copper* may be mentioned. A piece weighing nearly twelve ounces was found in Mad creek some years ago, and is now to be seen in Mr. Weir's museum in Muscatine. A lump of *Galena* weighing five pounds has been found in the drift at the foot of the bluff west of Lake Keokuk. Dr. Otto Kuntze has recently discovered *Quenstedtite** near Montpelier, where it is found in dry seasons as an incrustation on an outcrop of Des Moines sandstone. Its composition is reported as follows:

* *On the Occurrence of Quenstedtite near Montpelier, Iowa*, by Otto Kuntze, American Geologist, vol. XXIII, No. 2, p. 119.

SO_3	29.01
H_2O	32.32
Al_2O_3	0.27
Fe_2O_3	26.86
$Si O_2$	1.77

ECONOMIC PRODUCTS.

COAL.

Coal has been mined in this county for more than forty years. The two localities which have been worked most extensively are West Hill, in Muscatine, and the old Hoor property, on section 30 in Sweetland township. The latter has been abandoned for some years, and the former long ago ceased to be productive. The mining was carried on mainly to supply the local demand. As to the nature of the coal taken out in Muscatine, Hall, in his report on the county,* says that "its quality was very poor, as it contained an unusually large proportion of iron pyrites mixed with it." The coal from the Hoor bank is said by Keyes to have been of excellent character and the seam was free from irregularities or clay seams. Another coal bank was operated successfully for many years, on a small scale, by Mr. Robert Henderson, in the northeast quarter of section 9, in Montpelier township.

Three years ago some drifts were opened on Mr. Frank Nettlebush's farm, in the northeast quarter of section 27, in Sweetland township. There are now several entries in the slope of a ravine, at a level of about 120 feet above the river. Two of these are worked, mainly by one miner. The coal is about twenty inches thick, with a "soapstone" and miners' "slate" for roof. The first season 2,000 bushels were taken out, and the year after the whole output was 5,000 bushels. The coal is sold to farmers in the neighborhood, and is considered to be of good quality. Some small drift mines are occasionally worked on the middle branch of Pine creek,

*Geology of Iowa, James Hall, vol. I, p. 277.

where this is crossed by the road following the west line of section 8, in Montpelier township. This coal rests on the Cedar Valley limestone, and above it there is first about eight feet of shale and then sandstone. These are all the mines now operated in the county.

Though the supply of coal seems by this time to be exhausted, it is not impossible that there may yet be found some local developments of veins which can be profitably worked on a small scale. But it is not at all likely that the feather edge of the coal basin which extends into this region has any extensive or thick coal veins. The rapid rise to the north of the underlying limestone causes the coal measures to run out in a distance of from two to five miles from the river. All observations on the beds containing the coal show that these are very changeable, and several circumstances have combined to render them unproductive. The bottom of the Carboniferous sea in which they were laid down was uneven. Contemporaneous unconformities indicate that the marginal waters in this sea occasionally cut away their own deposits. Recent erosion has extensively dissected the thin sheet of coal-bearing rocks which still remains in the region. Such veins as really do exist are apt to run out in short distances, and to have a poor roofing, for which reasons they prove unprofitable. Under such circumstances prospecting for coal will usually bring disappointment. The future of coal mining in this territory can best be told from the experience in the past. Many old "openings" are seen in the bluffs of the Mississippi river and along the creeks in Montpelier and Sweetland townships. Some of these have been worked for a season or two, but most have been failures. They were usually made at the expense of the land owners, who thought they could afford to risk a little sum on the prospect of a coal mine. That many hundreds of dollars have been spent uselessly in this way is quite evident, though the parties who have paid for the explorations usually are reticent as to particulars. There is just enough of a probable chance for a profitable find occasionally to induce the land owners to engage in small speculations, but it is now a saying that no man has ever become rich by working a coal mine in Muscatine county. With much of the field exhausted and stronger competition in the market profits will no doubt be still less in the future.

BUILDING STONES.

In the west end of the county, and in the southern townships, there is no stone of any kind except a few bowlders. Over the east half of the county small quarries are quite frequent, especially along the rivers and the larger creeks. Good building stone is found, but not in such quantity or in such situations as to have encouraged extensive quarrying. Stone is taken out merely to supply local demand.

The Fayette Breccia.—The lower ledges in Gatton's and Wresley's quarries, southwest of Moscow, consist of the fossil-bearing upper part of the Fayette breccia. This is a strong, pure limestone, of compact texture, in heavy beds. The upper ledges are more brittle and more cut up by joints, and have been used by the Chicago, Rock Island & Pacific railroad for riprapping and ballast. The stone from Wresley's quarry was used in the construction of the old milldam in the Cedar at this place. Some of the lower unfossiliferous part of this breccia has been taken out for local use in the west bank of the Cedar above Moscow, and also in section 3, northeast of Moscow. This rock is a very pure limestone, and in Illinois it is crushed and sold to glass manufacturers, who use it as a flux.* Whether it would pay to furnish this rock for the same purpose from Moscow would probably

*An analysis of some of this rock from Rock Island, Ill., is given by James Hall in Geol. of Iowa, vol. I, p. 372. Dr. Hall remarks that it is one of the purest limestones which has been found in the whole western country. The analysis is as follows:

Insoluble in acid	.42
Carbonate of iron	.36
Carbonate of lime	98.77
Loss, alkalies, etc	.45
Total	100.00

depend on facilities for quarrying and handling, and on the cost for transportation.

The Cedar Vlley.—Other limestone quarries all belong to the Cedar Valley stage. Those on Pine creek are mostly in the calcareous and highly fossiliferous ledges, and yield a hard stone, sometimes in rather thin courses. The rock quarried along the bank of the Mississippi and in the creek east of Montpelier is a blue, dolomitic limestone, of an even texture, in heavy beds. It turns yellow and slightly harder on exposure. It has been used by the railroad for riprapping between Montpelier and Muscatine, and has lately been taken out on Mr. Charles Bar's property, near the mouth of Pine creek, by contractors, who transport it on barges down the river, where it is used by the government in the construction of wing-dams.

The Des Moines sandstone is soft, usually light brown or yellow in color, and quite variable in texture as well as in hardness and color. It is easily worked, and this perhaps in part accounts for its general use in Montpelier and Sweetland townships, where several farm houses and one small church have been built from it. It is quite durable, and the ferruginous ledges harden with age. Three quarries have been worked more than the other. One of these is in the west bluff, on the west branch of Pine creek, near the north line of section 18 in Montpelier township, on the land belonging to Mr. Charles Alteneder, who opened it many years ago. At this place the rock lies in heavy beds, some being four feet thick. The quarry wall now rises sixty feet from the bottom. The stone is rather fine in texture, and has some peculiar wavy, ferruginous bands, that seem to be due to infiltration of iron from percolating water. Another quarry is in section 21, in the river bluff in Sweetland township, and belongs to Mr. J. Stark. The stone is about the same kind as in Alteneder's quarry, but a little coarser in texture. At neither of these two places has much quarrying been done lately. More rock has been taken at the quarry on Lowe's run, in the northeast quarter of section 32 in Bloomington township, west of Muscatine. The stone at this place is less ferruginous and of gray or yellowish-white color, with here and there a layer of darker shade. This quarry belongs to Mr. Jesse Oaks. Considering the quality of the stone from these and some other quarries in the Des Moines, it seems that it might with advantage be more generally used. Some imported sandstone is neither stronger nor more lasting than much of this rock. The chief objection that can be urged against it is that it is somewhat variable in each quarry, and the occasional delivery of stone of inferior quality may have prevented a more frequent use of the better kinds of the home product.

GRAVEL AND SAND.

Good gravel is scarce in this region. Some has been taken out along the railroad in the east bluff of Mad creek, near the northwest corner of section 25 in Muscatine township, and has been used for ballast on the roadbed. About one-fourth of a mile northwest of this place, there is another old gravel pit on the property of Mr. Samuel Sinnett. The deposit is about four feet deep, resting on a yellow till and overlain by loess. It is variable in texture, changing from sand to coarse gravel with large bowlders. A somewhat more extensive deposit of gravel and sand occurs under the Kansan till in the bluff near the center of section 6 in Fruitland township, on land belonging to Mr. Charles Warfield and to Mr. Charles Miller. This gravel is in part sand. Some years ago it was used in macadamizing the Hershey avenue road for a distance of three miles west of the city of Muscatine. In the railroad excavation recently made west of Stockton, a gravel was uncovered in the west side of a low, flat hill which lies to the south of the road, and it was used for ballast on the roadbed. The deposit was not far from twenty feet in depth at one place. Most of the pebbles consist of Devonian limestone. It changes into sand above. This gravel will no doubt become useful in the improvement of the roads in the vicinity.

Sand for mortar is usually obtained from recent and alluvial deposits along the streams. East of Moscow the Chicago, Rock Island & Pacific railroad has worked a sand pit for road ballast. This sand is white and rather free from gravel.

CLAY INDUSTRIES.

The Fairport Potteries.—More than a dozen kilns were at one time in operation in the production of stoneware in the town of Fairport. The place is still known among the river people as "Jugtown." At the present time there are only two kilns running. One of these belongs to Mr. John Feustel, and has recently been rebuilt. Mr. Feustel employs from five to twenty men. Most of the clay now used by him is hauled across the river from the Illinois side during winter, and costs about $14 a ton when laid down at the factory. A smaller quantity of clay is also taken on this side of the river from the bluffs near Pine creek. Jars, jugs, churns, milk pans, flower pots, hanging baskets and vases are manufactured. The ware burns to a cream-white color. About forty kilns are burned in a year, and the goods are in part shipped by rail and in part freighted to the cities along the river by a small boat. The other kiln is owned by Mr. John Shellhorn, who uses clay from a pit in the Des Moines shales north of the city. This is mixed with a red, ferruginous clay from the alluvium of the river just below the town. The ware produced is chiefly flower pots, hanging baskets and vases, which are of fine quality and have a beautiful pink-red color. About fifteen kilns are burnt in a year. The decline of the industry at Fairport in recent years seems to be due to a lack of suitable clay near the works and to the general introduction of enameled iron ware in the market.

Brick and Tile.—The Montpelier Brick and Tile works, which were running for nearly fifteen years, closed down at the end of the season in 1897. This factory made paving brick and tile, and also some crockery ware. The clay used was taken from a pit in the Des Moines shale. Another industry which has been discontinued was the manufacture of hollow blocks for the construction of fire proof buildings by the Muscatine Terra Cotta Lumber company. The works were located north of the bluff road, southwest of the center of section 30 in Sweetland township. The factory was running from 1889 to 1892, and it also produced some paving brick. The clay used was a disintegrated coal measure shale.

Brick making is at present limited to the production of soft brick to supply the home market. Eight brick yards are located in Muscatine, and at West Liberty there is one. Neunhuis Brothers' yard is located below East Hill, north of Second street. The brick is made by hand, sun-dried and burned in open kilns. The output in one season varies from 500,000 to 1,000,000. The clay used is of two kinds, a laminated, calcareous silt, which underlies the Illinoian till, and loess. When burned alone or with a small admixture of loess, the silt makes a white, hard and strong brick. With a greater proportion of loess, the bricks turn red and do not become quite so hard. Both kinds are made.

The Muscatine Pressed Brick company's yard is located north of Woodland avenue, and east of Oak street. The brick is made by a Henry Martin soft mud machine, is dried wholly under roof, and burned in open kilns. The clay used is loess, which is excavated to a depth of sixteen feet. The upper six feet of this is compact and breaks into small cuboidal blocks, while the lower part of the bank is more open in texture. Some hard brick suitable for sidewalks is made from the upper clay, but the main product is a fine, soft, building brick. Usually about 1,500,000 bricks are made in a season. Mr. Carl Hagermeister operates a yard on Mulberry street, north of Woodlawn avenue. The brick is red, and made from loess clay, about 450,000 in a season. Hagermann & Koetting have their yard adjoining Hagermeister's on the same street to the north. The quality and the quantity of the brick maae is abouτ the same in both of these yards. The same kind of brick is also made from the same material by Mr. Charles

Samuels, near the junction of Cedar and Star streets, and by Fuller & Shoemaker near the crossing of Cedar and Eighth streets. Each burns about 300,000 bricks in a season. Mr. George Christopherson has a yard east of Mad creek on Second street and makes some 200,000 bricks in a season, using both the calcareous silt under the Illinoian till and loess, and making some white and some red brick. Brick and tile have been made for the last twenty-five years on the property now owned by Mr. J. W. Fuller, at West Liberty, southwest of the city. The clay used is a loess, rather more ferruginous than the loess at Muscatine. The brick is moulded by a Johnson Krieger soft mud machine, and dried under shelter. Some are burned in an open kiln and some in a down draft kiln which is also used for burning the tile. The usual output is 500,000 brick and 100,000 tiles.

The brick industry is thus represented by ten firms. These employ about thirty-two men during the summer season, and have a total output of about 5,000,000 a year. The price of the brick ranges from $5 to $6 per 1,000, and the total value of the brick made in a year is estimated to be about $27,000.

During the last few years about eight miles of streets have been paved with brick in the city of Muscatine. Most of the brick so used have been brought from Buffalo, in Scott county. Some have been imported from Galesburg and some shipped from Des Moines.

WATER SUPPLY.

The water works in Muscatine is owned by the Muscatine Water Works company. The first building of their plant was erected in 1875. At present there are twelve miles of water mains, from six to sixteen inches in diameter, with 117 hydrants. A reservoir is located on West Hill, and has a capacity of 2,000,000 gallons. The bottom of this reservoir has an elevation of 185 feet above low water in the river. The ordinary supply is furnished by pressure from this reservoir, but direct pressure can also be used. There are two pumps, run by two low pressure condensing engines. The full pumping capacity is 5,000,000 gallons in twenty-four hours. The water is taken from the Mississippi river through a conduit which extends 700 feet out into the river. No filter has yet been found necessary. Should it prove desirable, artesian water may be obtained in this city at a depth of from 900 to 1,100 feet. It may be expected to rise some seventy-five feet above low water in the river.

The water works at West Liberty are supplied from an artesian well, 1,768 feet deep, made in 1888. The water-bearing rock in this well is the Saint Peter sandstone and the Oneota limestone. A Dean duplex force pump is used to raise the water into a standpipe sixteen feet deep and twenty-four feet in diameter, the bottom of which is fifty feet above the ground. The quantity pumped daily is 75,000 gallons. There are twenty-nine hydrants and 330 taps in the city. Professor Norton states that in the amount of alkaline carbonates the water from this well exceeds that from any other well in the state.* An analysis made by Floyd Davis gives the solid contents of this water as follows:†

		GRS. IN U. S. GAL.
1.	Sodium chloride	11.659
2.	Ferrous carbonate	Trace.
3.	Sodium carbonate	38.152
4.	Potassium carbonate	18.125
5.	Sodium sulphate	43.738
6.	Sodium chloride	9.302
7.	Magnesium phosphate	.077
8.	Magnesia	.019
9.	Silica	7.678
10.	Alumina	0 222

The town of Wilton had an artesian well made in 1891 and this now furnishes a sufficient quantity of pure water to its inhabitants. The main supply comes from the Saint Peter sandstone. The water is now pumped into a tank and distributed through two miles of water mains. About 56,000 gallons

*Norton, Artesian Wells of Iowa, Iowa Geol. Surv., vol. VI, p. 282.
†Norton, Artesian Wells of Iowa, Iowa Geol. Surv., vol. VI, p. 281.

can be pumped in a day. The water is said to be somewhat laxative and diuretic, and beneficial in case of rheumatism. An analysis made by Mariner and Haskins, of Chicago, gives the solid contents as follows:*

	GRS. PER U. S. GAL.
Calcium carbonate	10.47
Magnesium carbonate	6.45
Sodium chloride	18.56
Sodium sulphate	33.45
Iron oxide and alumina	Traces.

On the uplands of the drift shallow wells take their supply from the base of the loess or from a sand under the loess, but farmers now very generally have deep wells going down from 100 to 300 feet, with pumps worked by windmills. In the west end of the county such wells average 150 feet in depth and draw their supply from sandy strata in the drift. In the east end some such wells extend down 300 feet and draw their supply from the upper part of the Niagara limestone. Along Mud creek some wells of nearly the same depth draw water from sandy strata in the lower part of the drift. On the West Liberty plain water is obtained from pumps, which are driven from twenty to forty feet into a sand under the surface loess. When such pumps go down more than thirty or forty feet, the water is apt to have a strong mineral taste. On some low tracts around Nichols, temporary flowing wells have sometimes been obtained by boring through the hardpan which covers the surface in such places. Below the bluffs east of the Cedar in Moscow township, and west of the Mississippi in Fruitland and Seventy-Six townships, there are frequent springs from the drift. Some of these are copious, and most of them never dry up. In a few instances the water from these springs is conducted through pipes into the farmhouses, and along the Burlington wagon road, west of Muscatine, the flow is frequently conveyed into high troughs convenient of access to wayfarers. On Muscatine island water is every-

*Norton, same place.

where obtained at shallow depth, mostly by drive-pumps. The supply is so copious that it is pumped by engines in dry seasons for irrigating the melon crop.

Water Power.—At Pine Creek mills Mr. Michael Missel owns a flour mill which is partly run by water. The power wheel is a twenty-six-horse-power turbine. The dam in the creek is seventeen and a half feet high. Steam power is also used, the water being sufficient to run the mill for about half the time during the year.

NATURAL GAS.

A tract of some small gas wells is found just to the south of this county. The gas seems to come from vegetation which is buried in the deep drift in that region. It has been found in some wells in the south part of Cedar and Seventy-Six townships in this county. The highest pressure observed here registered a little more than nine pounds on a steam gauge. The only instance where it has been utilized is on the farm belonging to Mr. C. Hadley, near the center of the south line of section 36 in Cedar township. The other places where gas was found in measurable quantity are on Mr. J. O'Brien's farm, near the north line of section 26 in the same township, on Mr. J. Reed's farm in the southwest quarter of section 15 in Seventy-Six township, and on Mr. Lewis Eliason's farm west of the center of section 31 in the same township. On the farm of Mr. W. B. Verink, near the center of the west line of section 14 in Cedar township, a slight escape of gas from a deep well, seventy-five feet deep, is yet noticeable. The quantity is not sufficient to sustain a flame. In all of these wells the gas is reported as coming from a white sand, which in some instances is associated with peaty material and is covered by bowlder clay. Inflammable gas was also tapped some years ago by a well from a similar stratum in the drift on a farm near the southeast corner of section 7 in Fulton township.

SOILS.

Genetically, the soils of this county may be classified as loess, terrace material, and alluvium. The first makes the soil of the drift plains, and covers about two-thirds of the area of the county. This is the typical Mississippi valley corn soil, for which crop it is admirably well adapted. It forms a rich loam of uniform texture, inclined to be somewhat sticky in low places, but loose and open on higher ground. On the flat lands in the north part of Fulton township, the natural drainage is slow, and some sections were by the early settlers for some time considered unsuitable for tilling. This land has proved to be particularly well adapted for barley, though other crops also do quite well. It is now as productive as the best farming land in the county, and well repays the cost of tiling, which on some tracts has been very expensive. On the sandy hills on the Illinoian drift plain, the soil is sometimes so light that it drifts and injures the crops. In a few places this drifting prevents cultivation. The flat lands from which these small, sandy hills rise, and which lie between them, usually have a very rich soil that yields excellent crops. On the high slopes bordering upon the bluff lines in the east end of the county the loess surface is in some places subject to erosion from heavy rains, and this cuts deep gullies that prevent further cultivation. This erosion is of course limited to small tracts, and usually begins on fallows used for pasture. It is most common along the creeks and ravines in the south part of Bloomington, Sweetland and Montpelier townships.

On the west half of West Liberty plain the soil is like that of the uplands in texture, but it is usually deeper and contains a greater quantity of mould. Over several sections of land under the bluffs of the Kansan drift plain there were formerly extensive marshes and peat bogs. These have been drained by ditches and now yield rich crops of corn and other grains. On a few low places there is sometimes found a hardpan that is apt to interfere with the under drainage in wet seasons and cause the soil to bake in times of drought. Partially successful attempts have been made to remedy this by boring through the hardpan and letting the water down into the sand below. Over the greater part of Orono township, and on that part of the plain which is nearest to the Cedar bottoms, the soil is more sandy. The veneer of loess runs out in this direction, and the underlying sand forms a typical terrace soil. Corn, oats and rye are the usual crops on this land, but in Orono township melons and sweet potatoes are also extensively raised. As a corn soil it is inferior to the uplands.

The bottom lands along the Cedar river are for the most part very fertile, but crops are occasionally damaged by overflow. Some low tracts have been protected by levees, and in other places the drainage has been improved by ditching. Corn, small grain and hay are the usual crops. The most productive soil in the county is probably to be found on some of the alluvial fans under the bluffs of the Mississippi river. These are frequently covered by a deep black loam, which yields from eighty to a hundred bushels of corn to the acre in good seasons, and on which failures are unknown. The soil on Muscatine island is entirely different, being coarser and sandy. Where the sand is coarsest and where the land is high corn cannot always be raised with profit. Nevertheless, this land has become very valuable in the production of melons, sweet potatoes and some other garden products. The Muscatine melon has become a staple article in the Chicago markets, and hundreds of carloads are shipped from this land every season. Some of the melon-soil in Fruitland township is really a gravel, but even this produces good or fair crops with favorable rainfall. The melon plant seems particularly sensitive to the conditions of the soil moisture, and a dry season prevents the melons from developing to their full size. Even the best melon land shows the effects of unfavorable weather, and the largest farms are provided with steam pumps that irrigate the land from shallow wells, when rain is insufficient during the growing season.

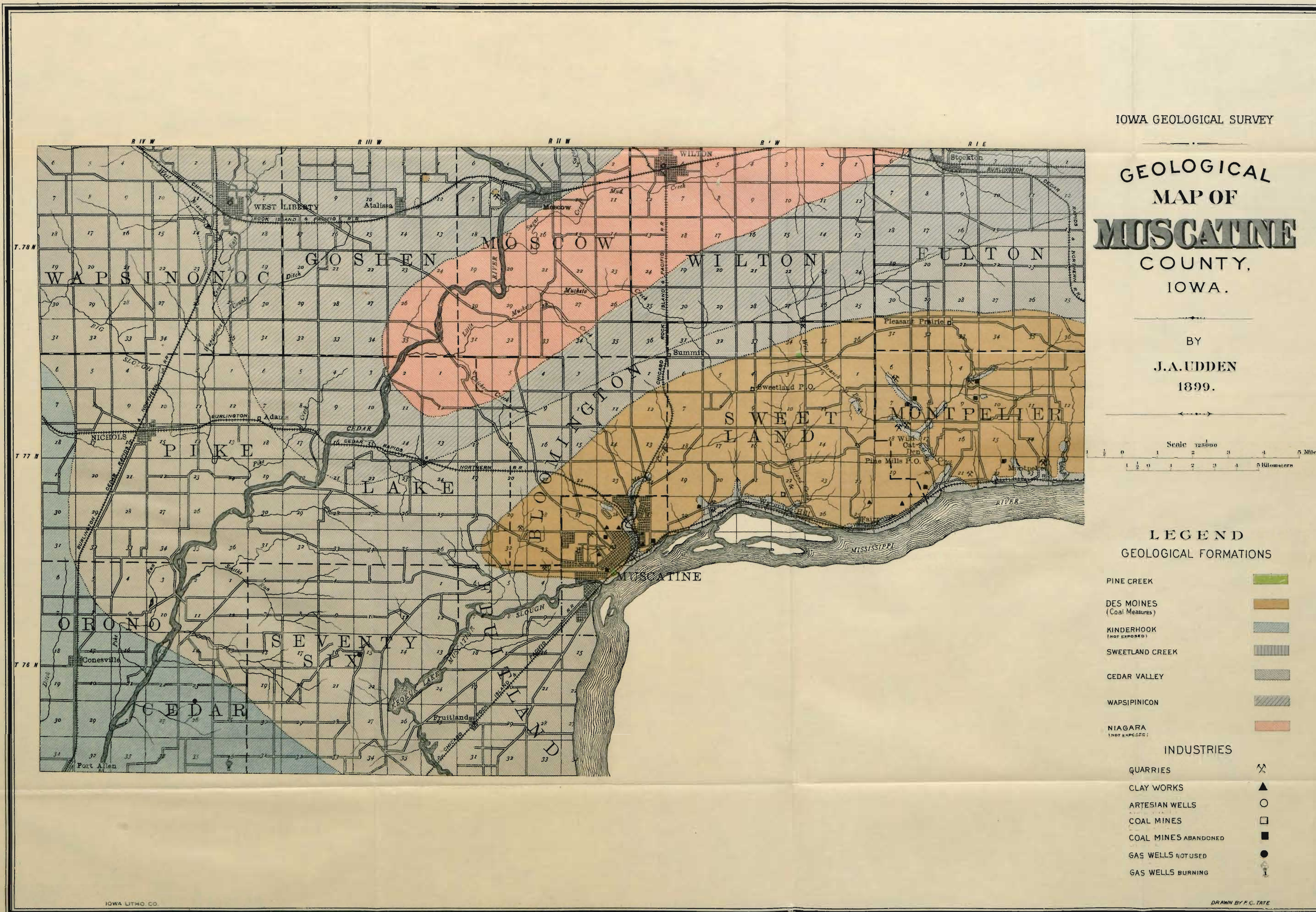
ACKNOWLEDGMENTS.

In the preparation of this report the author has received most valuable aid from Dr. S. Calvin, the director of the Survey, and from Dr. H. F. Bain, his assistant. He has also received important help from several other parties familiar with the geology of this region or with its fossils. In particular he desires to express his gratitude to Dr. C. R. Eastman, Mr. W. J. McGee, Mr. Frank Leverett, Dr. Charles Schuchert, Mr. G. P. Merrill, Prof. B. Shimek, Prof. W. H. Norton, Mr. P. C. Myers, Dr. Astrid Cleve, Mr. F. Reppert, Prof. F. M. Witter, and Mr. James E. Weir, who have kindly furnished information on various subjects that have come up for consideration in the course of his work.

FOREST TREES AND SHRUBS OF MUSCATINE COUNTY.

BY FERDINAND REPPERT.

The timber area of Muscatine county is confined to the region along the Mississippi and Cedar rivers. Originally these forest belts were in the main unbroken and continuous along these water courses, and from four to six miles or more wide. Much of this area has been cleared of its timber and converted into farm and pasture lands. The original larger forest trees have almost disappeared, so that what is now seen are mostly "second growth" trees. There is very little, if any, timber cut for export or manufacturing purposes. There are frequent groves on the prairie farms, planted to protect the houses and live stock from wintry blasts. The soft maple (*Acer dasycarpum* Ehrh.) is the principal tree planted for this purpose; small groves of black walnut and evergreen trees are occasionally seen. The forest trees which most largely contribute to the timber supply are the white oak (*Quercus alba* L.), bur oak (*Q. macrocarpa* Michx.),


IOWA GEOLOGICAL SURVEY
GEOLOGICAL MAP OF MUSCATINE COUNTY, IOWA.
BY J.A. UDDEN 1899.
LEGEND
GEOLOGICAL FORMATIONS
PINE CREEK
DES MOINES (Coal Measures)
KINDERHOOK (NOT EXPOSED)
SWEETLAND CREEK
CEDAR VALLEY
WAPSIPINICON
NIAGARA (NOT EXPOSED)
INDUSTRIES
QUARRIES
CLAY WORKS
ARTESIAN WELLS
COAL MINES
COAL MINES ABANDONED
GAS WELLS NOT USED
GAS WELLS BURNING
Scale 1/125000
5 Miles
5 Kilometers
R IV W
R III W
R II W
R I W
R I E
T 78 N
T 77 N
T 76 N
WAPSINONOC
GOSHEN
MOSCOW
WILTON
FULTON
PIKE
LAKE
BLOOMINGTON
SWEETLAND
MONTPELIER
ORONO
SEVENTY SIX
CEDAR
FRUITLAND
WEST LIBERTY
Atalissa
Moscow
WILTON
Stockton
NICHOLS
Adams
Summit
Sweetland P.O.
Pleasant Prairie
Pine Mills P.O.
MUSCATINE
Conesville
Fruitland
Port Allen
MISSISSIPPI
RIVER
IOWA LITHO. CO.
DRAWN BY F. C. TATE

shell-bark hickory (*Carya alba* Nutt.) and mocker-nut hickory (*C. tomentosa* Nutt.). A few other species contribute more or less to the wood supply, but the six species above mentioned largely predominate.

Clematis virginiana L. Virgin's bower. Woody at the base. Climbing over shrubs, etc., twelve to fifteen feet or more. Borders of woods and thickets; frequent.

Menispermum canadense L. Moonseed, yellow parilla. Smooth, shrubby vine, eight to ten feet or more. In alluvial soil along streams, etc.; frequent.

Berberis vulgaris L. Common barberry. Shrub four to six feet high, cultivated as an ornamental shrub; sparingly spontaneous.

Hibiscus militaris Cav. Rose mallow, hibiscus. Plant three to four feet high, soft woody near the base; flowers large, flesh-colored, darker at the base, handsome. In alluvial soil along rivers and streams; frequent.

Tilia americana L. Basswood, white-wood. One of the larger forest trees in all rich woodlands. Not common; most frequent along the Cedar river. The flowers yield nectar abundantly; July.

Xanthoxylum americanum Mill. Prickly ash. In rock and sandy woods; frequent; shrub six to ten feet high; prickly and pungently aromatic.

Ptelea trifoliata L. Wafer-ash, hop-tree. Shrub eight to twelve feet high; in dry soil, borders of woods, etc.; infrequent.

Celastrus scandens L. Climbing bittersweet. A twining shrub, climbing over shrubs and small trees in open woods and thickets; not rare.

Euonymus atropurpureus Jacq. Wahoo. Shrub five to ten feet; in moist woods; frequent.

Rhamnus lanceolata Pursh. Buckhorn. Borders of woods and in thickets along Cedar river; infrequent.

Ceanothus americana L. Red-root, Jersey tea. Small, shrubby plant about two feet high; dry woodlands and sandy prairies; common.

Vitis cinerea Engelm. Downy grape. Along the Mississippi and Cedar rivers; not so common as the next.

Vitis riparia Michx. River-bank grape, wild grape. In all woodlands, thickets and fence rows.

Ampelopsis quinquefolia Michx. Virginia creeper. A common vine in all rich woods; also planted about dwellings for shade and ornament. In a general way it resembles the poison ivy, from which, however, it is readily distinguished by its leaves, which are composed of five leaflets, while those of the poison ivy are of three leaflets.

Acer saccharinum Wang. Hard maple, sugar maple. Medium to large sized trees; most frequent on the bluffs along the Mississippi river.

Acer dasycarpum Ehrh. Soft maple, silver maple. One of the largest trees; most frequent along the Mississippi and Cedar rivers. Largely planted for groves on the prairies and for shade along the streets.

Negundo aceroides Mœnch. Box elder. A small tree frequent along streams, also planted for shade, and very desirable where large trees are not wanted.

Staphylea trifoliata L. Bladder-nut. Shrub eight to ten feet, in moist woods; not common.

Rhus glabra L. Common sumac. Common in dry soil, four to six feet, sometimes tree-like ten to twelve feet or more.

Rhus toxicodendron L. Poison ivy. Climbing trees, also occurring in fence rows and thickets. It is frequently low and spreading along the ground; common. By contact it produces very disagreeable skin poisoning in many persons.

Rhus canadensis Marsh. Sweet sumac. Shrub three to four feet, in sandy soil, often forming broad clumps; rather common.

Amorpha canescens Nutt. Lead plant. In dry open woods and sandy prairies; quite frequent; two to three feet high.

Amorpha fruticosa L., False indigo. Shrub five to ten feet; frequent; banks of streams.

Tephrosia virginiana Pres. Goat's rue, cat-gut. Shrubby plant one to two feet; not rare; in dry soil and sandy prairies.

Robinia pseudacacia L. Common locust. A small to medium-sized tree, along roadsides and borders of woods. This otherwise valuable tree is too subject to the ravages of the locust-borer, *Cystus robiniæ*, a beautiful yellow-banded beetle common on the flowers of the golden-rod in September.

Cercis canadensis L. Red bud. Small tree twelve to twenty feet. Wooded hillsides along the Mississippi and alluvial sandy bottom lands of Cedar river; not frequent.

Gymnocladus canadensis Lam. Kentucky coffee-tree. A small to medium-sized tree, in alluvial soil along the Mississippi and Cedar rivers; not rare.

Gleditchia triacanthos L. Honey locust. Medium to large-sized tree, often planted for shade and ornament. Some of the trees are quite thorny while others are almost or wholly thornless.

Prunus americana Marshall. Wild plum. In woodlands along stream banks, etc.; frequent.

Prunus chicasa Michx. Chickasaw plum. On Muscatine island near the sand mound; local.

Prunus virginiana L. Choke cherry. Shrub or frequently tree-like, eight to twenty feet; in wooded ravines and borders of woods; frequent.

Prunus serotina Ehrh. Wild black cherry. A medium-sized forest tree, more or less frequent in all woodlands.

Spiræa salicifolia L. Meadow-sweet. Small shrub two to three feet, in wet soil along the Cedar river; not common.

Physocarpus opulifolius Maxim. Nine-bark. Shrub three to five feet, in hilly woods along streamlets, etc.; infrequent.

Rubus occidentalis L. Black raspberry. Frequent in thickets and fence rows.

Rubus villosus Ait. Blackberry. Borders of woods, thickets, etc.; common.

Rubus canadensis L. Low blackberry. Trailing extensively in neglected fields and borders of woods; fruits sparingly.

Rosa blanda Ait. Wild rose. Rocky, sandy soil; frequent; two to five feet high.

Rosa arkansana Porter. Wild rose. Common in dry soil; one to three feet high.

Rosa rubiginosa L. Sweetbrier. Along roadsides near old habitations; escaped from cultivation; not frequent.

Pyrus coronaria L. Wild crab apple. Tree, frequently twenty feet high, but generally smaller; often forming small thickets.

Pyrus americana DC. Mountain ash. This has been found in one or two instances along the border of woods, where the seeds were probably carried by birds.

Cratægus coccinea L. Hawthorn, red haw. Border of woods and in thickets; frequent.

Cratægus coccinea mollis Torr. and Gray. Red haw. Common; distinguished among our species by its large, bright scarlet fruit, one-half inch or more in diameter and edible.

Cratægus tomentosa L. Hawthorn, red haw. Not common.

Cratægus crus-galli L. Cockspur thorn. Cedar river region; not frequent.

Amelanchier canadensis Torr. and Gray. Juneberry. Small tree fifteen to twenty feet; in hilly woods; frequent; seldom has much fruit, although the trees bloom freely in early spring.

Ribes cynosbati L. Prickly gooseberry. Hilly woods; not common: fruit prickly,

Ribes gracille Michx. Missouri gooseberry. In open woods, etc.; rather frequent.

Ribes floridun L'Her. Wild black currant. Borders of moist woods; not frequent.

Cornus circinata L'Her. Round-leaved dogwood. Shrub six to eight feet; along Sweetland creek; infrequent.

Cornus sericea L. Kinnikinnik. Wet banks, etc.; shrub, four to eight feet; frequent.

Cornus asperifolia Michx. Dogwood. Tall shrub, often tree-like, twelve to fifteen feet high; in sandy soil; frequent.

Cornus alternifolia L. f. Dogwood. Tall shrub, or often tree-like, ten to fifteen feet high; hilly woods; frequent.

Sambucus canadensis L. Common elderberry. Along fences, borders of thickets, etc.; frequent.

Viburnum lentago L. Black haw. Along woodland streams, etc.; shrub, or often tree-like, six to fifteen feet high; not common.

Lonicera glauca Hill. Honeysuckle. Hilly woods and rocky ledges; frequent.

Diervilla trifida Mœnch. Bush honeysuckle. Rough or stony hillsides at Wild Cat Den; local.

Fraxinus americana L. White ash. Medium to large-sized trees; frequent, but becoming scarcer.

Fraxinus pubescens Lam. Red ash. Creek bottoms; probably infrequent; collected but once.

Fraxinus viridis Michx. f. Green ash. Along wooded streams; frequent; the most common ash.

Fraxinus sambucifolia Lam. Black ash. Along streams, etc.; not common.

Tecoma radicans Juss. Trumpet-creeper. Has escaped from cultivation more or less about old habitations.

Catalpa speciosa Warder, and probably unintentionally with it *C. bignonoides* Walt., have been largely grown and planted, but no escapes have so far been noted.

Ulmus fulva Michx. Slippery elm. In rich woods; not common.

Ulmus americana L. White elm. A very common and large tree in all river and creek bottom lands.

Celtis occidentalis L. Hackberry. Along streams in low ground; not common.

Maclura aurantiaca Nutt. Osage orange. Largely used for hedges; self-established specimens are seldom seen.

Morus rubra L. Red mulberry. Small tree fifteen to thirty feet high; not common; more frequent along Cedar river.

Platanus occidentalis L. Sycamore. Often a large tree; in alluvial soil along streams; not common.

Juglans cinerea L. Butternut. A rather small tree; rich woods near streams; not common.

Juglans nigra L. Black walnut. In rich soil along streams; frequently planted along roadsides near farm houses; native trees of much size have become rare.

Carya olivæformis Nutt. Pecan-nut. Infrequent; a few trees near Wyoming Hill, and in the "big timber" below Muscatine city, along the Mississippi.

Carya alba Nutt. Shell-bark hickory. In all upland woods; the most common of the hickories; not many large trees exist any more.

Carya sulcata Nutt. Big shell-bark hickory. In the "big timber" below Muscatine, and less frequently along Cedar river.

Carya tomentosa Nutt. Mocker-nut hickory. In nearly all upland woods, and rather frequent.

Carya amara Nutt. Bitter-nut hickory. River and creek bottom land; sometimes on upland; frequent.

Betula nigra L. Red birch. A small to medium-sized tree along streams; rather common.

Corylus americana Walt. Hazelnut. Common in open thickets and borders of woods; two to six feet high.

Ostrya virginica Willd. Iron wood. Hilly woods frequent; small tree.

Carpinus caroliniana Walter. Water beech. A small tree along woodland streams; not common.

Quercus alba L. White oak. One of the most common oaks; not many of the larger native trees are left standing.

Quercus macrocarpa Michx. Bur oak. Common in low and on high ground; very large trees not frequent.

Quercus bicolor Willd. Swamp White oak. In low ground along streams; frequent.

Quercus muhlenbergii Engelm. Chestnut oak. Hilly woods; not frequent.

Quercus rubra L. Red oak. A very common tree in all upland woods.

Quercus coccinea Wang. Scarlet oak. An abundant upland oak.

Quercus palustris Du Roi. Pin oak. Common in wet soil along the Mississippi and Cedar rivers.

Quercus imbricaria Mich. Shingle oak. A few small trees only in Cedar township.

Salix nigra Marsh. Black willow. Along streams, a small to medium sized tree.

Salix amygdaloides Anders. Black willow. With the former and very similar.

Salix alba vitellina Koch. Yellow willow. Small to medium sized tree with yellow branches and twigs; cultivated and self planted from detached twigs.

Salix longifolia Muhl. Long leaved willow. Very common along the shores of the larger streams, six to twelve feet.

Salix discolor Muhl. Pussy willow. Along the smaller streams and wet places; five to ten feet or more high.

Salix humilis Marsh. Prairie willow. In dry soil, two to four feet high; not frequent.

Salix cordata Muhl. Heart-leaved willow. Along streams, etc., five to ten feet high; frequent.

Salix purpurea L. Purple willow. Bank of Mad creek, near Muscatine city, four to six feet high; local.

Populus tremuloides Michx. Quaking aspen. A small tree in moist woods; not common.

Populus grandidentata Michx. Large-toothed aspen. Medium sized tree, in rich, moist woods; not common.

Populus monilifera Ait. Cotton-wood. Along streams; frequently a large tree.

Pinus strobus L. White pine. On rugged hills at Wild Cat Den, twelve miles above Muscatine; some of the trees still standing are two feet or more in diameter.

Juniperus virginiana L. Red cedar. Represented only by scraggy specimens on rock ledges; Wyoming Hill, Wild Cat Den, etc.

Note.

Gray's Manual, sixth edition, has been followed in the preparation of the above list.

I wish to express my thanks here to Prof. T. H. Macbride, for help and suggestions, and to Prof. L. H. Pammel for comparing specimens of Cratægus and Fraxinus, at the Missouri Botanical Gardens; and to C. R. Ball for determining specimens of Salix.

From the loess described on page 358, the following fossils have been collected, (identified by Shimek):

Helicina occulta Say.
Valvata sincera Say.
Polygyra multilineata (Say) Pils. (?)
Polygyra monodon (Rock) Pils.
Strobilops virgo Pils.
Bifidaria pentodon (Say) St.
Pupa muscorum L.
Cochlicopa lubrica (Müll) P. & J.
Pyramidula alternata (Say) Pils.
Pyramidula perspectiva (Say) Pils.
Pyramidula striatella (Anth) Pils.
Succinea obliqua Say.
Succinea avara Say.
Succinea ovalis Gld.
Limnæa caperata Say.

GEOLOGY OF SCOTT COUNTY.

BY

W. H. NORTON.

GEOLOGY OF SCOTT COUNTY.

BY W. H. NORTON.

CONTENTS.

INTRODUCTION.

Scott county is not only one of the most populous and wealthy of the counties of Iowa, but it is rich also in geological phenomena of peculiar interest and importance. Although it comprises an area of only 447 square miles, there outcrop within its borders the consolidated sediments of various stages of three great geological series—the Silurian, the Devonian and the Carboniferous. In a number of localities these are of special industrial value, and furnish mines of coal and clay and quarries of building stone and lime. As the frontiers of three geological systems of indurated rocks lie within the county, so within the same narrow limits the borders meet of three great sheets of drift, which record three distinct invasions of continental glaciers in late geological time. In various forms of topography, due to the action of different geological agencies, Scott county is equally rich. Unscored plains of alluvium and of glacial drift, past plains now maturely dissected by valleys of erosion, rocky gorges of young rivers, billowy hills of frontal loess moraines,—all these varied contours give the landscape a diversity of beauty and a wealth of geologic interest.

Few counties in Iowa offer better facilities for geological investigation. Fronting on the Mississippi and bounded on the north by the Wapsipinicon, the eastern and northern townships have been so far dissected by these master streams and their tributaries that numerous exposures are afforded of the indurated rocks as well as the unconsolidated Pleistocene deposits. The excavations made in the years since the early settlement of the county have added to the natural sections of gorges, scarps and hillside ledges, many artificial geological sections in mines, wells, quarries, and railway cuttings.

It is not strange, therefore, that Scott county long since attracted the attention of geologists. In the course of the early surveys of the Mississippi valley made by David Dale Owen* the geological areas of the county were roughly delineated, and fossils were described and figured from Davenport and Buffalo.

The survey of Hall and Whitney† describes accurately the "limestone of the Rapids of LeClaire," and devotes twelve or more pages to the discussion of the higher rocks of the county. Out of thirty-eight species described by this survey from the Devonian, eighteen are listed from Scott county and six from the opposite bank of the Mississippi at Rock Island. Since that time the fossils of the county have been patiently collected and carefully preserved, as the fine cabinets of the Davenport Academy of Science, Rev. Dr. W. H. Barris and Mr. Asa Tiffany testify. Their rich fauna has been described by Barris, by Hall, by Worthen, by Meek, and by Lindahl. Aspects of the glacial deposits of the county have been treated by McGee, McWorther, Pratt, Calvin, Bain, Leverett, and Udden, and of the older formations by Barris, Tiffany, Calvin, Udden, Norton and Keyes.

Topography.

The topography of Scott county is due to the action of many forces acting through vast periods of time, and it is not always an easy matter to disentangle the complex causes of its various forms of relief. All topographic forms may be divided into two classes, those of construction and those of erosion. To the former class belong the hills of the Iowan frontier, some aggraded valley floors, and the uneroded remnants of the drift plains. To the latter class belong all other reliefs in the county; for, with these exceptions, every hill

*Rept. Geol. Surv. of Wisconsin, Iowa and Minnesota, Philadelphia, 1852.
†Geol. of Iowa (Hall), vol. I, p. 73 seq, p. 278 seq. 1858.

and valley, every bluff and precipice, strath and streamway is due to the corrasion of running water in rill and river, to rain wash, and all the various processes known as weathering.

CONSTRUCTIONAL RELIEFS.

Iowan Drift Plains.—In northeastern Iowa there is associated with the Iowan drift sheet a topography which is strikingly distinct and in part entirely unique. There is the bowlder strewn drift plain, with its gentle undulations, its sags and swales due to initial inequalities in the ice-moulded surface of the till, its drainage so immature that storm water lingers upon it in sloughs and shallow lakelets, its soil peaty and black because of the rapid accumulation of humus consequent on the comparative inefficiency of the agents which, in mature districts, remove it almost or quite as rapidly as it forms. The Iowan drift plain is but slightly represented in Scott county. It comes well down to the Wapsipinicon flood plain on the Clinton county side, but to the south of the flood plain it occurs only in a narrow belt in the northern part of Winfield and Butler townships; and over a considerable portion of this belt, this drift-plain is in part effaced by the peculiar hills characteristic of Iowan areas which are next to be noticed.

The Paha.—Paha are boat-shaped hills or long narrow ridges with northwest-southeast trend, and are composed in part of water-laid sand and silt and in part of ice-moulded till. These unique relief forms are found in Iowa and Illinois along the entire southern margin of the Iowan ice invasion. They are not confined, however, to the limit of its advance, but occupy a large part of the area of its southern extension, the "land of the paha" as it has been termed by McGee* to whose first descriptions and interpretations but little has been added by later students.

The "land of the paha" lies largely to the north and west of Scott county, and the great paha hills and ridges of Cedar

*Pleistocene History of Northeastern Iowa, 11th Annual Rept., U. S. Geol. Surv.

and Jones are here but feebly represented. Still, the paha of the Iowan frontier, which stretches from the east bank of mud creek north of Allen Grove, through Winfield and Butler townships, north of Donahue and Long Grove and through Walnut Grove, and on nearly to the Mississippi at Princeton, are typical in form, in orientation and in composition and structure. That the paha are hills of construction, and are not the wasted remnants of a once level upland, is best seen from a station a little to the south of their belt. Looking from such a station toward the south, the east, or the west, one sees everywhere a dissected upland carved into valleys and hills of erosion. Everywhere an even sky line, the original level of the upland meets the eye. But turning to the north the sky line changes. It undulates in gently convex curves which rise definitely above the surrounding region. The paha here overide the upland for a narrow zone along its northern margin. This is seen more clearly by contrast whereever, as in section 26, Butler township, the paha are interrupted for a short distance and the upland descends unmodified to the Wapsipinicon flood plain. In some of the adjacent sections the paha abut against the steep northern edge of the upland, while in Winfield and Allen Grove townships, where the upland descends gently to the north, they are built in part upon it and in part on the Iowan drift plain which continues the gentle descent to the Wapsipinicon flood plain. But whether they occur on the bowlder dotted Iowan drift plain or override the margin of the loess mantled Illinoian upland, in all cases their contours and their trend are not under the control of any streams which might be supposed to have carved them out of an initial land mass. The paha are indifferent to any erosional divides. They may indeed form divides between streamways, but here the streams are under the control of the hills, and have been diverted from their arborescent courses to courses parallel, and with the northwest-southeast trend so characteristic of paha regions. Or the paha may lie athwart the natural divides, as in section 19 of Butler and 24 of Winfield townships.

In shape the paha may assume the forms of long, low swells, sometimes simple and comparatively even topped, but usually complex and lobate, the crest line rising in long, boat-shaped summits, and falling in low, broadly concave cols. Of

FIG. 41. Paha near St Ann's church, northeast of Long Grove.

these the Saint Ann paha (Fig. 41), north of Long Grove, is an example. Again, the dolphin-backed eminences may be more distinctly individuated and form separated hills, of which several may be strung along a common axis. An illustration of this form is offered in the paha of Allen Grove township, section 23, (Fig. 42.) Associated with a change of composition from loess to sand occurs a third variety, a narrow range of short, more or less detached, hummocky hills, with steeper slopes and rounded or somewhat peaked summits. Paha in section 19, Butler township, will serve as illustrations of this type. A fourth variety is found in the high and massive ridge of sand and loess which stretches for nearly four miles along the Wapsipinicon flood plain, in Princeton township. The ridge is crested with dune-like hummocks

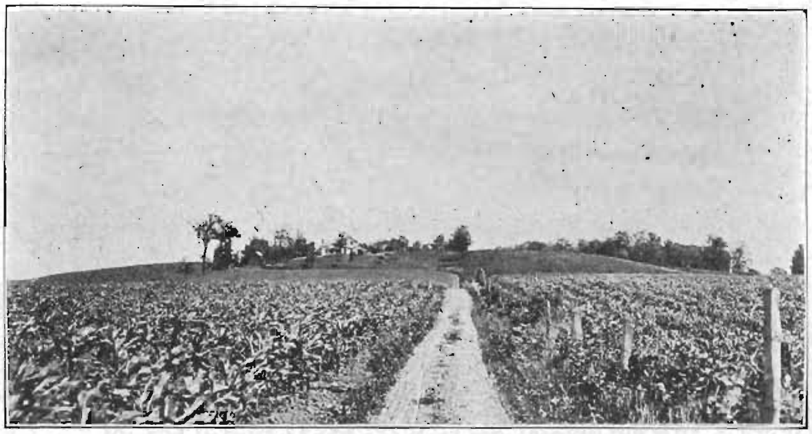


FIG. 42. Paha north of Allen Grove.

(Fig. 43), grassed or forest-covered, but with barren patches here and there of wind-blown sands. Between these hummocks, or between the ridge and the Illinoian upland, several shallow ponds occur, a few acres in extent, fed through springs by the storm water which falls on the surface of the adjacent hills. Much as this ridge resembles a region of dunes, its position, its alignment, its composition, and its structure refer it to the class of the paha.

Within the area of the Iowan drift, and well down into the Wapsipinicon flood plain, there occur in Winfield and Butler townships, as in section 18 of Butler, long, narrow, parallel

FIG. 43. Sand hills on Iowan frontier, Princeton township.

sandbars with pahoid trend which, perhaps, belong in the same category.

All these constructional forms so far described belong to the region which has been associated with the invasion of the Iowan ice. But they occur far to the south of the Iowan area. In the southwestern part of the county near Durant, in sections 32 and 33 Cleona township, low rounded hills separated by broad swales are found, which have every appearance of paha. Their structure is probably the same as that of an isolated hill, just across the line in Muscatine county, transected by the C., R. I. & P. Ry., in which a nucleus of till is covered with water-laid deposits — gravel, sand and loess.

Illinoian and Kansan Drift Plains.—Beyond the Iowan frontier the topography of Scott county may be described as that of nearly level upland plains more or less dissected by erosion. All the valleys and hills in these plains have been carved by weather and water; but their initial flat surfaces were surfaces of construction, and these in places remain but little changed. In structure they consist of glacial till covered with loess. Thickening toward the Iowan frontier and toward the Mississippi river, the loess forms a mantle of fairly uniform thickness over the remainder of the area. Since it wraps about the hills and descends into the flood plains of the valleys, the initial features of these plains cannot be attributed to it but to the glacial till beneath. This argument is supported by the fairly uniform and slight thickness of the loess over areas as yet undissected. We may then conceive of the country south of the Iowan drift sheet as once covered by approximately level constructional plains of glacial till, which have been since deeply eroded in places and still later covered with the loess mantle.

The slopes of these plains may easily be restored. In the northwestern part of the county lies a now maturely dissected upland which extends south to within a mile of New Liberty and to within about the same distance of Round Grove, thus occupying the greater portion of Liberty township. While no flat topped areas remain on the divides, the rounded summits of the ridges fall into a plane lying from 800 to 820 feet above sea level. This we may designate as the Kansan upland, since it is carved in the Kansan drift sheet and its loess mantle. The upland extends north to Yankee run in Cedar county, and slopes gently toward the southeast from an elevation of about 880 A. T., which it reaches southwest of Lowden. In Cedar county the Kansan upland merges by imperceptible degrees of lessening erosion into a plain, which stretches south of Bennett and crosses the west line of Scott county from New Liberty southward. In Scott county the division is marked, the maturely dissected upland overlooking the plain from an elevation of about twenty feet. In the neighborhood of New Liberty the plain stands at a height of about 800 feet A. T., and here one or two sections remain uninvaded by drainage channels. Going south, however, channels multiply and deepen, until within two or three miles from New Liberty tabular divides of any extent have disappeared and the district has practically been reduced to slope. The level tops of the remaining ridges still indicate the initial surface, which thus is seen to decline southward to about 740 A. T., where it overlooks Mud creek.

Across the valley of Mud creek lies a loess-mantled drift-plain, which extends thence south and west to the Mississippi river, occupying thus about three-fourths of the area of the county. This we may call the Illinoian drift plain, since it is supposed to represent the drift deposited by a lobe of glacial ice here moving westward from the region of Illinois. Over much of the area the plain remains flat and featureless. Even its edges along the Mississippi river are tabular areas representing old plain surfaces. Thus the slope of the plain may readily be reconstructed, after allowing for the varation in the original thickness of the loess cover. The present surface stands highest at the north, about Eldridge at about 800 A. T., and at the south, on the high prairie about Blue Grass, at nearly the same elevation. Between Blue Grass and Eldridge runs a central sag at 740 A. T., west of Mount Joy; and level tracts at this elevation extend to Davenport, to Le Claire and to Maysville. The Illinoian plain, as it approaches the Mississippi in Buffalo township, dips toward the river with a slope perceptible to the eye. Toward the Wapsipinicon there is also a short northern slope best seen where, in a few places, the Iowan paha are absent. McGee* has noted the slopes which, on either side of Duck creek, dip toward that central axis. All these slopes are constructional and are not due to the erosion of the present streams.

At one point the Illinoian topography crosses the broad channel of Mud creek. In the southwest corner of Cleona township, extending into Allen Grove, lies a broad shelf at from 720 to 740 A. T., about forty feet above the Mud creek flood plain and as much below the adjoining hills of the Kansan upland. Upon this lies a low loess ridge parallel to the channel of the creek, suggesting an embankment upon a current-cut terrace. This shelf overlies, it may be noted also, the deep preglacial channel of "Cleona river."

Fluvial Plains of Aggradation.—Constructional relief forms built up by deposits of rivers are of marked extent in the county. The flood plain in the ancient channel now occupied by Elkhorn and Mud creeks, and the far larger flood plains of the Wapsipinicon are examples which may be more conveniently described under the drainage of the county.

EROSIONAL RELIEFS.

Causes and Conditions.—The Iowan frontier separates, as we have seen, two essentially different topographies. To the north the land is modeled, to the south it is carved. To the north the hills are heaped and moulded, to the south they are hills of circumdenudation, remnant hills left by the removal of material by the wash of rains and the cutting of streams. Carved out thus by running water, the summits conform everywhere to the divides, and have no more definite alignment or

*11th Ann. Rept. U. S. Geol. Surv., p. 405.

orientation than that imposed by the initial slopes of the drift plain and the consequent courses of the streams. Outside the Iowan drift the diversity of aspect of different sections of the county depends, then, on the degree of erosion which any section has suffered. This is under the control of several causes, the most important of which are age, material, nearness to local base levels of erosion and initial height above them.

Since erosion is a constant process, since creeks and rivers are unceasingly cutting down their beds and conveying the wash of the hillsides to the sea, the longer the time since they began their work upon any district, the more will they have accomplished, the more severe will be the erosion of the district, and the further advanced will it be in the cycle through which topographic forms flow under the agencies of destruction. Conversely, the younger any district is, *i. e.*, the shorter the time since it received its initial form, the less must it have suffered from erosion. In the earliest stages of the cycle of destruction, an originally level or nearly level tract will have but few streams, and these will have barely incised their channels into the land surface. Their branches will be few and short. Large areas will remain undrained, and here and there storm water will gather in original inequalities of the surface, forming lakes, ponds, marshes and swamps. No district in Scott county south of the Iowan frontier presents these characteristics of the first stage in the sculpture of the land. With the lapse of time and the unceasing work of running water, the chiseling of the land is carried forward to another stage with different and equally defined characteristics. Lakes and marshes have now been filled and drained. Streams have cut their channels deeper and now run, at least in their lower courses, in steep-sided, V-shaped valleys. Their affluents are more numerous and have pushed their head waters by retrocessive erosion back far into the areas originally undrained. Flat-topped remnants of the original plain are still left on the divides. Hills are wider still than valleys, and more of the land mass remains than has been cut and carried away. An advanced stage may be seen when the work of erosion has gone so far that the original land mass is thoroughly dissected, when the divides have narrowed into ridges, and of these perhaps only those at greatest distance from the master streams still touch the initial plane. The whole county has been reduced to slope. Later stages than this need not be mentioned, since they find no illustration within our area.

With this brief word indicating the changes which time brings about on the face of the land as it advances from infancy to youth and to maturity, we may scarcely more than enumerate the other factors which have wrought out the physiognomy of the county. Of these elevation is a factor of prime importance. The work of the stream depends upon its energy—the energy of molar motion which is dependent on gravity. The higher the fall, the greater the power. The more elevated the district, the swifter will be its streams, the more energetic their corrasion, and the sooner therefore will the district reach any given stage in the erosional process. High uplands may therefore be maturely dissected, while low initial plains as old in years linger still in their topographic infancy.

Relative hardness of material and distance from local base-level are concomitant causes, accelerating or retarding the normal processes of erosion. The softer the terrane, the more easily it is carved and the more rapidly does it pass through the stages in the cycle of destruction; while the harder the terrane, the longer will it linger in each successive stage of the process. Other things being equal, horizontal nearness to base levels implies in the earlier stages of the erosional cycle streams of relatively steep gradient, swift and of great corrading energy, while distance from base levels implies slight gradient and slow streams of little eroding power.

Illustrations of these laws of earth sculpture are everywhere at hand in Scott county. The scenery of every creek teaches the topographic effect of nearness or distance from the base level of the master stream. Take, for example, the Black Hawk. South of Davenport the stream debouches upon the flood plain of the Mississippi between bluffs about 150 feet high. Their sides are complexly lobate, furrowed deeply with ravines, and are often too steep for profitable agriculture. Naked scarps of yellow till and loess show where the creek swings against the side of the bluff and saps it. Roads are diverted here from rectilinear courses to secure easier gradients. But with each mile of distance from the base level of the Mississippi, the height and steepness of the hills along the Black Hawk diminish, until in about five miles, the traveler on the B., C. R. & N. Ry. finds himself on a plain flat as a floor and scarcely scored by drainage channels. Now, in age, in elevation, and in hardness of the strata the high prairie at Blue Grass is practically the same as the rugged country of the lower Black Hawk. It differs simply in distance from the base level of the Mississippi and in the exemption from erosion which that distance has so far insured. Thus also the traveler going north from Davenport on the C., M. & St. P. Ry., in about five miles leaves behind the deep and complex pinnate valleys along the Mississippi and reaches the level tracts around Mount Joy. The same change is accomplished in still less distance in going west from the dissected margin of the upland at Le Claire, and also south from the Wapsipinicon in the eastern part of Butler township.

The influence of the relative hardness or softness of terranes is illustrated in the soft loess-silt; the yellow loam which everywhere covers Scott county except within the Iowan frontier and on the river bottoms. Loose textured as is the loess, the fact of its presence is proof of the recency of its deposition. So easily is it eroded that, were it of any considerable age, geologically speaking, it must long since have been washed away to the sea. Indeed, most of the valleys of the county were cut before the loess was laid down, as may be seen from the fact that it descends the hillsides well down to the creek bottoms. Where the loess is of considerable thickness, and especially where it was deposited on country already deeply eroded, there obtains a most intricately dissected relief, which is best seen on the Kansan upland about Big Rock. Here the channels of the permanent streams and their primary and secondary ravines are cut in older and heavier deposits, but the ultimate branches, the twigs of the erosion system, are cut largely or wholly in the loess. These are often so close that it may be said that no room exists for another. In form they are often spatulate, the broad and comparatively shallow bowl of the spoon lying well up toward the crest of the upland. The ravine constricts, however, as it descends, and opens into the ravine to which it is tributary by a narrow gateway. Sometimes the bowl has deepened and forms a little cirque, in which occasionally a tiny grove is growing. The spatulate form is normally developed wherever a layer of softer material overlies one of greater resistance. The stream, whether a permanent one or merely the occasional course of the water of rains, cuts through the weaker bed and reaches the lower, harder bed first, in its middle or lower track. Here, its down cutting is delayed by the greater resistance it meets. The grade of the stream above is thus lowered, since it cannot be cut below the point of passage over the harder stratum. Erosion spends itself, therefore, above this point, in widening the valley or the gully. Spatulate ravines in process of formation show a ravine bifurcating, rarely trifurcating, toward the crest. These upper branches widen and at last cut into the neighboring branches, while the stem ravine is deepening its bed. Loess gullies usually begin where the slope of the hillside is steepest, and this, on convex slopes, is in the central portion. Here, down cutting is most active, while above this portion, where the slope is more gentle and less water is at work, the effect of rain wash is more toward sheet erosion. On long slopes, less steep, there are developed ravines of corresponding length, separated by narrow, lingulate lobes. These tongue-like divides descend with a gentle and fairly uniform grade to near the floor of the trunk valley, where their slope becomes more steep. The obtuse angle thus formed may express a change from a weaker stratum above to a more resistant stratum below, as from loess to till, or from till to rock. Or it may express simply the more active erosion, the more rapid down cutting, going on in the trunk valley.

On well kept farms the extreme twigs of loess erosion stems are not allowed to develop, but so soft is the silt and so rapidly is it cut down by rain wash, that eternal vigilance is the price of ungullied hillsides. When constant watch has not been kept the lobes of the hills are most closely ribbed, or, if the disaster is recent, they are disfigured by close parallel gashes (Fig. 44). The beginnings of trouble may be

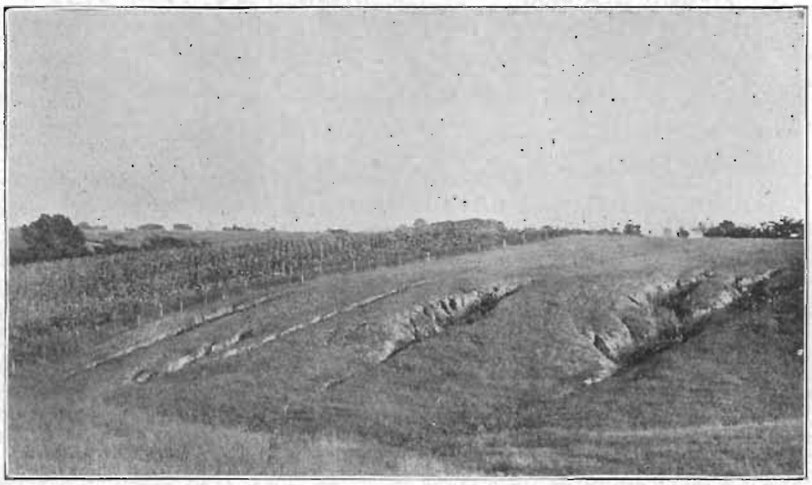


FIG. 44. Characteristic l ess-gullies, and even sky line of Illinoian plain; Princeton township.

seen on hillsides in pasture, where, in a season of drought, the grass has here and there been trodden out. In such spots the loose loam, now unprotected by its mattress of grass, is blown away by the wind or washed out by an occasional rain, so that slight pittings of the surface are the immediate result. The heavy rains of fall and spring deepen these depressions into gulches where the grade of the hills is greatest, *i. e.*, on the central portion of the slope. This may coincide with a loess-mantled shoulder of till, so that a system of loess gulches is often seen to start on a line with the summit of Kansan till exposed in the roadway.

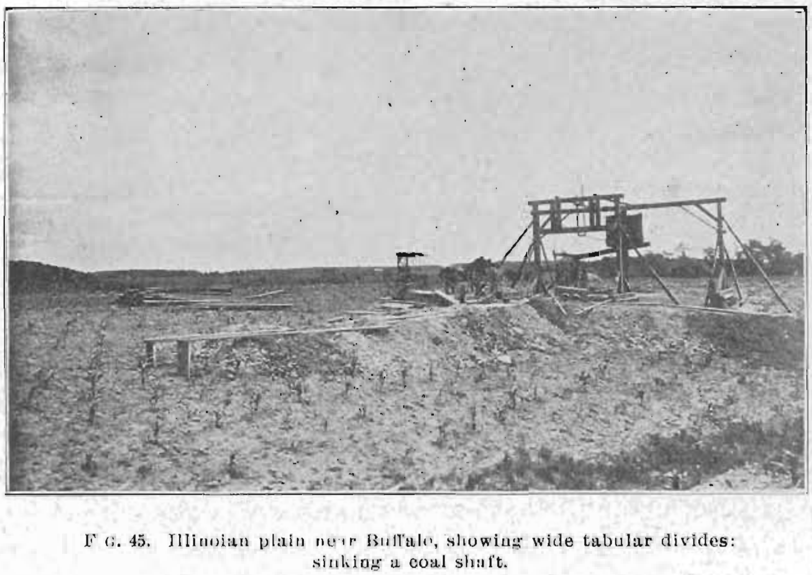
The ready corrasion of the loess is best seen on the steeper hillside roads. Here a wagon rut soon cuts to a miniature canyon a few inches perhaps in width but several feet deep, and in two or three seasons an unmended road becomes impassable.

Elevation as a factor in topographic form is better illustrated by comparing Scott county with outside areas, than by comparison of different districts within its limits.

Recent as are the superficial deposits of the county, in which its relief is for the most part worked out, the youthful expression of the face of the country is due largely to its low altitude above the local base levels of the master streams. The Illinoian plain descends to within about 150 feet of the Mississippi at the south, and to within 100 feet of the Wapsipinicon flood plain at the north. The higher levels of the Kansan plains and uplands lie about 150 feet above the latter datum. So slight are the local differences that we have not succeeded in disentangling any special topographic features due to these rather than to other causes. But by comparison with other regions it may be seen that, with equal age, had any considerable elevation been given the county, its streams, instead of moving sluggishly over muddy bottoms in shallow valleys, would rush and cascade over the rocks into which they had deeply cut their gorges, and there would have resulted a rugged region, more picturesque indeed than the present, but far less suited to the needs of man.

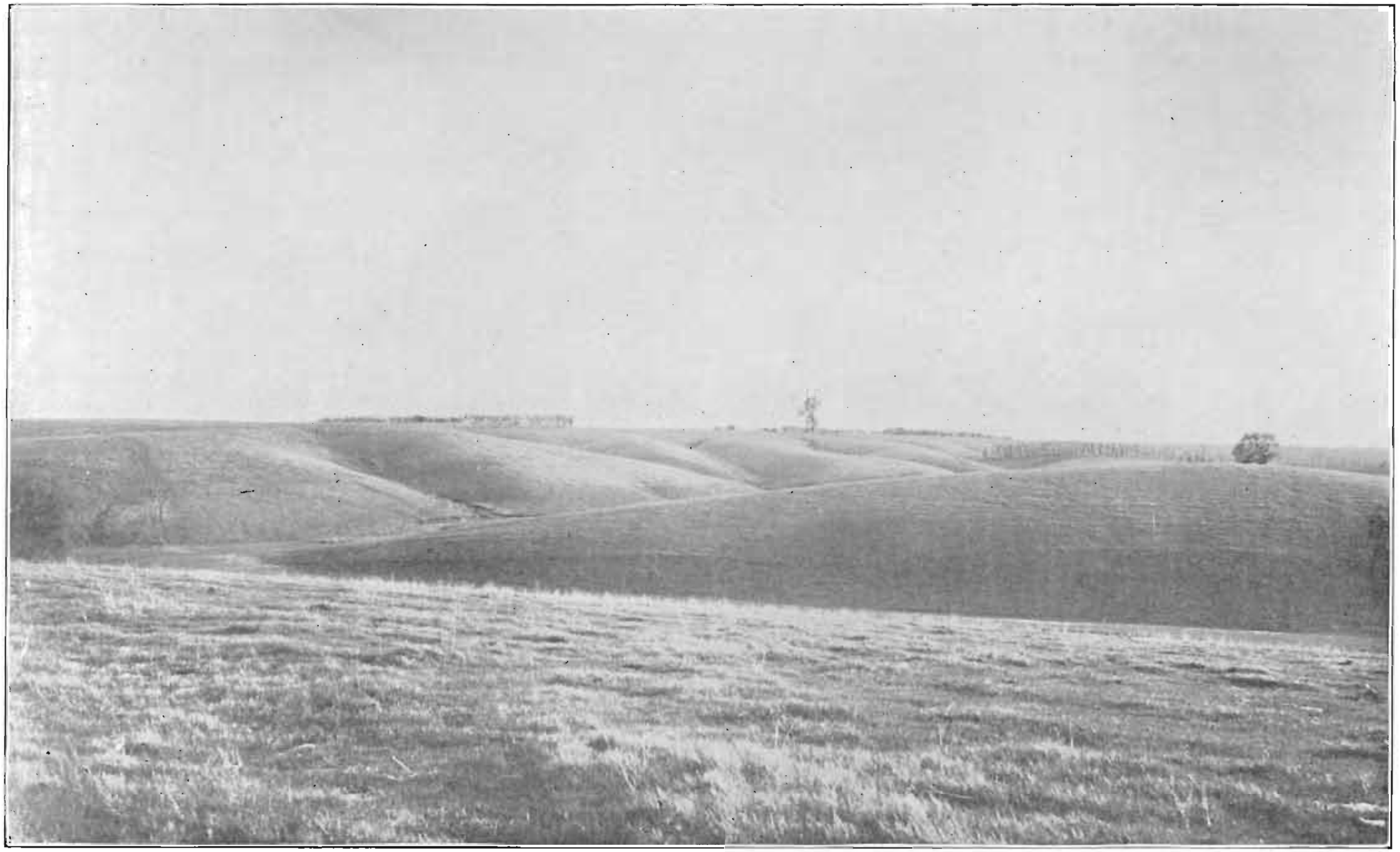
We have seen that, other things being equal, the topography of any region varies with its age. Using, therefore, this delicate test, there have been discriminated in Scott county three topographic areas of different age, the Iowan area, the Illinoian plain, the Kansan upland. The narrow belt south of the Wapsipinicon bottoms, designated as the Iowan area, is one of extreme youth. Erosion has had time to make few changes in it as yet, and it remains substantially as laid down by the Iowan ice and its attendant waters.

The Illinoian.--The Illinoian plain is evidently older than the Iowan. Its surface is, at its margin, deeply carved. Even in the interior, about Blue Grass, Walcott, Mount Joy and Eldridge, rainwash and storm water have swept out broad shallow depressions which have drained any ponds which once may have existed. No sedgy Iowan sloughs are here found. But the Illinoian plain still is young. Erosion has, for the most part, only nibbled at its edges. Even to its margins, overlooking the two master rivers, remnants of the original plain surface are left. The mesa-like tops of these outermost salients are well seen in the level streets of that portion of Davenport built on the bluffs, and unfortunately for the builder and the taxpayer illustrations are not wanting in the same district of the sharp, steep bevels chiseled by stream and rainwash. Deep as are these complex, pinnate valleys along the margin of the Illinoian plain, everywhere the eye crosses the valley to find on the other side the flat-topped divide at the



F G. 45. Illinoian plain near Buffalo, showing wide tabular divides: sinking a coal shaft.

Iowa Geological Survey
V. 9
1898
Blank Page Facing p 408



TYPICAL TOPOGRAPHY OF LOESS-MANTLED KANSAN UPLAND, LIBERTY TOWNSHIP.

same level. If imagination refills the valleys with the material washed out from them, the initial plain is at once restored. Somewhat back from the river the divides are so wide that stations may be taken from which the valleys are invisible, and the original plain becomes a matter of vision. Even the valley of the Mississippi thus sinks out of sight, the bluffs in Illinois ranging their flat-toped summits in the same plane with those of Iowa. This phenomenon is sometimes startlingly distinct. The northern Illinois asylum for the insane at Watertown, perched on the high bluffs overlooking the Mississippi, forms an imposing landmark far up and down the great river. But from view points on the Iowa side north of Davenport, the castellated towers of the asylum apparently rise in the far distance from a level plain, which seems to stretch unbroken to the observer. The youth of the Illinoian is seen also in the wide area of the interior scarcely as yet scored by erosion channels. The region stretching from Blue Grass to Mount Joy, Eldridge and Porter's Corners, exhibits nearly the initial form of the upland plain out of which all the reliefs of the Illinoian area have been carved. To the eye much of it lies as level as the flood plain of a great river. The horizon line is as even as that of the ocean. Indeed, riding over this prairie on a summer afternoon, one seems to be voyaging over a sea of verdure. Level fields of corn and grain stretch away to the limit of vision. The distance lies hazy and blue, while here and there rise islands of darker green, the planted groves of the farmsteads. The tabular area on which Blue Grass is situated is more than five miles long and from one to four miles wide, and within these limits the maximum relief is less than twenty feet according to the topographic maps of the United States Geological survey. From Green Tree Tavern one may travel north and west to Walcott for fourteen miles, and according to the same authority he will not have changed his elevation above sea level more than twenty feet in the distance.

The Kansan.—The Kansan upland of Liberty township is much more completely dissected, and, therefore, may be held to be of greater age than the Illinoian plain. Valleys and ravines have invaded the entire area, covering it with arborescent lines of drainage. Divides once tabular have been worn back into convex typical ridges. The crest of at least the axial ridges retain the horizontality of the original plain out of which they have been carved. (Plate VIII.) The skyline is therefore for the most part even, but the heavy deposits of loess cause here and there slight sinuosities. With the lapse of time these crests will be broken down into cols and rounded summits, but that stage is far in the future, according to our common standards of measure. Roads generally maintain their rectilinear courses over this rough country, the county commissioners making the best of the situation by cuts and fills. In several instances roads are laid out along the ridges and up the valleys. Railroads make use of the creeks as natural highways, the Burlington, Cedar Rapids & Northern railway using the south branch of Walnut creek, and the Chicago, Milwaukee & St. Paul railway the north branch. Another evidence of the age of this region is found in the well opened valleys of its creeks and their broad flood plains. These will be considered in detail under the topic of drainage.

The Kansan plain immediately about New Liberty retains its original constructional features for the most part. Still no water stands upon it; slight depressions, water worn, everywhere leading away to the creeks. But south toward Mud creek it conforms in its erosion to that which Kansan plains elsewhere have suffered under similar circumstances of altitude and distance from base level.

DRAINAGE.

Scott county occupies an angular space between the Mississippi and its affluent, the Wapsipinicon, the latter river constituting most of its northern boundary, and the former bounding it to the east and south. No part of the county is more than eleven miles from one or the other of these master streams. Disregarding its many meanders the course of the Wapsipinicon along the northern border is about twenty-seven miles, while the frontage on the Mississippi is about thirty-six miles in length. Yet something more than one-half of the county drains to the shorter course of the smaller river. The basin of the Wapsipinicon, which in Jones county is markedly narrow, widens in Scott and Clinton counties to twenty-five miles.

The Wapsipinicon River.—The different portions of the valley of the Wapsipinicon in Scott county show two distinct types. As it enters the county near Big Rock it leaves a flat-bottomed valley, three miles wide, whose rock floor has been filled to a depth of 300 feet, and enters a gorge some forty rods wide, within which the river swiftly runs over a rocky bottom, washing on either side the bases of precipices thirty feet high, and hills which rise 100 feet above the river. This gorge—one of the picturesque spots of the county—is less than a mile in length, and probably marks the position to which the river was once pushed over to the southwest, from its older track, by the Iowan ice. Beyond the gorge the river again enters the open, level valley-plain, three miles wide, silt-filled to an unknown depth. Down this plain it sluggishly wanders with many meanders to the Mississippi, which it enters through several distributaries. From the terraces which mark the limits of floods of the present river, the alluvial plain gradually rises some fifty feet to where it meets the boundary hills. Near the Mississippi, northwest of Princeton, these are high and steep, and descend to the plain by low ledges of rock on which talus slopes are as yet but little developed. Further to the west, in Winfield township, the line of demarkation is fainter, the Iowan drift plain merging into the Wapsipinicon bottom. With some sandy tracts and some lagoon ponds these bottoms comprise much fine and fertile alluvium, unsurpassed as corn and grass lands in the county.

Down this flood plain, evidently fashioned by another and much larger stream, the Wapsipinicon swings in easy curves whose inner radii are from fifty to seventy rods. Here and there are cut-offs and bayous. In Allen Grove township, in especial, the earlier meanders along which the county line was originally drawn have been mostly cut off, so that patches of Clinton county now lie on the south side of the river, while Scott extends its jurisdiction over tracts which once lay within the horseshoe bends to the north, but which are now cut off from the rest of the county by the present channel. Some of these old channels are not yet filled, and even in mid-summer droughts they convey perhaps one-fifth of the water of the river. According to the county maps these cut-offs have been so numerous as to imply a distinct change in the regimen of the river since the settlement of the county. An elevation of the region would lead the stream to thus shorten its course, as would any cause which increased its erosive and transporting power. Of the possible causes the probable one, though it has not been tested by any local investigation, is that change produced by the plow and the axe which has affected all our streams, and which greatly increases their volume and energy in times of flood.

In Liberty township the flood plain lies about seven feet above ordinary stages of the river while the highest floods overflow a terrace twelve feet above the same datum. In the same township, below the gorge already described, an isolated rocky hill stands on the flood plain, cut off from the hills of the banks by a wide and ancient channel now in cultivated fields. The affluents of the Wapsipinicon cross its wide flood plain in courses more or less diverted down stream. Thus Mud creek approaches its master stream to within a mile at a normal angle and then runs along it at this distance for some five miles, until the Wapsipinicon swings in to the right bank and picks it up. The lower courses of Jones creek, Lost creek, Martin creek and Glynn branch have been rectified, and cross all or part of the flood plain in public or private ditches.

Rock and Walnut Creeks.—The valley of Rock creek forms a natural frontier along part of the northern county line, the hills of the right bank rising from Liberty township. Rock outcrops at various points along the stream, as the name suggests, and especially near the village of Big Rock. The valley is wide and open above the village, with flood plains occasionally one-half a mile wide. Rock creek is about fourteen miles in length and maintains an unusually uniform flow. It is the only creek in the county utilized for water power, and at Big Rock twelve feet of head is estimated to furnish fifty-two horse power for a flour and feed mill just across the county line.

Parallel to the valley of Rock creek lies that of Walnut creek, the next affluent of the Wapsipinicon toward the south. The headwaters of its southern branch are gathered on the Kansan plain about New Liberty, at about 800 A. T. Entering the Kansan upland and descending rapidly, it cuts through the drift and discloses the country rock at many places near the stream level, at about 700 A. T. In its lower course its valley widens to a flood plain as wide as that of Rock creek, and here it receives its northern branch which comes to meet it over a rich bottom land of still greater extent. At Dixon the valley narrows, and the stream has cut a scarp of forty feet in till and loess. Here the trench of the stream is about a rod wide and about twelve feet deep. A mile east of the village it enters the flood plain of the Wapsipinicon.

Mud Creek.—The next tributary of the Wapsipinicon, Mud creek, has the largest area of supply of any of the county creeks. It is itself an insignificant stream, occupying near its mouth a trench four or five rods wide and six or seven feet deep. But it has a magnificent valley — first noted by Leverett, large enough for the Mississippi—*i. e.*, a broad flood plain from half a mile to more than a mile in width, marshy in places and with here and there a shallow pond. From either side the hills come down into the valley with gentle slopes, loess covered, and loess also is found on the flood plain. No distinct banks are seen except where the creek now swings against the hills. Furthermore, the valley neither constricts nor ends at the head of the creek. It continues broad and spacious past Durant and Wilton to the great bend of the Cedar. From Durant southward it is occupied by a southward flowing tributary of the Cedar, called Elkhorn creek.

The divide between the two creeks, three miles north of Durant, consists of an imperceptible rise in the flat bottom of the flood plain, and on it lie several small ponds (Fig. 46). Above Durant the valley divides, and the town is situated

FIG. 46. Ancient channel of Mississippi river at the divide between Mud and Elkhorn creeks.

on a long low ridge, an island in the ancient river which cone filled these waterways. In this region of inosculating channels, this river must have occupied a space from two to three miles across. Connecting with the great valleys of the Cedar to the south and the Wapsipinicon to the north, and through them into the Mississippi, connecting also through a short reach of the Wapsipinicon with a similar abandoned channel extending up Brophy's creek, past Goose lake, to the Mississippi at the mouth of the Maquoketa, this ancient river which flows by Durant cannot have failed to have received its share of the floods of waters which slowly moved southward in Pleistocene times within the Mississippi valley and in parallel channels. Certainly this great waterway was not fashioned by its present creeks.

Each tributary of Mud creek traverses in its lower course a broad re-entrant of the ancient flood plain. Thus that of the little creek that comes down past Maysville is a mile and one-half long and half a mile and more wide. It is believed that these broad flood plains were filled from the main channel rather than aggraded by their own creeks.

Other Affluents of Wapsipinicon River.—East of Mud creek a number of short streams, Jones creek, Martin creek, Glynn branch, Mason creek and Contention branch, flow north into the Wapsipinicon over the Illinoian plain and through the Iowan area. In the latter their northern courses are not sensibly diverted. Lost creek also rises on the Illinoian plain and flows eastward on the slope toward the Mississippi, until within hailing distance of the headwaters of Bud creek which continues its general direction eastward, it turns north, is diverted northwest by the massive paha ridge in sections 28 and 29, Princeton township, and then issues forth upon the Wapsipinicon flood plain. The situation suggests the capture by Lost creek of the headwaters of Bud creek, but the unscored Illinoian plain along the divide does not bear this out. These creeks all flow in narrow valleys overlooked by the unworn tabular divides of the Illinoian plain.

The Affluents of the Mississippi are of similar nature, creeks of steep gradient rising back on the prairie and flowing at first in shallow sags, in which crops are cultivated to the immediate streamway, gradually deepening their channels until they flow out on the flood plain of the Mississippi between walls of rock surmounted by steep and high bluffs of till and loess. Of these Spencer and Crow creeks are the largest north of Duck creek, their courses being about ten miles in length. Duck creek rises near the Muscatine county line, on the level prairie between Walcott and Blue Grass, and follows an apparently initial depression in the Illinoian plain, or in its loess cover, nearly due east to near its mouth, thus running parallel, but in the opposite direction, to the Mississippi for about seven miles. Most of this distance would be saved should a short, little creek west of Davenport, down whose valley run the tracks of the Chicago, Rock Island & Pacific railway, sometime cut through the col, less than twenty feet in height according to the United States topographical maps, which now separates their valleys. To north of Davenport the valley of Duck creek is shallow and open, cut in loess and in till, but near its mouth it has cut its narrow way in rock whose precipices rise in places thirty feet in height.

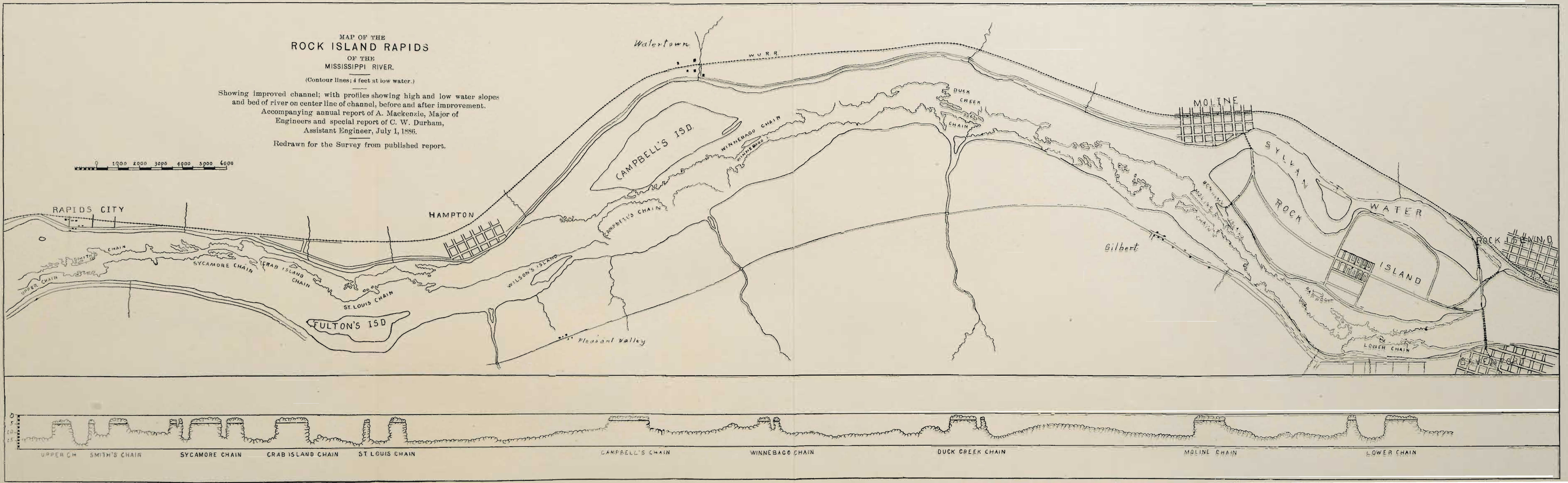
Black Hawk creek runs parallel to Duck creek, but falls into the Mississippi at the bend below Davenport. Owing to a local depression in the rock surface the lower valley is cut only in loess and till, although in places Carboniferous shales are seen near water level. The valley is utilized by the Burlington, Cedar Rapids & Northern railway as its gateway to Davenport, and the railway profile shows a descent for the little stream of 100 feet in somewhat less than three miles. Midsummer droughts leave water only in pools, while storms may make it a destructive torrent, washing away embankments and bridges. On reaching the Mississippi flood plain it turns southwest, hugging the river bluffs, and then, within about 160 rods of the river, turns northeast and continues this course for about a mile until it discharges at Fisherton.

Buffalo, the southern township of the county, is drained by seven parallel creeks, from one to five or six miles long, which resemble Black Hawk creek in their courses to the flood plain of the Mississippi, except that for a mile and more back they flow over rocky bottoms and have made many vertical cuttings in the Devonian limestone of the region.

The Mississippi.—For the first four miles of its course along the east front of Scott county the Mississippi traverses the wide alluvial flood plain of an ancient river now occupied on the Iowa side by the Wapsipinicon. At the mouth of the latter river the Mississippi divides its waters, sending a part through the bayous with which the distributaries of the Wapsipinicon inosculate, the main channel being diverted to the east by the sediment of the affluent. On this wide plain, to the eye as level as the sea, no rock is anywhere in view. But at Princeton the Mississippi enters a rock-cut valley scarcely wider than the river itself. On either side the bluffs descend abruptly to a flood plain so narrow that room is given only for road and railway, and a street or so of the villages which are located along this portion of the river course. Ledges of limestone outcrop in the hills and extend to the water's edge, and beneath, harassing the river in rapids. At Smith's island this gorge widens a little with the outcrop of weak Carboniferous shales. Below the island it constricts again with the reappearance of hard Silurian limestone. From Valley City to below the mouth of Duck creek the valley is more open, being nearly two miles wide at Watertown. On the right bank lies a beautiful and fertile flood plain, more than a mile wide, consisting of alluvial silt with some stretches of sand spread over a current-cut terrace of rock. Midway this wider track there enters on the left bank the ancient river valley now occupied in part by Rock river. At Davenport the Mississippi swings well in against the western bluffs, leaving Rock Island as a detached portion of this terrace flood plain separated from both the Iowa and the Illinois shores. On the same fluvial floor of rock, lying about twenty feet above the river and formed by lateral cutting and covered with a thin veneer of alluvium, stand the lower portions of Davenport. Below this city the bluffs retreat from the stream, leaving a flood plain a mile wide, but again sweep round to the river at Horse island above Buffalo, narrowing the plain to about a quarter of a mile in width from this point to the county line.

Terraces.—With the exception of this flood plain terrace the terraces of the Mississippi in Scott county are by no means conspicuous. In Davenport a narrow bench, about fifty feet above low water, is utilized by the Chicago, Rock Island & Pacific railway tracks. At Crow creek an indistinct terrace lies thirty feet above the flood plain, or about the same height as the bench at Davenport. Between Le Claire and Princeton an ill-defined platform on the hillside occurs at about fifty feet above water level and in section 14 S. W. qr., Le Claire township, a broader terrace of buff sand reaches thirty-seven feet above the same datum, which may be referred to the Wisconsin sub-stage of the Pleistocene.

Rock Island Rapids.—A topographical feature of special economic interest is the series of rapids extending from Le Claire to Davenport and known as the Rock Island rapids. For more than seventy years these rapids have been a notorious obstacle to the navigation of the river, and for nearly as long a time their improvement has received the attention of the government. The brief sketch appended is founded on reports of government surveys, especially those of Lieut. Robert E. Lee, 1837, Lieut. G. K. Warren, 1854, and Major Mackenzie, 1886. Rock Island rapids occupy a stretch of the river fourteen miles in length and have a fall of 20.4 feet at low water. Over the entire distance the bed of the river consists of rock deeply worn in pools and rising in ledges known as "chains," which stretch across the stream from bank to bank, leaving originally a depth in places of only thirty inches, even in the channel, in midsummer droughts. The portion obstructed by "chains" aggregates about three miles, leaving eleven miles of unimpeded navigation between the head and foot of the rapids. Over certain chains the difficulty was not so much the depth of the water as the narrow and tortuous channel and the swiftness of the current. The greatest measured velocity over any chain has been 8.36 feet


MAP OF THE
ROCK ISLAND RAPIDS
OF THE
MISSISSIPPI RIVER.
(Contour lines; 4 feet at low water.)
Showing improved channel; with profiles showing high and low water slopes and bed of river on center line of channel, before and after improvement.
Accompanying annual report of A. Mackenzie, Major of Engineers and special report of C. W. Durham, Assistant Engineer, July 1, 1886.
Redrawn for the Survey from published report.
1000 2000 3000 4000 5000 6000
Watertown
W. U. R. R.
RAPIDS CITY
HAMPTON
CAMPBELL'S ISD
FULTON'S ISD
WILSON'S ISLAND
DUCK CREEK CHAIN
WINNEBAGO CHAIN
CAMPBELL'S CHAIN
UPPER CHAIN
SMITH'S CHAIN
SYCAMORE CHAIN
CRAB ISLAND CHAIN
ST. LOUIS CHAIN
MOLINE
SYLVAN
WATER
ROCK ISLAND
Gilbert
Pleasant Valley
LOWER CHAIN
DAVENPORT
UPPER CH
SMITH'S CHAIN
SYCAMORE CHAIN
CRAB ISLAND CHAIN
ST LOUIS CHAIN
CAMPBELL'S CHAIN
WINNEBAGO CHAIN
DUCK CREEK CHAIN
MOLINE CHAIN
LOWER CHAIN

per second. The location of the chains is shown on the accompanying map. The geological formations to which they are assigned are as follows:

Upper chain	Le Claire limestone
Smith's chain	Le Claire limestone
Sycamore chain	Le Claire limestone
Crab Island chain	Le Claire limestone
St. Louis chain	?
Campbell's chain	Otis beds
Winnebago chain	Otis beds
Duck Creek chain	Lower Davenport beds
Moline chain	Lower Davenport beds
Lower chain	Lower Davenport beds

Up to 1886 there had been removed from these claims in deepening, widening and straightening the channel 87,926 cubic yards of material, at a cost of $1,166,650. About $350,000 has since been spent in the prosecution of the work, which is still in progress.*

History of the Drainage.—The history of the rivers of this region is a long and complicated one, and no single county, perhaps no one state, supplies sufficient data for its exposition. Nothing further will here be attempted than to suggest the local problems involved, and their solution will be left to the results of a much more complete research.

Scott county lies immediately to the south of the driftless area, and is separated from it by a narrow tongue of Iowan drift. In glacial times that area was bounded on both sides by the fronts of the lobes of great continental glaciers. It is possible that at one or more stages of the glacial epoch these lobes met to the south of the driftless area and thus inclosed, behind an ice dam, a sheet of water whose drainage would be over the confluent ice in the region of Scott county. Streams thus cutting their way through the ice would be let down upon the land beneath regardless of its relief. There is a body of evidence going to prove that while the ice streams flowed from either side toward the central axis of the Mississippi, they did not reach it concurrently in certain stages of glacial

*Letter of Capt. O. D. Townsend, Upper Miss. Impr. Com.

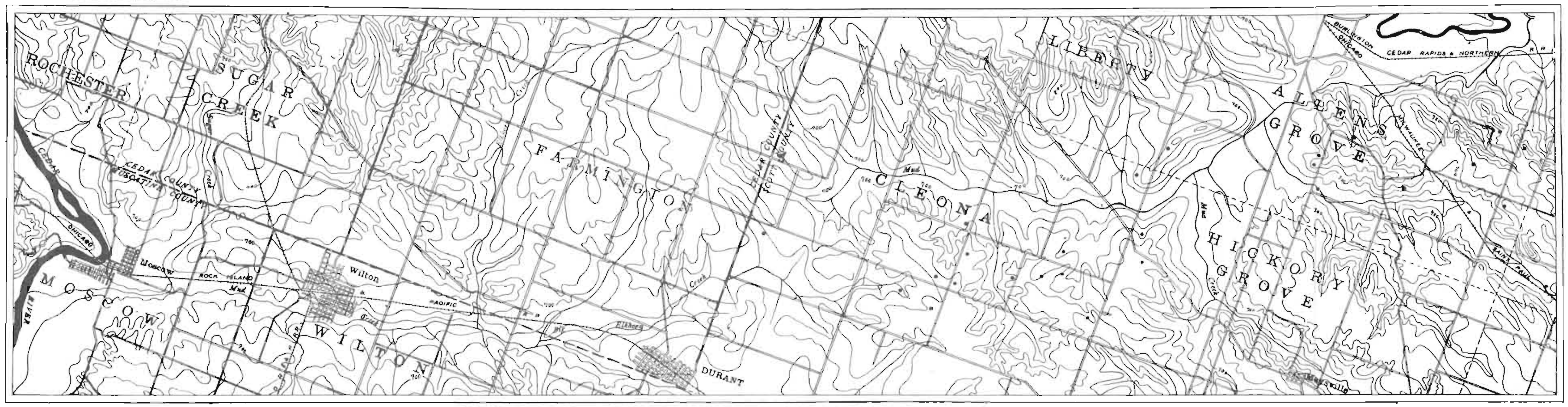
history. At one stage the Illinoian ice crossed the Mississippi channel and invaded Iowa; at another the Iowan glacier carried the wave into Illinois. The effect of the migration of the fronts of these great glaciers must have been to push the river draining the driftless area sometimes to the west into Iowa and sometimes to the east into Illinois.

Elevation and deformation are also factors of which account must be taken. Deep river channels lying 130 feet below the present local base level of the Mississippi can be accounted for only by a previous elevation of the region. Local evidences of deformation, such as warped terraces, may be looked for, closing some old channels and opening others. On the accepted theories of Pleistocene history we should expect to find in this region a complicated series of southward drainage channels, some deep and some shallow, some open and some closed, some rock-cut and some lying wholly in the drift.

Some seven channels have been investigated more or less fully which confirm this expectation. Of these the channel now occupied by the Mississippi from Sabula to Clinton is one of the oldest. It measures from four to seven miles across from bluff to bluff, and the artesian well at Sabula found the fluvial floor of rock only at 163 feet below the level of the fluvial floor of the flood plain; *i. e.*, at 419 A. T. Certainly a channel with so aged a physiognomy may be considered preglacial.

It probably connects through the deep, wide, silt-filled valley of the lower Wapsipinicon with Cleona channel. This is known to reach a depth of 400 A. T., and is at least between two and three miles in width. It is now completely filled. Hills stand above the old waterway, and its existence would not be suspected were it not for the deep wells of the region. These show the presence of several distinct tills in the old valley, and its date may safely be considered as preglacial.

Goose lake channel and the channel which passes by Durant resemble each other closely. Each is now drained by small creeks, one flowing north and one south, separated



ANCIENT CHANNEL OF THE MISSISSIPPI RIVER, NOW OCCUPIED BY MUD AND ELKHORN CREEKS.
Redrawn from Davenport, Wilton Junction and Durant sheets of the U. S. Geological Survey. The black dots locate deep wells in drift.

by a low, swampy divide. In each loess is deposited in places, and their age may be reckoned as pre-Iowan. Each would accommodate the volume of the Mississippi, but, while Goose lake channel would be filled by a rise of the great river of about seventy feet, a rise of 140 feet would be required to flood the other, according to the atlas sheets of the United States Geological Survey. This would even now be effected were the Mississippi blocked with glacial ice at Le Claire, together with the Marais D'Ogee channel. Durant channel follows closely the western edge of the Illinoian drift sheet, as has been shown by Leverett, its discoverer, who has traced its course southward to where it re-enters the Mississippi near Fort Madison. It is, therefore, reasonable to suppose that the line of the southern drainage of the region was held in this channel by the incursion of the Illinoian ice.

A low, open, alluvial waterway extends from Fulton, Ill., southeastward along the valley of Cat-tail creek and connects with the broad flood plains of the Rock river. With the same flood plain connect the still broader bottoms, known as the Marais D'Ogee, which continue into Illinois the great valley of the Wapsipinicon. So recent is the occupancy of the Marais D'Ogee by the Mississippi, if not its original excavation, that the great river still sends a portion of its waters at highest flood around by that eastern route, and a slight deformation would suffice to divert to it the entire river.

The present channel of the Mississippi from Princeton southward has already been described. Any extended discussion of its age would be premature. The narrowness of the rock-cut channel, the absence of flood plains, the relatively steep gradient, the long stretches of rapids, all are features of topographic youth, and point to an age much less remote than that of the deep and wide, silt-filled channel above Princeton. It is evident that there has been a local rejuvenescence of the river from Princeton southward, and

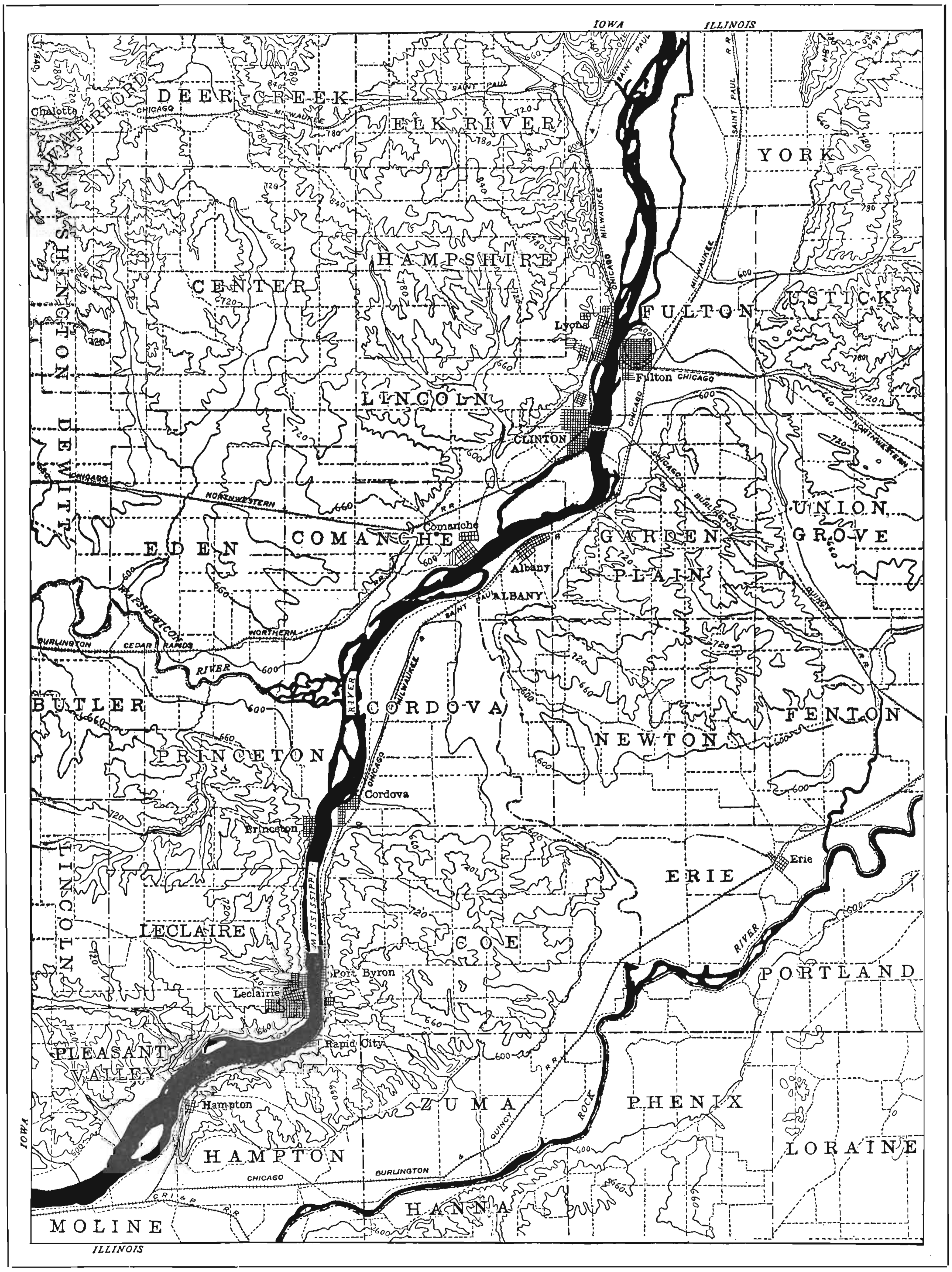
Cleona channel supplies a more ancient path from which the river may have been diverted.

STRATIGRAPHY.

Taxonomic Relations.

The subjoined table affords a conspectus of the geological formations of the county. The last column is subject to revision in the sub-stages of the Cedar valley and Gower. Those under the Cedar valley stage are not all very clearly made out; and those under the Gower are only retained as sub-stages provisionally, until it is seen whether work in other counties confirms the conclusion pretty surely indicated in Scott, that they are but lithological phases of contemporaneous deposition.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.	Alluvial.	
		Glacial.	Iowan. *Sangamon.* Illinoian. *Yarmouth.* Kansan. *Aftonian.* Pre-Kansan.	
			Residual Clays. *Geest.*	
Paleozoic.	Carboniferous.	Upper Carboniferous	Des Moines.	
	Devonian.	Middle Devonian.	Cedar valley.	Dielasma beds. Spirifer Parryanus beds.
			Wapsipinicon.	Upper Davenport. Lower Davenport. Independence. Otis.
	Silurian.	Niagara.	Gower.	Anamosa. Le Claire.



Map of Mississippi river and its ancient channels in northeastern Scott county and adjacent portions of Iowa and Illinois.
Redrawn from Clinton sheet, U. S. Geological Survey.

Geological Formations.

SILURIAN.

GOWER STAGE.

The entire body of the Silurian rocks in Scott county belongs to the Niagara series. The lowest stage of the Niagara, the Delaware stage of Calvin, has not been recognized in the county, and all the Silurian limestones are referred to the upper stage, here termed the Gower. These limestones form the country rock over the northern and larger part of Scott county, their southern limit trending slightly northwest from Valley City to about five miles north of Durant. Exposures of the Gower occur in all the townships north of this line, except in Sheridan and Lincoln, where it lies buried deeply beneath the drift.

There are two distinct lithological types of the Gower limestone. The pure, hard, crystalline dolomite free from chert and especially adapted to the manufacture of lime, known as the Le Claire limestone from its occurrence at the village of that name. The light-buff, granular dolomite, evenly bedded and extensively used for building stone, has been named by Calvin by the term long used in commerce, the Anamosa stone. These subdivisions have been ranked hitherto as distinct stages, but the evidence at hand does not seem to warrant any chronological separation. The terms Le Claire and Anamosa will therefore be used merely as convenient designations of different lithological varieties of rocks of the same stage. Regarding both building stone and lime rock as practically contemporaneous, a name for the stage of their deposition becomes needful. None so appropriate suggests itself as Gower, the name of the township in Cedar county in which occurs many outcrops of both the Le Claire and the Anamosa stone, and in which are situated the famous Bealer quarries at Cedar Valley.

The Le Claire Stone.—The Le Claire limestone is a practically pure dolomite, a double carbonate of lime and magnesia represented by the chemical formula of (Ca. Mg.) CO_3. The normal ratio in pure dolomite is, calcium carbonate 54.33 per cent, magnesium carbonate 45.65 per cent. The following analysis of the lime rock at Le Claire by Dr. C. F. Chandler* shows not only a close approximation to this ratio, but also the remarkable freedom of the rock from siliceous, ferrous and argillaceous impurities:

Insoluble silicates or sand	0.42
Oxides of iron and alumina	0.53
Carbonate of lime	57.54
Carbonate of magnesium (by loss)	41.51

No nodules of chert occur, and although cavities are plentiful, in none is found quartz either in crystals or in chalcedony. The color of the rock is normally a light bluish-gray, varying to darker shades as well as to almost white. Weathered cavities and cracks are often stained buff. The rock is fine, close and crystalline in grain, brittle, with irregular or subconchoidal fracture. Cavities, largely due to the removal of fossils, abound and give to the rock a porous or vesicular appearance and a trachytic harshness. Useless for building stone, it forms a rock unsurpassed in perhaps the whole geological series for the manufacture of lime. A distinguishing characteristic of the Le Claire rocks is the absence or abnormal disposition of its bedding planes. Like the Racine limestone of Wisconsin, it often forms huge mounds in which scarcely a trace of stratification is visible.

These mounds are often fossiliferous, and in them occur irregular masses of breccia and conglomerate difficult to delimit, since the matrix is identical with the fragments in color and texture. Especially towards the sides and summits obscure stratification lines occur, merging into the mound proximally, and distally dipping outward and downward at considerable angles. An excellent example occurs at Schmidt's lime quarry southwest of Dixon. Others are to be seen about Le Claire, forming the centers of apparent anticlines.

*Hall, Geology of Iowa, vol I., pt. 1, p. 368.

Outcrops of Le Claire stone are usually traversed by parallel planes, commonly about a foot or less apart. These affect masses of limestone more than twenty feet in vertical thickness and with a dip usually from 12 to 25 degrees, but occasionally rising as high as 40 degrees. Along these planes,

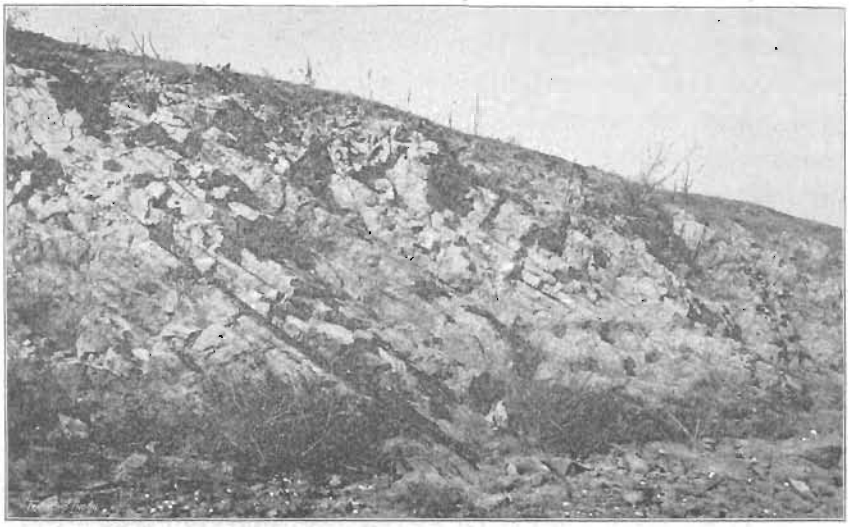


FIG. 47. Le Claire limestone showing oblique bedding. Beds dip to the northeast; (one-half mile south of Le Claire, Iowa.)

tilted as high as 32 degrees and 36 degrees, frequently lie layers of fossils, and the colonial aspect of the fauna of different layers, here crinoid stems, here Rhynchonellas and there spire-bearing brachiopods, or Pentameri, strongly suggests that the fossils have not been washed to their present resting place, but remain in the place of their growth. Nowhere do these planes transect fossil belts, and as pointed out by Calvin,* they therefore cannot be placed in the category of slaty cleavage. The inconstancy of the dips is notable. Within short horizontal distances they vary in degree and direction. For example, in the most southern exposure below Le Claire, along the Mississippi (S. E. qr. Sec. 4, Le Claire Tp.),

*Proc. Iowa Acad. Sci., vol III, 1896, p. 56.

the dip is 30 degrees east southeast; at the schoolhouse, 15 rods east, the rocks lie in a nearly horizontal plane; while a quarter of a mile up stream the dip is 15 degrees north.

In the same township, Sec. 14, Nw. qr., Se. ¼, the Le Claire stone is exposed on a low platform near the edge of the Mississippi river. It is here thinly bedded. On the south the layers dip from 35 to 48 degrees northeast. Toward the north, for fifty feet succeeding, the bedding is obscure, and this gives place to limestone of the same facies dipping 4 degrees southwest. Layers are often seen to interbed and merge with breccia and the structureless rocks of the mounds.

The interpretations which have been given to these abnormal planes are diverse. At an early date Hall believed them due to the flexures of strata once horizontal*. White† and McGee‡ concurred with Hall in regarding them as due to deformation. Worthen§ had earlier suggested false bedding or slaty cleavage as explanations.

Hall afterwards revised his earlier opinion and suggested that these dips might be due to oblique lamination.‖ Norton¶ showed that the assumption of the deformation gives a thickness to the beds at Le Claire far in excess of anything which can be conceded. Later measurements confirm this statement. For a distance of 3,300 feet below the village the uninterrupted dip averages some 20 degrees. If the bedding planes represent tilted strata, the original thickness of the tilted block must have been more than 1,000 feet.

Calvin** has recently given the entire subject a more thorough investigation, and holds that the phenomena in question are neither due to folding nor to lateral compression, as in slaty cleavage; but are examples, on a scale perhaps hitherto unknown, of false bedding or oblique lamination, such as is to

* Rept. Geol. Surv. Iowa, Hall and Whitney, 1858. p. 73 seq.
† Geology of Iowa, White, vol. I, p. 131. 1870.
‡ Pleistocene Hist. of Ne. Iowa, p. 340. 1891.
§ Geol. Surv. of Ill. vol. I, p. 130. 1835.
‖ Twentieth Annual Report, Regents N. Y. p. 307.
¶ Iowa Geol. Surv., vol. IV, p. 134.
** Proc. Iowa Acad. Sci., vol. III, pp. 52-53.

be seen wherever in sea, lake or river, a current is extending a bar by dumping sand or silt over its edge, thus adding layer after layer lying at angles more or less inclined. "The phenomena suggest that during the deposition of the Le Claire limestone the sea covered only the southern part of the Niagara area; that at times the waters were comparatively shallow, and that strong currents, acting 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 * * *. In the town of Le Claire, on the west side of main street, there is evidence of the erosion of the sea bottom by currents, and subsequent filling of the resulting channels with material of the same kind as formed the original beds. In eroding the observed channel some of the previously formed layers were cut off abruptly, and in refilling the space that had been scooped out the new layers conformed to the concave surface and lapped obliquely over the eroded edges of the old ones."* The entire thickness of the Le Claire stone is nowhere displayed in Scott county, and no section reaches the maximum thickness of the beds, some ninety feet, observed in Linn county, near Mount Vernon.

The Anamosa Stone.—Intimately associated with the crystalline lime rock known as the Le Claire are beds of a soft, granular building stone, lying in even and horizontal or slightly undulating layers. They are best seen in the quarries about the village of Le Claire, where the stone differs from that of the typical quarries near Anamosa in little except in a slightly stronger tint of buff and a less frequent lamination.

Chemically the Anamosa stone is a dolomite, differing in its constituents from the Le Claire in the larger per cent of the insoluble ingredients. While in the Le Claire there is less than one per cent of insoluble ingredients, in the Anamosa they have been found to form six times as large a proportion. In Scott county, as elsewhere, the Anamosa stone runs in

*Calvin. Op. cit., pp. 54-57.

even, parallel courses, whose thickness depends in part upon weathering, but in which layers from eight inches to a foot are most common. To these dimensions quarry layers of several feet in apparent thickness can usually be split readily. Bedding planes are smooth surfaced, and are not separated by intercalary seams of clay. Joints are distant, allowing the quarrying of stone of any desired horizontal dimensions. The fracture of the rock is even and smooth, affording the utmost advantage to the sledge and chisel of the workman.

The weathered zone of the Anamosa, which may reach ten feet in depth, consists of spalls and calcareous plates from a fraction of an inch thick up to three or four inches in thickness. Two distinct lines of lithological variation occur. One is a transition from a granular to a crystalline condition, a trend toward the Le Claire. The other is a change to a harder rock of finer and more compact grain, with subconchoidal fracture, weathering more or less readily into rhombic chipstone. Layers of this nature are termed "flint" by quarrymen, on account of their fracture and relative hardness, although wholly destitute of silica. This variation trends toward the Devonian lithological types.

The trend toward the Le Claire is exhibited in many quarries throughout the county from Big Rock to Princeton, and as far south as Valley City. The rock lies in heavy layers, commonly two feet thick, traversed by few or no lines of lamination and, like the typical Anamosa, disposed in gentle undulations as if laid down on an uneven surface. In texture, the stone is more or less vesicular, sometimes so finely so as to suggest the texture of pumice, and is also distinctly more crystalline than the pure Anamosa type. It is more earthy than the Le Claire and can never be used for the manufacture of lime. It is darker and more ocherous in its colors than the Le Claire and resembles in many respects beds of the Delaware stage, from which it is distinguished by its most intimate associations with other beds of the Gower. It still more resembles the Coggon beds which in Linn county* were found immediately to underlie the Devonian series. The characteristic Coggon fossils have not been found in these beds in Scott county, and they can not be definitely assigned to the Coggon horizon.

Relation of the Le Claire and the Anamosa Beds.—From his studies at Le Claire, Hall reached the conclusion that the Anamosa beds there exposed, rested in synclinal axes of the Le Claire and belonged not only to a later stage, but even to a distinct epoch. While he placed the Le Claire in the Silurian, as co-ordinate with the Niagara, he assigned the Anamosa to the Onondaga Salt group. Worthen and Meek, White and McGee referred all the strata of the Silurian in Iowa to the Niagara, refusing to draw any lines of subdivision within the formation. Calvin and Norton, however, have distinguished the Le Claire from the lower beds of the Niagara, to which Calvin has given the name of Delaware, and have also separated to a greater or less extent the Anamosa and the Le Claire limestones. In the geology of Linn county† Norton states that the theory of simultaneous deposition of the two limestones under different conditions, the "lime rock" of the Le Claire, representing the irregular aggregation of reefs, and the granular limestones of the Anamosa the remoter deposits of calcareous sediments derived largely from the reefs, seems best to explain all the phenomena of the beds in question observed in Linn county. The close paleontological relations of the two beds, the lithological gradations between them, and the occurrence of crystalline lime rock in places upon the granular limestone of the Anamosa beds are mentioned. At the same time the great thickness of the Anamosa, its wide distribution, the appearance in it of post-Niagara species, are taken to indicate that it represents a somewhat later stage of Silurian sedimentation. Since the publication of the report just cited, quarries have been opened on the Cedar

* Norton: Geology of Linn Co., Iowa Geol. Surv. vol. IV, p. 138. 1894.
†Iowa Geol. Surv., vol. IV., pp. 130-134. 1894.

river west of Mount Vernon, which show clearly the most intimate relation between the Le Claire and Anamosa types. The highly inclined lime rock of the former is seen to pass directly by lateral gradation into slightly inclined beds of building stone of the latter type.

In Scott county alternations along the same horizons between the Le Claire and the Anamosa are frequent; the intermediate lithologic forms between them are numerous. The Le Claire lime rock is moreover interbedded with the Anamosa, or superior to it, so that it becomes impracticable to maintain a formational distinction corresponding to the lithological one. At Steffen's the crystalline lime rock passes laterally into granular building stone within the limits of a small quarry. At Becker's quarry, Le Claire, the former overlies the latter.

TYPICAL SECTIONS OF THE LOWER LE CLAIRE TYPE.

I. SCHMIDT'S QUARRY, LIBERTY TP., SEC. 14, SW. QR., SW. ¼.

Dolomite, white, crystalline, brittle, vesicular, massive, with some obscure and variant lines of bedding. A similar mound some 30 feet thick is exposed by the roadside an half mile southwest (Liberty Tp. Sec. 22, N. ½).

II. LEDGE OUTCROPPING ON ROCK CREEK, LIBERTY TP., SEC. 6, SE. QR., NW. ¼.

Dolomite crystalline, gray, weathering to highly pitted surfaces, in layers up to 4 feet thick, dipping from 23 degrees to 32 degrees east northeast; thickness, 15 feet.

III. ANKEN'S QUARRY, LIBERTY TP., SEC. 13, NE. QR., NE. ¼.

Some 12 feet are here exposed of even bedded, crystalline dolomite in layers up to 1 foot in thickness, the lower 2 feet of the section being in thin layers a few inches thick. The rock forms a slight syncline whose greatest slope in the eastern part of the quarry is some 4 degrees west. Some small Rhynchonellas were observed, and on the dump fragments were found of softer, granular, vesicular limestone which was not seen in place. Adjacent ledges show the Le Claire limestone of the usual type dipping 40 degrees north.

IV. MEEVES' QUARRIES, LIBERTY TP., SEC. 18, W. ½.

Several small quarries have been opened for local uses on the farms of George and of Henry Meeves. Some have been filled up, and those examined showed a rough, crystalline limestone. A close-grained and laminated flagstone, which approaches the Anamosa type, is said to have been taken from another.

V. STEFFEN'S QUARRY, CLEONA TP., SEC. 5, SW. ¼.

This quarry includes several outcrops opened at different times along both banks of a small tributary of Mud creek. The opening now worked on the left bank of the stream has a quarry face of 14 feet, and excavations have been made for 9 feet below the present floor.

	FEET.
3. Loess	3
2. Till, Kansan, brown, non-calcareous, with a number of small bowlders, separated from loess by a distinct pebble line	2-10
1. Limestone, upper surface deeply pitted by weathering. The cavities, descending nearly to the quarry floor, are lined with brown, unctuous residuary clay and are filled with till, and across them the pebble line on upper surface of till passes without downward deflection. Rock, highly inclined in even layers, varying in dip from 20 to 30 degrees southeast. To within nine feet of the surface layers are thin, rarely reaching six inches, and layers up to a foot readily split up. Below, the layers run from six inches to a foot in thickness, and some beneath the present floor are said to reach three feet, and to readily cleave to desirable thickness. Above, the layers are hard, blue, crystalline lime rock; but below, this passes into a granular, light buff building stone, of the Anamosa type. Some layers are covered with short, flexuous, rod-like fossils, which have not been described, but which are often seen in quarries of the Anamosa stone. Joints are distant, and stone 10 feet square can be taken out	14

Ten rods below this section, on the same bank of the stream, occurs an outcrop of even and horizontally-bedded crystalline limestone, and twenty rods distant a mound of lime rock, with southward dipping strata on its south flank.

VI.

Fifteen rods below the above section, on the right bank of the creek, eight feet of hard, bluish-gray Le Claire rock occurs, with the bedding planes dipping 15 degrees northwest, and the layers running from four inches to eighteen inches thick. Within three rods to the north this dip becomes horizontal in the following section:

	FEET.
3. Limestone, granular, in spalls up to four inches thick..	5
2. Limestone, in two and three layers, irregularly bedded, semi-crystalline..........	4
1. Limestone, hard, of close grain, laminated, but not readily cleaved, to quarry floor....................	6

VII. BUD CREEK.

South of the town of Princeton Bud creek cuts a gorge in the Le Claire some eighty feet in depth. The dolomite here is buff or gray, hard, crystalline, vesicular, and lies in regular layers, dipping 3 degrees and less toward the west. The rough surface layers are, for the most part, a foot or less in thickness, although layers occur four feet and even six feet thick. Silica is wholly absent, and fossils are rare, a few moulds of Le Claire corals alone being seen. Some of the heavy layers are intermediate in texture, approaching nearly to the Anamosa type.

VIII.

In Princeton, opposite an old warehouse, a mound of Le Claire is shown in a slight excavation. The Le Claire occurs also in Allen Grove Tp., Sec. 7, Ne. ¼, where it has been burned for lime for fifty years. Half a mile north, Sec. 6, Se. ¼, lies an old quarry, showing ten feet of semi-crystalline limestone in horizontal layers up to fourteen inches. The upper half of the ledge is more evenly bedded, and resembles the rougher and more porous stone of the Anamosa beds. The lower portion is harder and more crystalline. At Big Rock the Le Claire outcrops at a number of places near the village. It is seen associated with the Anamosa in many outcrops along the bluffs bordering the Wapsipinicon in Princeton township, usually nearly horizontal, but occasionally dipping as high as 15 degrees, and along the Mississippi river from Princeton nearly to Island City its outcrops are quite too numerous to mention. For nearly two miles southwest of Le Claire the ledge along the river is practically continuous.

THE ANAMOSA TYPE.

VELIE & NASON'S QUARRY, LE CLAIRE.

	FEET.
7. Loess, weathered jointed, indurated, brown and reddish-brown, becoming more clayey toward the base, where it passes into No. 6.........................	4

6.	Clay, pebbly, dark red, non-calcareous, sandy or highly stony in places	3
5.	Till, gray, not accessible	25
4.	Limestone, soft, granular, weathered into spalls and thin calcareous plates, some as thin as a mm. Upper rock surface but slightly pitted. Limestone buff and dark buff, often finely laminated with darker brownish lines	12
3.	Limestone, buff, lustre earthy, granular, in layers about 6, 8 and 12 inches thick. Bedding planes continuous, even, parallel; joints distant	31
2.	Limestone, more irregular in bedding and texture. In one place it constitutes a single massive layer of hard, gray lime rock, graduating into layered buff, granular building stone which thickens and thins, forming lenticles about 20 feet in length	8
1.	Limestone, buff, granular, in even courses	4

The floor of the quarry is composed of thin irregular layers of finely laminated rock, buff and gray, of finer grain and more brittle than the rock above, and worthless for either building stone or lime. This is said to extend at least 17 feet below the quarry floor. At the west end of the quarry the dip is not more than 3 degrees. This increases toward the east until it reaches 12 degrees west, 20 degrees south.

H. BEEKER'S QUARRY, LE CLAIRE.

The rock of this quarry is in part of the Anamosa type, but is less regularly bedded. The layers are about one foot in thickness and dip 10 degrees north northeast.

		FEET.
4.	Limestone, granular, buff, slightly more compact than Anamosa type, in layers 6 inches and upward in thickness	5
3.	Limestone, crystalline, gray, largely fragmental, the fragments being small	4
2.	Limestone, gray, crystalline, compact; in two or three layers, with moulds of long Amplexus-like corals	4
1.	Limestone, resembling Anamosa type in color and granular condition, but closer textured, harder and with less even fracture	10

A. LANCASTER'S QUARRY, PRINCETON.

		FEET.
3.	Limestone, gray, crystalline, pure, vesicular and cavernous, stratified, used for lime	10
2.	Limestone, intermediate in character between Nos. 3 and 1, in heavy layers, weathering in places into rhombic chipstone	10
1.	Limestone, buff, granular, fine of grain, somewhat coarser textured than the Anamosa type, non-laminated, in heavy layers ranging from 24 to 28 inches in thickness, even and regularly bedded and over most of the quarry approximately horizontal; an excellent building stone	8

F. H. THEILMAN'S QUARRY, LE CLAIRE.

This quarry, which lies across a small creek and to the north of Velie and Nason's, displays some 18 feet of the same excellent building stone. From below, the thickness of the layers is as follows: 12 inches, 16 inches, 10 inches, 6 inches, 6 inches, 24 inches; above which are layers from 6 inches to 12 inches. The quarry has been worked some 8 feet deeper than its present floor. On the east face the dip is 5 degrees west northwest; on the west face the dip is 2 degrees northwest. The upper rock surface, as in the quarry across the creek, forms a low hill fairly smooth of surface and unbroken by pits.

On the same side of the creek lies a small quarry, with a face of 17 feet, belonging to G. H. Davis. The stone, as in the quarries just described, is of pure Anamosa type. It lies in layers up to 18 inches thick, dipping slightly toward the west.

GAMBLE'S QUARRY, LE CLAIRE.

This quarry is situated in the heart of the village and has not been worked for a number of years. The stone is of the best and was extensively used in the buildings of the Rock Island arsenal. The quarry face is about 30 feet. The stone runs in even, parallel courses, with a slight dip, not over 3 degrees toward the west. The lower 14 feet are a light buff, granular, homogeneous limestone, with smooth even fracture, in layers from 6 to 14 inches thick, traversed by vertical distant joints running 10 degrees north of west and 30 degrees west of south. Above these layers lie 3 or 4 feet of rough vesicular and cavernous limestone weathering to a most irregular face, of no value except for riprap. The remainder of the quarry lies in the zone of weathering and shows layers from 2 inches to 6 inches thick. The extremely thin weathered plates and spalls, often seen in quarries of this rock, do not here appear.

FIG. 48. Overturn fold in Anamosa limestone (retouched). Pinneo's quarry, Princeton township.

C. W. PINNEO'S QUARRY, PRINCETON TP., SEC. 35, SW. QR.

		FEET.
2.	Limestone, buff, weathered into thin layers from a fraction of an inch to 4 inches thick. Horizontal at west end of quarry; at east end flexed into a strong overturn fold 8 feet high, with overturn toward the east. Upper surface weathered into pits, two of which are filled with white plastic, gritless clay (Carboniferous ?) with white saccharoidal sandstone at bottom	10
1.	Limestone, light buff, in even layers from 6 inches to 10 inches thick, fine grained, undisturbed from their horizontal position except under the anticline of the upper layers, where they form a slight monocline with a fall of 9 inches in 7 feet	10

RICH'S QUARRY, PRINCETON TP., SEC. 34, NE. QR., NW. ¼.

Like the two quarries just described, this has been opened in the ledges of limestone which form the bases of the high hills which front the Wapsipinicon flood plain in this township, and its floor is approximately level with the plain.

		FEET.
5.	Superficial deposits resting on unpitted rock surface..	2
4.	Limestone in thin layers, mostly from 2 to 4 inches thick, a few reaching 8 inches, and some consisting of thin calcareous plates............................	12
3.	Limestone, close, granular, slightly harder and more brittle than typical Anamosa stone, in even, horizontal courses from 6 to 20 and 24 inches in thickness, buff in color, with few cavities and smooth surfaced, including a foot or so of thinly laminated "flinty" limestone.....................	14
2.	Limestone in layers from 2 inches to 18 inches, semi-crystalline..	7
1.	Limestone in thin, gray, crystalline, calcareous plates............	5

INTERMEDIATE TYPES.

The following sections represent beds of the Gower stage which resemble the Anamosa in their even and regular and slightly undulating courses, and in their buff color. They differ from the type in their heavier bedding, in absence of lamination, and in a more vesicular texture in their semi-crystalline facies. They are intermediate between the Anamosa and Le Claire types:

JAMES MOHR'S QUARRY, LIBERTY TP.

		FEET.
4.	Loess...........	2
3.	Geest, dark brown, unctuous, residual clay resting on a rock surface pitted to depth of about 1 foot.......	⅙-½
2.	Limestone, crystalline, hard, in layers up to 8 inches in thickness. On upper surface decayed to a depth of from 4 to 8 inches, to limestone meal or flour....	3
1.	Limestone in layers up to 18 inches in thickness, rising from approximately horizontal at west end of quarry to a southwest dip of 7 degrees at the east end, rock buff, semi-earthy, vesicular; near base earthy and finely mottled with drab.....	15

Across the creek substantially the same rock outcrops at the same level, but here it dips 15 degrees east and 20 degrees south. A quarter of a mile to the west lies the mound of Le Claire stone already described under Schmidt's quarry. A few rods west of this, an old quarry at the same level shows 12 feet of reddish-buff limestone in layers about 2 feet thick, not laminated, very finely vesicular, and partially crystalline, dipping 6 degrees northeast.

D. SNYDER'S LEDGES, LIBERTY TP., SEC. 1, NE. QR., NE. ¼.

This natural section, in ledges from 20 to 30 feet in height, along the gorge of the Wapsipinicon river, exhibits admirably the characteristics of these beds. They have been quarried in places for local uses. The rock is for the most part, a soft, earthy dolomite, dark buff or ocherous yellow in tinge, and finely vesicular. The layers are heavy, many being 2 feet in thickness and some upwards of 3 feet. No lamination planes appear. Here and there the rock takes on a more crystalline and harder facies. The bedding planes are not so smooth as in the typical Anamosa stone. Infrequent cavities are seen up to 4 inches in diameter, and a low cave about 10 feet above the river is said to have been penetrated to a distance of 80 feet. The rock stands in smooth surfaced walls without chipstone, and the only talus is formed of huge blocks detached by frost and the roots of trees.

COWLE'S QUARRY, BIG ROCK.

At this quarry, and outcrops adjacent, a soft, buff, highly and coarsely vesicular dolomite is exposed, moderately even in its courses, which run about horizontal, and mostly from one to two feet in thickness. The vesicles in the rock are largely due to the moulds of fossils, and these, or their corresponding casts, are occasionally well enough preserved for identification. The following species were noted: *Atrypa reticularis*, *Leptœna rhomboidalis*, *Spirifer radiatus*, *S. eudora*, *Rhyncho-*

treta cuneata americana, *Siphonocrinus nobilis*, *Eucalyptocrinus cornutus* (?).

At D. Rasch's quarry, in the same village, twenty-five feet of much the same rock is exposed as at Cowle's quarry.

GLEGG'S QUARRY, BUTLER TP., SEC. 17, NW. QR., NW. ¼.

		FEET.
4.	Limestone, spalls, hard	5
3.	Limestone, buff, granular, crystalline, in two layers	1½
2.	Limestone, rough, cavernous, without lamination, massive	4
1.	Limestone, buff, fossiliferous, in horizontal layers from 3 to 6 inches	5

The same beds outcrop on the south side of the region of outcrop of the Le Claire and Anamosa types at Le Claire, abutting on the northern Devonian frontier. The following sections are taken from this district:

LE GRANDE'S QUARRY, TWO AND ONE-HALF MILES BELOW LE CLAIRE, ON THE MISSISSIPPI RIVER.

		FEET.
1.	Limestone, brownish-buff, vesicular, earthy, crystalline, to level of water in Mississippi river	12

The upper two or three feet constitute a level and uniform layer. Below this lies a massive dome, in which bedding planes are obscure or absent, on each side of which the rock lies in outward dipping layers. To the south the dip is 10 degrees south southwest. On the north side the dip is more gentle. The rock, in texture, is intermediate between the Anamosa and Le Claire, while its attitude is wholly that of the latter.

H. HANNA'S QUARRY, PLEASANT VALLEY TP., SEC. 12, SE. QR., SW. ¼.

This quarry has a face of some thirty feet, and has been excavated along a ledge of a branch of Pigeon creek, the quarry floor lying eight feet above water level. The rock is heavily bedded, vesicular, and in certain layers running from one to five feet in thickness, pitted with cavities one to three inches in diameter, which may be confluent. The strata have a scarcely perceptible dip toward the west. The stone is a coarse, more or less crystalline, brownish-buff dolomite, some more compact and crystalline layers being lighter in color, and the more porous beds the more deeply stained by the oxidizing agents.

J. DODD'S QUARRY, PLEASANT VALLEY TP., SEC. 12, SE. QR., SW. ¼.

This little section is of special interest since it is found within 40 rods of the lowest beds of the Devonian, the Otis limestone, and must therefore lie near the summit of the Silurian column.

	FEET.
3. Limestone, magnesian, vesicular, buff, in layers 1 foot in thickness or less; more or less decayed..........	8
2. Limestone, magnesian, buff, with cavities up to 3 inches in diameter; evenly-bedded layers from 1 to 2 feet in thickness, dipping some 5 degrees east southeast..	7
1. Concealed to water of creek..........................	6

DYER'S QUARRY, PLEASANT VALLEY TP., SEC. 10, SE. QR., SE. ¼.

This quarry has been worked along ledges on Crow creek and well exhibits the rapid lithologic and structural alternations which obtain at this horizon. The ledge quarried farther up stream shows 23 feet of buff, granular, laminated, magnesian limestone, slightly more compact than the pure Anamosa type. For 10 feet from the top, this is weathered to characteristic spalls from a fraction of an inch to 2 or 3 inches thick, which graduate into the heavier layers of the main body of rock, which runs in even, smooth-surfaced courses up to 18 inches thick, dipping from 9 degrees to 22 degrees northeast, across the creek; 15 rods southwest of this exposure there outcrops crystalline lime rock. In thinness and evenness of layers, and in the dip which here amounts to 27 degrees northeast, this body of Le Claire stone corresponds with the granular Anamosa stone exposed so short a distance away at about the same level. Six rods further down stream the lime rock continues unaltered in texture, but now lies in layers 4 or 5 feet thick or more, and approximately horizontal.

The following section belongs to the Niagara limestone but may represent higher beds than those described:

QUARRY OF WM. RHEIMS, CLEONA TP., SEC. 7, NW. ¼.

		FEET.
4.	Limestone, magnesian, horizontally bedded, brown, semi-crystalline, weathering into small chipstone, with one or two 6-inch layers more resistant.......	9
3.	Limestone, magnesian, light gray, laminated, earthy, in places vesicular, more thinly bedded than above, passing in places into thin beds. This includes a distinct layer of buff magnesian limestone 1 foot thick..	6
2.	Limestone, magnesian, gray, irregularly bedded, thin layered, weathering to small, sharp angled chipstones.........	6
1.	Limestone, magnesian, brown, earthy, ocherous, in thicker beds than above, partly concealed.........	3

DEVONIAN.

The water front of Scott county along the Mississippi river exhibits a complete natural section of the Devonian strata of Iowa with the exception of their highest members, the Lime Creek shales and the State Quarry beds. As the strata dip gently toward the south and west, the lowest beds of the series lie farthest toward the north and east, appearing above the Niagara, first about one mile below Valley City, on the south fork of Pigeon creek. The highest beds in the section are disclosed in the southern townships, in numerous sections, from the vicinity of Buffalo to the south county line.

WAPSIPINICON.

Otis Limestone.—The outcrops of this limestone are so few and slight, that, with its associated beds, the Independence shales, it has escaped notice in the county until the present survey. In all respects the rocks referred to in this sub-stage are identical with the limestone first noted in Linn county, and named after Otis, a small station five miles east of Cedar of impalpable calcareous silt, affording a very fair quality of lithographic limestone. It is hard, brittle, breaking with a conchoidal or sub-conchoidal fracture. In color it varies from light to dark drab and brown, and weathers toward white. Often thinly bedded, these thin layers merge into massive beds, four or five feet thick, unevenly laid and sur-Rapids, where its full thickness is seen. So constant is its facies that, were their labels removed, specimens from widely separated outcrops, from the ledges of the Mississippi, the Cedar and the Wapsipinicon, could not be told apart. Lithologically, the Otis is a non-magnesian limestone, thus standing in strong contrast with the dolomites of the Gower stage, which it overlies. It is dense, of the finest grain, compacted faced. These are often finely fragmental, the matrix of the same color and texture as the fragments, and slight in amount. Sometimes the layers are simply crackled. A determinative characteristic of the Otis, and one which fortunately is seldom wanting south of central Linn county, is the presence of a little gregarious brachiopod, *Spirifer subumbonus* Hall. For the time represented by the Otis sub-stage, the Devonian sea bottom in this region in Iowa swarmed with this little animal, other species being strangely absent or unrepresented in the record of the rocks.* From what region *Spirifer subumbonus* migrated hither is an unsolved problem. In the New York area it abounded in Hamilton and Tully times. In Iowa, the day of this earliest visitant of the Devonian fauna soon closed. The end of the Otis sub-stage witnessed a slight elevation of the sea bottom, an approach of the shore line, and a distribution of clay silts where lime deposits had before prevailed. With this change of depth and bottom, with the passing of the Otis, and the incoming of the Independence, the little spirifer either became extinct or withdrew from the region, or possibly survived a little longer during the Independence, with such changes of form as to be no longer

*Since the above was written we learn that Prof. J. A. Udden has found on Pigeon creek, below Valley City, a minute coral.

recognized as the same variety. On the basis of this extremely restricted fauna, consisting of a single species not found elsewhere below the Hamilton, the Otis cannot rank lower than the Middle Devonian of the New York series.

In Scott county no clear contact of the Otis with an inferior limestone is found, although the Niagara occurs within about forty rods of the most northern outcrops. In Pleasant Valley township, Sec. 13, Se. qr. Nw. ¼, the Otis appears in the road opposite the house of W. E. Haskins, in conjunction with a vesicular magnesian limestone upon which it may rest. In Linn county several excellent contacts between the Devonian and the Silurian occur, where the Otis is seen to pass downward through transitional layers into a buff, heavily-bedded magnesian limestone, called the Coggon, and supposed to be the uppermost member of the Silurian series in the region. The Otis outcrops only along a narrow zone between the mouth of Duck creek and Valley City.

Independence Shale.—In its typical exposure in a miner's shaft, near Independence, was found a fine, fissile and highly fossiliferous shale, varying in color from light gray to black. In Linn county the Independence is represented by a heavy and persistent bed of buff shales and argillaceous limestone, called the Kenwood, which occupies the same horizon beneath the brecciated beds of the Lower Davenport sub-stage, as the Independence. At one locality, near Linn Junction, this has been found to include shales of the same facies as that at Independence, and carrying the same fossils. In Scott county the fossiliferous shale has not been found, but the Kenwood type of the Independence is seen at two outcrops on Crow creek resting directly, as in Linn county, upon the Otis limestone. The greatest observed thickness of these beds in Pleasant Valley township is seven feet, and the total thickness of the formation may not greatly exceed this measure. Lithologically it is a rough, brown, earthy, ferruginous limestone, in layers from two to four inches thick, and carrying lenticular nodules of flint.

Lower Davenport Beds.—Immediately south of the area of outcrop of the Otis and Independence, in the east half of section 27, Pleasant Valley township, occurs a Devonian terrane which has been designated the lower Davenport.* It is in these beds that Duck creek has cut the steep and narrow gorge near its mouth. Devil's glen, as the spot is called, is one of the most picturesque places in the county, and its beauty, together with its nearness to Davenport, suggests its appropriation as a permanent park. The lower Davenport is quarried for lime at Gilbert and for building stone and ballast at several quarries along the Mississippi near Camp McClellan. It fronts the river in low ledges above Davenport and along Rock Island, and extends as far west as the quarries of West Davenport, where it is overlain by the upper Davenport beds. But one fossil, a cyathophylloid coral, has been found in them.† The lower Davenport limestones are unfossiliferous. They contain too small a percentage of magnesium carbonate to prevent their rapid effervescence in cold dilute hydrochloric acid. The prevailing color of the stone is drab, weathering to light gray. For the most part the limestone is hard, compact, and fine grained, with earthy lustre, and smooth subconchoidal, conchoidal, or splintery fracture. Near the base one or two layers are partially crystalline, and a distinct bed in the quarries near Camp McClellan is a finely mottled gray, with a texture and weathering corresponding to that indicated by the alternation in color. Near the base certain layers of an earthy, ferruginous, brown or buff limestone occur. These are seen beneath low arches in the strata along the Mississippi ledges, and here in one place the same lithological variety is seen to fill unconformably a long, low depression in the gray limestone of the normal type. In places white and saccharoidal layers occur. The lower beds are massive and moderately heavy; but the upper layers are

*Norton: Proc. Iowa Acad. Sci., vol. I, pt. IV, pp. 22-24. 1893.
†Udden, Journal Cinn. Soc. Nat. His., vol. XIX, p. 93.

commonly finely laminated, weathering to thin and even calcareous plates.

With all these variations the lower Davenport has a distinct lithological facies wholly different from that of any other terrane of the Devonian except the Otis, and from this it is clearly separated by the Independence. The facies of the lower Davenport is not confined to a limited area It characterizes a continuous and constant horizon of the Devonian from Davenport at least as far north as Fayette, and is lithologically identical in all its outcrops, whether on the Mississippi, the Cedar, the Wapsipinicon or the Volga. In Linn county its brecciated fragments rest upon the Independence, and in several localities it is seen to underlie the upper Davenport beds. The maximum thickness is perhaps forty feet.

In the quarries of West Davenport the lower Davenport retains its hardness, brittleness, and fineness of grain. It is more irregularly bedded, and massive and even, thin laminæ are uncommon. Barris* early noted the decided change which here, as elsewhere, occurs in passing downward into the lower Davenport beds. "There succeeds a rough rock, concretionary in appearance, closely approaching the character of chert. In Cook's quarry (and I suppose the same might hold true in reference to Smith's) the workmen only blast down until they come to what they call the 'flint rock.' Mr. Cook told the writer that he could at once recognize the presence of this rock by the peculiar ring it gave back to the stroke of the iron bar, even though its surface was covered up by water." Nowhere are the "flint-like" characteristics just described more noticeable than in these quarries. They consist of the comparative hardness of the rock and its smooth conchoidal or splintery fracture; yet, with the exception of rare siliceous nodules, no flint or silica in any form is contained in it.

Brecciation of the Lower Davenport.—For the most part the Lower Davenport beds in Scott county retain the attitude in

*Proc. Davenport Acad. Sci., vol. II, pp 263-264. 1878.

which they were laid as sediments on the sea floor. In Johnson, in Linn and in Buchanan counties these beds are so highly disturbed, so completely brecciated, that the evidences of the cause and nature of the process have been largely destroyed, and the origin of the breccia has remained one of the riddles of Iowa geology. But in Scott county the disturbing forces were much less intense. They affected here but one terrane and that so slightly that much of it remained undisturbed, and the brecciated portion retains structures which offer valuable clues to the nature of the stresses to which it has been subjected. The earliest stage in the process is seen where the thin calcareous plates of the formation have been slightly flexed. The stress here was sufficient only to crackle the brittle rock at right angles to its planes of lamination, and the layers are now penetrated by a network of calcite veins of infiltration from the narrowest visible to 2 or 3 mm. in diameter.

An advanced step is frequent where, under a somewhat stronger stress, the rock has been broken into small angular fragments. These retain for the most part the plane of the layer to which they originally belonged, but by the disarrangement of the fragments the upper and lower surfaces of the layers are made more or less uneven. That the rock is a true crush breccia and not one formed either out of scree or by the deposition in water of angular detritus, is proven by the sharp and unworn edges and corners of the fragments and in especial by the fact that often their sides are matched and lie in juxtaposition. The matrix here is very small in amount and often difficult to define. Many of the cracks are filled with calcite, and where the interspaces are considerable between the larger fragments, they are filled with small particles of the rock and a calcareous silt of a slightly different color.

An interesting phase is where the thin laminæ so characteristic of the formation have been separated and slightly broken and now lie in a matrix of different color and texture, still retaining largely their original parallelism. Such, certainly, are not formed by the cementation of beach shingle. No other theory for their formation is tenable than that of crush under lateral pressure.

In the quarries in West Davenport illustrations are found here and there of an advanced stage in the process where, under a severe stress, the fragments are wholly disarranged. They retain the flint-like sharpness of their edges, and their interstices may be filled with a fine greenish clay resembling that of the coal measure pockets which abound in the same quarries.

On Rock Island the ledges of lower Davenport limestone show but slight disturbance. Low anticlines and synclines are not infrequent, and in several restricted areas, seldom more than a rod or so wide, the strata have yielded to horizontal thrust and are flexed, crumpled or completely shattered. An example of a layer bent beyond its limit of elasticity and fractured, is given in figure 49.

FIG. 49. Lower Davenport beds, partially brecciated, showing large imbedded fragment, with characteristic lamination, flexed and broken.

On the Iowa side, opposite Rock Island, the same phenomena may be seen, but not so clearly, since the ledges have in large measure been concealed or destroyed by the growth of the city of Davenport. Here the strata are occasionally seen to lie in low arches from 20 to 100 feet long, under which, at water's edge, a brownish, softer limestone sometimes appears. This, in its position and appearance, resembles the Independence, and in the fact that it contains a few small angular fragments of the Lower Davenport type, as in the brecciated zone in Linn county. It also reappears in fragments of breccia. It seems best correlated, however, not with the Independence, but with a brown, ferruginous limestone, carrying similar drab fragments of Lower Davenport type found near the summit of the Lower Davenport beds at Duck Creek. In the hollows of some of the synclines the Lower Davenport is locally brecciated as on Rock Island. In this region, as at Fayette, Linn Junction, and other classic localities of this brecciated horizon, it contains occasional siliceous, elliptical nodules with curiously carious surfaces, and reaching 6 inches and more in diameter. These however, are not characteristic of the Lower Davenport, being found more numerous in the Independence.

Upper Davenport Beds.—In the quarries in the vicinity of Davenport there rests upon the Lower Davenport beds a limestone of distinct lithological facies and carrying an abundant and characteristic fauna. The extension of this limestone in Linn county has been described and named the Upper Davenport.* The most eastern outcrop of which the writer is aware was in Fulton's old quarry, now filled up, in the Sixth ward, on Fourth avenue, Davenport. It extends at least as far west as to the quarries of West Davenport, and an exposure on the bank of the Mississippi river, opposite the foot of Offerman's island (Rockingham Tp., Sec. 9., Nw. ¼), resembles it in texture, although no fossils were found to complete the identification. The Upper Davenport is a tough, hard, gray, semi-crystalline, granular limestone, lying in irregular and rough-surfaced layers varying in thickness up to 2 feet, which break unevenly under the sledge. Blocks often show slicken-

*Norton: Proc. Iowa Acad. Sci., 1893, vol. I, pt. IV., pp. 22-24, and Iowa Geol. Surv., vol. IV., 1894, p. 160.

sides on vertical surfaces, and occasionally a small angular imbedded fragment is seen of the Lower Davenport limestone. The rock is highly fossiliferous as a rule, and certain layers are formed of a coquina of brachiopod shells; but so firmly are they cemented, so tough and hard is the rock, and so resistant to decay, that fossils are disengaged with difficulty, and perfect forms are rarely obtained; 15 feet is probably a sufficient allowance for the entire thickness of the beds. The Upper Davenport limestone has been recognized by nearly all workers in the field as a distinct stratum. In 1877 Barris* emphasized the demarkation of these beds from the Cedar Valley shales above, and the Lower Davenport below, in the statement that "this series of beds seems to be well defined in both its upward and downward limits, the Hamilton above and this flint rock below." Tiffany† also speaks of "upper fossiliferous strata" as distinct from the lower unfossiliferous beds, and like Barris assigns them to a lower geological formation than the beds above. In 1891 Calvin‡ defined the Gyroceras beds of Buchanan county (the equivalent of the beds in question), as "a rather hard, compact limestone, a few feet in thickness and containing numerous specimens of a large Gyroceras, with which are associated robust forms of *Pentamerus comis* Owen." In 1893 Norton§ recognized the same beds in Linn county, and identifying them with the fossiliferous "Corniferous" of Barris at Davenport, suggested the designation of Upper Davenport. In 1897 Barris‖ describes more fully "the lowest fossil-bearing rocks found in the vicinity as the Phragmoceras beds." In the same year Udden¶ classifies the Devonian rocks below the Cedar valley in this locality in two beds, the upper of which is the equivalent of the Upper Davenport of the writer, "consisting of three or four ledges of a strong, somewhat granular, thick-bedded limestone, with large cepha-

*Loc. Geol. of Davenport and vicinity; Proc. Davenport Acad. Sci., vol. II., pp. 262-264.
†Geology of Scott county, etc., Davenport, 1885, p. 13.
‡Am. Geol. vol. VIII., p. 142.
§Proc. Iowa Acad. Sci., pp. 23-24. 1893.
‖Proc. Davenport, Acad. Nat. Sci., vol. VII., p. 1.
¶Journal Cincinnati Soc. Nat. Hist., vol. XIX, p. 93.

lopods, numerous corals and brachiopods and other fossils."

While there has thus been a general agreement as to the delimitation of these beds, there has been a wide difference of opinion as to the rank which should be assigned to them. Hall* classified both Davenport limestones as Upper Helderberg, making no special distinction between them. Worthen refers them to the Hamilton, as does White,† who says, "all the Devonian strata of Iowa evidently belong to a single epoch, undoubtedly referable to the Hamilton period," and with some modifying statements confines them still more strictly within the limits of the Hamilton shales. For paleontological reasons Barris‡ assigned these beds to the Corniferous, stating "that they contain a series of fossils entirely different from any in the Hamilton group. Their general affinities seem to be with the fossils of the Corniferous and Upper Helderberg." McGee§ rechristened the entire series of calcareous Devonian sediments with a term originally proposed by Owen, the Cedar Valley limestone, and this classification Barris‖ has recently accepted. The director of the present Survey and his assistants have considered it unwise to attempt any correlation with the divisions found to obtain in New York. The classifications suggested have been made for local convenience in such parts of the field as the members of the corps have occupied. And wherever the lower strata of the Devonian have been studied in Iowa, some subdivisions have seemed necessary. Thus, with the discovery of the Otis limestone, the more or less calcareous outcrops of the Independence, and the distinct fauna and lithological facies of the Upper and Lower Davenport beds, it seemed best not only to distinguish them from from one another, but grouping them together as the Wapsipinicon stage, to thereby separate them from the Cedar Valley limestone of McGee. Such a separation has been found convenient in Buchanan, in Linn,

*Geol. Iowa, 1858, vol. I, pt. I, pp. 81-84.
†Geol. Iowa, 1870, vol. I, p. 187.
‡Proc Davenport Acad. Nat Sci., vol. II, p. 269. 1878.
§11th Ann. Rep. U. S. Geol. Surv., p. 319.
‖Our Local Geology. Proc. Davenport Acad. Sci., vol VI, p. 1, seq.

in Johnson and in Scott counties. And with the discovery that the Otis and Independence underlie the Upper Davenport, it became impossible to refer the latter to the Corniferous. The Upper Davenport beds were made the highest member of the Wapsipinicon stage because in Linn county a sufficient faunal break seemed to occur between these beds and the shales of the Cedar Valley above. This was seen in the relative predominance of different species above and below this line, in the presence of different species, and in changes in the varietal forms of the same species, as, for example, in the presence of the variety *Orthis macfarlanei* in the Upper Davenport, and of *Orthis iowensis* in the Cedar Valley. In Scott county the reasons seem equally cogent for drawing the line between the two stages at this horizon. The lithological break is as distinct and the change in fauna as abrupt as in Linn county. A list of twenty-four species is given by Barris,* which are restricted to the Phragmoceras (Upper Davenport) beds, and only eight are named which pass upward into the beds next higher. If it appears that the difference in fauna has been exaggerated, the upper limit of the Wapsipincon may well be redrawn.

Fauna of the Upper Davenport.—The fossils of these beds have been collected with great pains for many years, and have been carefully studied by members of the Davenport Academy of Natural Sciences. In its publications are recorded lists of fossils and descriptions of new species, for which science is indebted chiefly to the indefatigable labors of Barris. The following comprises the Molluscan, Crustacean and Crinoidan fauna so far as now known:

*Proc. Davenport Acad. Nat. Sci., vol VII, p. 5. 1897.

Proetus clarus Hall.‡
Proetus crassimarginatus Hall.?‡
Proetus prouti Shumard.*‡
Proetus rowi Hall.‡
Phacops rana Green.*
Calceocrinus barrisi Worthen.*
Megistocrinus nodosus Barris.*
Stereocrinus triangulatus Barris.*
Gyroceras pratti Barris.*
Phragmoceras walshi M and W.*
Actinopteria decussata Hall.*
Conocardium cuneus Conrad.*
Paracyclas elliptica Hall.*‡
Paracyclas lirata Conrad.*
Capulus echinatum Hall.‡
Capulus erectum Hall.†‡
Platystoma lineatum Conrad.*
Straparollus lativolvis Calvin.*
Athyris vittata Hall (abnormal form).†
Atrypa reticularis Linn.*†‡
Newberria johannis Hall.*†‡
Orthis macfarlanei Meek.‡
Pentamerus comis Owen.*‡
Pentamerella arata Hall.*
Pentamerella dubia Hall.‡
Pentamerella micula Hall.*
Productella spinulicosta Hall.* ‡
Rhynchonella venustula Hall (*intermedia* Barris).*‡
Spirifer bimesialis Hall.†
Spirifer asper Hall.‡
Spirifer subundiferus M. and W.*
Spirifer fimbriatus Conrad.*

Teeth and plates of several species of fish occur in the Upper Davenport, of which only *Ptyctodus calceolus* N. & W.

*On authority of Barris.
†On authority of Calvin.
‡On authority of Norton.

has been identified. An interesting assemblage of corals is found, including *Acervularia profunda* Hall, *Phillipsastrea billingsi* Calvin, which is found six feet from summit of beds, and a form assigned with some question by Calvin to *Favosites placenta* Rom.*

Sections of the Wapsipinicon Stage.—The width of the belt of known outcrops of the Otis and Independence beds does not exceed two miles. The most southern outcrop is in Pleasant Valley Tp., Sec. 23, Se. qr., Ne. ¼, at the crossing of Crow creek. The stream has here cut through the thin alluvium veneer which covers the flood plain of the Mississippi and discloses a ledge, three feet high, of two layers dipping 3 degrees southwest. The rock is a dove-colored, compact limestone, with *Spirifer subumbonus.* A few rods east a shallow quarry has been opened in the same limestone.

A half mile north of the preceding station, where the Davenport road crosses Crow creek, in Sec. 23, Ne. qr., Ne. ¼, the same rock is exposed, and from this point up the creek, on Sec. 14, Se. ¼, it recurs in the stream beds and in several ledges, one twelve feet high. Here the beds are seldom less than a foot thick and are somewhat lenticular. In places they are crackled and fragmental, making the surface and fracture highly irregular. At the farthest point up stream at which the rocks are exposed they lie in thin beds, and here also are more or less fragmental. The Otis recurs near Pigeon creek, by the roadside in Pleasant Valley Tp., Sec. 13, Ne. qr., Sw. ¼. The total thickness of the Otis may reach twenty feet. In all these outcrops the Otis remains the same non-magnesian, dense, hard, brittle, fine-grained, drab limestone already described.

The Independence, of the Kenwood type, is seen in the county only in Pleasant Valley Tp., Sec. 14, Se. ¼, along Crow creek. Here it rests directly upon the Otis, and consists of a brown, ferruginous, earthy limestone, seven feet in thickness,

*In the reports on Buchanan and Johnson counties Calvin draws the upper limit of the Wapsipinicon stage just below the Phillipsastrea horizon.

in thin layers, with nodular masses of chert, and weathering to a stiff clay. Its upper limit has not been seen.

THE LOWER DAVENPORT.

DEVIL'S GLEN, DUCK CREEK, PLEASANT VALLEY TP., SEC. 27, NW. $\frac{1}{4}$.

		Feet.
11.	Breccia; fragments many, small, mostly under 2 inches in size, of Lower Davenport limestone; matrix of nearly same color, bedding planes partially preserved	8
10.	Limestone, crystalline, purplish-brown, irregularly bedded, containing a few angular fragments of Lower Davenport limestone	1
9.	Limestone, drab, weathering to light gray, hard, compact, fine-grained, in layers 3 to 4 inches thick. Finely laminated, as shown by bands 2 mm. to 6 mm. in width, of distinct alternations in shade of color	$4\frac{1}{2}$
8.	Limestone, as above, laminæ picked out by weathering, in places flexed, broken and even brecciated, the layer as a whole retaining its even bedding	$1\frac{2}{3}$
7.	Limestone, of color and texture as No. 9	$\frac{1}{3}$
6.	Shale, highly calcareous, brittle, finely laminated, reddish-brown, ferruginous	$\frac{1}{2}$
5.	Limestone, dove-colored, hard, brittle, finely laminated Nos. 5, 6 and 7 have weathered back from face of cliff, and from the distinct line that passes midway across it	$\frac{1}{3}$
4.	Limestone, of lithographic fineness of texture, light gray	$1\frac{1}{3}$
3.	Limestone, coarser in texture, coherent laminæ picked out by weathering	$4\frac{1}{3}$
2.	Limestone, brittle, drab, weathering to white, compact, semi-crystalline, in two layers, breaking in places into thin, irregular chipstone	$5\frac{1}{4}$
1.	Limestone, finely crystalline, white or light gray, weathering into thin, calcareous plates; passing downward, and in places laterally, into mottled, vesicular, darker gray limestone, which merges into a basal, light yellowish gray, massive, finely crystalline limestone, briskly effervescent in cold, dilute hydrochloric acid	8

GILBERT LIME QUARRIES.

		FEET.
2.	Limestone, evenly and horizontally bedded, fine-grained, dense, white or light gray, weathering to detached laminæ from 1/8 of an inch to 1 inch in thickness, passing gradually into No. 1	5
1.	Limestone, darker gray, in layers, less regular in texture and bedding, rough surfaced, to water in Mississippi river	7

GILBERT, BOLAND AND ANDRE'S QUARRIES.

		FEET.
2.	Limestone, as No. 2, in above section	8
1.	Limestone, mottled gray, in even layers, up to 10 inches, slightly vesicular	6

CAMP M'CLELLAN, L. GOEMEL'S QUARRIES.

		FEET.
3.	Limestone, white and gray, layers from 1/2 inch to 4 inches in thickness, brittle, subconchoidal fracture, laminæ often curved from deposition over convex or concave surfaces, and in places brecciated	3
2.	Limestone, gray, mottled, in irregular layers from 6 to 12 inches in thickness	7
1.	Concealed to water in Mississippi	3

These quarries are deeply penetrated by pockets and chimneys filled with fine, gray Carboniferous sandstone and shale. There are examples where the cavernous openings so filled have no visible channel connecting them with the surface, and where the shale is intercalated for a distance between separated laminæ. Here the shales and sandstone might at first glance be supposed to belong to the Lower Davenport. Indeed, while Hall,* in his description of these outcrops, refers in a footnote to the coal measures, his statements might easily lend themselves to an erroneous impression. "There beds are separated by shaly partings and there is often much shale or clay in the interstices. Large spheroidal masses of greenish clay often interrupt the continuity of the beds, and sometimes these masses are connected with the fissures that reach the surface. The large amount of shaly

*Geology of Iowa, vol. I, pt I, pp. 82-84.

matter, either mingling with the material of the rock or occurring as shaly seams between the beds, would appear to have rendered the conditions of the ancient ocean in a great degree unfit for the development of animal life." So far as the writer has observed the shaly matter of these beds is wholly confined to the shales of the coal measures. The limestone of the Lower Davenport beds is unusually free from argillaceous admixture, and that the absence of fossils is not due to clay silts which are supposed to have rendered the ancient ocean unfit for animal life, is obvious from the fact that the highly argillaceous shales of the Cedar Valley beds, which occur but a few feet above in the geological section, are crowded with the remains of the animal life of the time.

SECTION OF THE UPPER DAVENPORT BEDS.

QUARRY OF MRS D. MEUMENN, DAVENPORT, FIRST WARD. ON FLOOD PLAIN OF THE MISSISSIPPI.

		FEET.
3.	Soil, black, sandy, with sparse gravel, passing into joint clay of same color containing sand and gravel......	2
2.	Limestone (Upper Davenport), gray, granular, crystalline, close textured, tough, hard, in rough-surfaced, irregular layers varying in thickness from 14 inches at base to 4 to 6 inches above. Blocks often show slickensides. Most abundant fossils *Phillipsastrea billingsi* and *Pentamerus comis*. Rarely a small angular fragment of the Lower Davenport type is seen imbedded. Rock is penetrated by numerous cavities filled with clay (Carboniferous), often containing bowlderets of Upper Davenport type with rounded surfaces, together with sandstone and rolled pebbles, of quartz and jasper	6
1.	Limestone (Lower Davenport beds), brownish-drab, of finest texture, hard, brittle, in irregular layers 9 inches and less in thickness, unfossiliferous, also penetrated as No. 2 by pockets of clay which in places becomes a conglomerate of worn limestone pebbles in a clay matrix............................	5

QUARRY OF HENRY SCHMIDT, DAVENPORT, FIRST WARD. ON FLOOD PLAIN OF MISSISSIPPI RIVER.

		Feet.
5.	Soil, black, passing into No. 4	1
4.	Joint clay, drab, slightly sandy and containing a few pebbles, lower foot stained and mottled by ferric oxide	$3\frac{3}{4}$
3.	Shale (Cedar Valley), calcareous, yellow, highly fossiliferous	$1\frac{1}{4}$
2.	Limestone (Upper Davenport beds), of color and texture described in above section, layers 6 to 10 inches thick, joints oblique, stylolated; fracture irregular, upper surface in places a coquina of detached valves of a Newberria with other brachiopods and corals	12
1.	Limestone (Lower Davenport). Upper surface extremely uneven, due to irregularities of deposition. Contact with No. 2, in some places marked by a thin band, not exceeding 2 inches thick, of greenish clay. At eastern end of quarry these beds rise and pinch the Upper Davenport to a thickness of about 5 feet. Lithologically a light, brownish-gray or medium dark drab, fine-grained limestone of conchoidal fracture, containing small and very rare crystals of sphalerite; more or less brecciated, fragments small, retaining their sharpest flint-like edges intact, edges of fragments often match although slightly detached. Matrix always slight, sometimes of calcite crystals, occasionally of clay, and often of limestone slightly more earthy and lighter in color than the fragments	8

Numerous cavities reach to the bottom of the quarry. Joint seams have been widened in places to about 5 feet, and pipes and chimneys occur filled with light bluish-gray or greenish, finely laminated clay, or with a scree of such clay and pebbles and fragments of Cedar Valley shale and Upper Davenport limestones. A selvage one or more inches wide, of brownish, acicular, matted, transverse crystals of calcite sometimes separate the filling from the smooth and decaying walls of the cavities. These cavities have been fully described by Barris.*

*Proc. Davenport Academy of Nat. Sci., vol. II, pp. 234-235.

CEDAR VALLEY STAGE.

The limestones and shales of this stage of the Iowa Devonian extend from the south line of the county as far to the northeast as Davenport. In the quarries in this city the lowest beds of the Cedar Valley consist of a soft, friable calareous shale crowded with fossils and separated from the hard limestone of the Upper Davenport by a sharp line of demarkation. The bedding planes in each of the two stages are everywhere parallel, and no trace of unconformity is to be seen. Instances of supposed unconformity which have been cited are perhaps due to the filling of cavities in the Upper Davenport with scree from higher beds.

Southwest of Davenport no Devonian limestone is seen along the river bluffs until the creeks are reached which traverse the southwest quarter of section 13, Buffalo township. Thence south to the county line every water course discloses the strata of the Cedar Valley limestone, and several large quarries afford artificial sections. So fossiliferous are the strata that the region about Buffalo has long been classic ground to the paleontologist. Large collections have been made from these beds, including the type specimens of a number of species. The time allotted to the present investigator precluded any thorough collection, with systematic classification by closely discriminated horizons. Such horizons would scarcely be expected to extend far beyond the limits of the locality, and their delimitation may well be left to that careful investigation of resident geologists whose work has already been so fruitful.

A fairly well defined basal bed, some 30 feet in thickness, consists of limestones more or less argillaceous, and calcareous shales normally blue in color but deeply weathered to buff and brown. Although in part barren, they are as a whole, highly fossiliferous. They lie in even and nearly horizontal layers, thin, or of moderate thickness, traversed by rather frequent oblique joint planes, and nowhere shattered orbrecciated as in Linn county.

All observers have noted the prevalence of encrinal layers largely made up of fragments of crinoid stems. A characteristic species of these beds is Spirifer pennatus. The fossils associated with it are much more numerous than the following list of the commoner forms:

*Atrypa reticularis.** †
*Atrypa aspera.** †
Chonetes scitula.†
Crania hamiltoniæ Hall.*
*Orthis iowensis.**
*Orthis vanuxemi.**
*Pentamerus comis.**
*Pentamerella dubia.** †
*Pholidostrophia nacrea.** †
*Stropheodonta demissa.**
*Stropheodonta perplana.**
*Spirifer asper.** †
*Spirifer subvaricosus.** †
*Tentaculites hoyti.**
*Aulopora cornuta.**
*Favosites alpenensis.**
*Monticulipora monticula.**

SPIRIFER PARRYANUS BEDS.

There rests on the beds just described a layer of white limestone, about 1 foot thick, with flinty fracture, weathering into conchoidal chipstone, and containing many masses of darker gray color, roughly columnar in shape, with radiating plates which afford a somewhat cruciform transverse section. This horizon is fairly constant throughout the region. At John Saur's old quarry, Sw. ¼, Sec. 13, Buffalo Tp., its most eastern outcrop, it lies 47 feet above low water in the river. At Clark's quarry, about one-half mile west of Buffalo, three

*On the authority of Calvin.
†On the authority of Norton.

miles west and three-quarters of a mile south of Saur's, the same stratum is found about 20 feet above the same datum. This is the closest approximation made to the dip of the limestone of the region.

Above the layer just described lies a hard, light gray, crystalline limestone, with a system of joint planes different from the argillaceous beds beneath, and on the whole a distinct assemblage of fossils. *Spirifer pennatus* has now disappeared and *Spirifer parryanus*, which occurs sometimes with *S. pennatus* a few feet below the white stratum, has become a characteristic and one of the most abundant species. Associated with it are many corals which in places are so abundant as to constitute a reef. Of these *Acervularia davidsoni* E. and H., *Cladopora iowensis* Owen, were noted, the former being especially common. *Atrypa reticularis* occurs in a robust form with *Newberria johannis*, *Capulus erectum* and a Dielasma. This bed is 3 feet thick at John Saur's quarry, and 7 feet thick in Dutcher's, and its total thickness cannot much exceed the latter figure.

Passing up the creeks of section 14 and the sections west, there is seen to succeed a stratum of shale and argillaceous limestone, 6 or 7 feet thick, weathering to a greenish clay, and abounding in *Athyris vittata*. *Spirifer parryanus* continues through this bed, and with it are *Sprifer asper*, *Atrypa reticularis*, the small, fine ribbed type of the Lime Creek shales, *Cyrtina umbonata*, *Orthis iowensis*, *Stropheodonta demissa*, normal type, as well as a small, finely striated variety.

Upon this shale there rests heavily-bedded layers of gray and buff dolomite, weathering to darker shades, in places soft, earthy, ocherous, in others hard and crystalline, forming superficial sparkling crusts simulating sandstone. In the lower layers occurs a horizon in which *Stropheodonta demissa*, in several varieties, weathers from the soft limestone in great numbers. Associated with it are *Spirifer subvaricosus*, *Orthis iowensis* and *Atrypa reticularis*, the latter in a robust and coarse-ribbed form; 2 or 3 feet above are found casts of

Spirifer capax, which Calvin has shown are identical with *S. parryanus*, together with *Stropheodonta demissa*, and several species of coral, among them *Ptychophyllum versiforme*. Layers, probably a little higher, are characterized by giant forms of the commoner Devonian brachiopods. *Atrypa reticularis* is found measuring 44 mm. in width, and a flaring *Orthis iowensis* reaching 50 mm. *Stropheodonta demissa* continues common and assumes a transverse form reaching some 50 mm. wide by 30 mm. long. These dolomitic beds are apparently equivalents of the so-called Montpelier sandstone.

DIELASMA BEDS.

On Dodge's ravine, south half of section 15, Buffalo township, the beds just described are overlain with a thin gray limestone containing many terebratuloid shells and lamellar stromatoporoids. *Dielasma iowensis* Calvin, is here common, and a small species is associated which may be allied to *D. romingeri*, *Athyris vittata*, *Rhynchonella venustula*, a small form of *Atrypa reticularis*, and a small, strongly plicated variety of *Stropheodonta demissa* were collected from the same bed. These layers are provisionally separated from the *Spirifer parryanus* beds, as no trace was found of that shell.

SECTIONS OF THE CEDAR VALLEY STAGE.

L. E. DUTCHER'S QUARRY OF BUFFALO TP., SEC. 13, SW. QR., SW. ¼.

		FEET.
2.	Limestone, hard, gray, crystalline, fossiliferous, *Spirifer parryanus* abundant, in horizontal layers, 4 to 9 inches thick. Rare and small pits filled with coal measure clays indent the upper surface.......	7
1.	Limestone, argillaceous, blue, weathering to buff, upper 9 feet highly encrinal. Main joints run north 35 degrees east and do not continue into No. 2.....	14

OLD QUARRY, SAUR'S RAVINE, ¼ MILE WEST OF DUTCHER'S QUARRY.

		FEET.
4.	Limestone, gray, crystalline as No. 2 in preceding section	6

		FEET.
3.	Limestone, white, of finest grain, weathering to conchoidal chipstone, with many irregular columnar masses of darker limestone	½–1
2.	Limestone and shale, blue and buff, highly fossiliferous, weathering to thin lamellar chipstone; including harder, less shaly beds above of encrinal limestone largely composed in places of columns of crinoids, maximum thickness of any layer, 8 inches	16
1.	Limestone in bed of creek, gray, argillaceous, no fossils noticed	

WALKER'S QUARRY, BUFFALO TP., SEC. 22, NW. ¼, LEFT BANK OF DODGE CREEK.

		FEET.
4.	Limestone, Spirifer parryanus beds, light gray, crystalline, with abundant stromatoporoid corals and *Acervularia davidsoni*	2½
3.	Limestone, grayish white, with columnar masses and septaria-like partings	¾
2.	Limestone, encrinal in part	6½
1.	Limestone, argillaceous to quarry floor, fossiliferous, Nos. 1 and 2, originally blue in color, are now deeply oxidized along all partings, retaining only blue cores	6

In an older quarry, a few rods up stream, the same beds are seen. Below No. 3 of the preceding section lies a brownish, argillaceous limestone, highly fossiliferous, some two feet thick, resting upon encrinal layers, with shales and limestones interbedded, aggregating nine feet in thickness. Beneath this there lie at the base of the quarry three feet of heavy, dark bluish-drab limestone, breaking into irregular masses with subconchoidal fracture, pyritiferous, very sparingly fossiliferous. Further up the creek, in section 22, the following sequence of beds was observed:

		FEET.
6.	Soft, buff, earthy limestone, with numerous casts of *Spirifer parryanus* and large corals, among them *Ptychophyllum versiforme*	11
5.	Weathered, buff, argillaceous limestone, *Stropheodonta demissa* very abundant, with *Spirifer subvaricosus* and other brachiopods	3

4.	Soft, buff, earthy, massive limestone, with a few individuals of *Stropheodonta demissa* and *Stictopora crassa?*	4
3.	Soft, drab, argillaceous limestone, unfossiliferous....	2
2.	Yellow, argillaceous, limestone or calcareous shale, crowded with *Athyris vittata* and other small brachiopods........	3
1.	Gray, crystalline limestone, with many corals, with *Spirifer parryanus;* forming bed of creek........	

Still higher up the same creek the following section is seen in section 15, Buffalo township, Sw. qr., Ne. ¼:

		FEET.
6.	Shale of coal measures, greenish, fissile........	2
5.	Limestone, ocherous, rough, varying locally in hardness, layers heavy and cavernous, upper half unfossiliferous, lower half contains many lamellar stromatoporoids........	6
4.	Limestone similar to the above crowded with Dielasma of several species, including *D. iowensis*, Stromatoporoids abundant........	½–¾
3.	Limestone, ocherous, containing many Stromatoporoids	1
2.	Limestone, varying in hardness, with moulds of fossils and casts of a giant flaring *Orthis iowensis* and other brachiopods, deeply stained with iron and manganese........	4
1.	Limestone, argillaceous, bluish-drab, weathering to buff, in three layers........	2½

In Fridley's ravine, Buffalo township, Sec. 20, Ne. ¼, the beds immediately above the Athyris shale are more firm and crystalline. A small quarry on the hillside, fifteen feet above the creek, shows:

	FEET.
Limestone, magnesian, buff, hard, with sparkling surfaces, resembling sandstone, contains large transverse forms of *Stropheodonta demissa*........	

A few rods down stream this recurs at five feet above the creek and rests upon soft, buff, argillaceous limestone, three feet thick, crowded with *Athyris vittata* and other brachiopods. This passes into harder blue limestone containing the same fossils, exposed for two feet above water level.

CARBONIFEROUS.

SURFACE DISTRIBUTION.

The Carboniferous strata of Scott county are separated from the great coal field of Illinois only by the narrow and late cut trench of the Mississippi. It is to this field that they belong genetically, since they were laid down at the same time, along the shore of the same sea, with the once continuous deposits across the river.

The largest and richest Carboniferous area in the county lies in Buffalo township. Le Claire township includes a valuable outlier whose shales are worked at Island City, and another lies deeply buried beneath the drift in the northwestern part of the township. Carboniferous deposits are reported in well records near Eldridge. They outcrop near the western and northern limits of the county, in Cleona and Liberty townships. About Davenport there are no quarries which do not show pockets of Carboniferous sandstone or shale. So many are these outliers that it is not difficult to believe that well nigh the entire county once lay beneath the Carboniferous sea, and was covered with a continuous veneer of its offshore silts.

The surface upon which the Carboniferous muds and sands were laid is an exceedingly uneven one. The outlier at Island City, for example, occupies a channel cut in the Niagara limestone, a little more than a mile wide where it is transected by the trench of the Mississippi, and more than 200 feet deep. In Buffalo township the valleys of the creeks show many sections of pre-Carboniferous channels, with vertical walls, filled with coal measure clays. About Davenport the Devonian was deeply dissected before the deposition of Carboniferous strata. This was in part by open waterways, but often also by subterranean stream courses in caverns. On Rock Island an eroded basin filled with coal measure shale was found in constructing the shops of the arsenal. This was explored for more than 1,000 feet. Its width was 900 feet and its depth was seventy feet and more. In building the Rock Island bridge coal shales were found in places at pier No. 5, to a depth of twenty-five feet below low water, or fifty feet below the ledges of Devonian limestone on the island adjacent.*

In the quarries of Davenport these shales occur as the fillings of crevices. Barris notes one in Cook's quarry 20 or 30 yards in length and 3 feet wide, extending nearly or quite down to the Lower Davenport beds.† More frequently they are seen to occupy pits and irregular cavities and caverns whose connection with the surface is not always to be found. Above Camp McClellan an exposure of these clays may be seen filling a cavern whose roof of Devonian limestone is still partially in place. In Fulton's quarry there was noted, some years since, a cavity 30 feet wide filled with most thinly laminated, non-calcareous, fissile, greenish shale extending nearly to the quarry floor. In the same quarry was a vertical crevice filled with a conglomerate of rolled pebbles of quartz, many of which were 3 inches in diameter. About Davenport there occurs also a fine, white, laminated sandstone associated with the greenish clay, and without doubt of the same age. In places this has infiltrated into the finest seams of the limestone, and here and there the fine clay parts the calcareous plates of the Lower Davenport beds into laminæ as thin as paper. In the larger cavities the limestone forming the sides exhibits a weathered surface and occasionally is parted from the clay by a selvage of brown calcite in fine, transverse, acicular crystals. Often the clays contain fragments of the adjacent limestone. The attitude, composition and stratigraphy of these deposits point directly to their age as Carboniferous. Still more conclusive are the fossils which have been found in them, the impression of a large Euomphalus "very similar to a Carboniferous form,"‡ and a fossil plant identified by Barris§ as one

*A. S. Tiffany, Geology of Scott Co., etc., Davenport, 1885, pp. 14-15.
†Proc. Davenport Acad. Nat. Sci., vol. I., p. 261.
‡Hall: Geology of Iowa, vol. I., pt. 1, p. 130.
§Proc. Davenport Academy of Nat. Sci., vol. III, pp. 163-168.

belonging to the coal measures. At Black Hawk the cuttings of the Chicago, Burlington & Quincy railway disclosed a Carboniferous outlier beneath the drift, with 18 inches of coal.

Carboniferous outliers occur in the immediate valley of the Mississippi at water level and below, from Muscatine county as far north as the city of Clinton. Furthermore, the intricate dissection of the pre-Carboniferous country rock just described, the filling of the finest seams and crevices, and the numerous small cavernous channels, preclude the hypothesis that there has here been any deep denudation of the pre-Carboniferous country rock since Carboniferous times. For in all probability the seams and cavities thus filled with sea silts were near the rock surface at the time of their filling. Yet it would be unsafe to conclude that the present valley of the upper Mississippi antedates the Carboniferous. The present rock-cut valley of the river is a shallow one, and the greater elevation of the country rock, and of the outliers in the western part of the county, may be largely due to post-Carboniferous deformation. Since the coal measure outliers in the northern part of the county rest immediately and unconformably on Silurian strata, we may infer that the rocks of that area had formed a land area during Devonian times and had been sculptured by running water, with a maximum relief of about 200 feet. With the coming in of the Des Moines stage of the Carboniferous a progressive depression of the land from the south northward brought in the Carboniferous sea, at least into the deeper valleys, if not over the entire surface. The elevation above tide of the bottoms of the various outliers, so far as known, is about as follows:

	FEET A. T.
Buffalo Tp.	560
Davenport Tp.	500
Island City	488
Eldridge	580
Le Claire Tp., Porter's corners	465
Cleona Tp., Sec. 4	614
Cleona Tp., Sec. 7	725
Lincoln Tp., Sec. 2	620
Liberty Tp., Sec. 22	735

The lithological characteristics of the Carboniferous deposits of the county are given under the detailed sections, and it will there be seen that, like the strata of the Des Moines stage to which they belong, they consist chiefly of shales with some sandstone, fire clay and ironstone, argillaceous, bituminous limestones, and discontinuous seams of coal.

SECTIONS OF THE CARBONIFEROUS, BUFFALO TOWNSHIP.

J. JAMES & SON, SEC. 3, SW. CORNER. COAL SHAFT RECORD.

		THICKNESS.	DEPTH.
9.	Yellow clay, Pleistocene	22	22
8.	Forest bed ("black dirt, like barnyard, with wood")	½-4	26
7.	Blue clay, Pleistocene	11	37
6.	Soapstone, Carboniferous	17	54
5.	Sandstone, light yellow	30	84
4.	Black, slaty shale	2	86
3.	Blue rock, hard, argillaceous and ferruginous limestone	11	97
2.	Coal	2⅙	99
1.	Fire clay	16	115

RECORD OF J. ANDERSON'S COAL SHAFT, ROBT. WILLIAMS' FARM, SEC. 11, NW. ¼.

		THICKNESS.	DEPTH.
7.	Glacial clays	48	48
6.	Soapstone	4	52
5.	Sandstone, white	2	54
4.	Shale, blue	5½	59½
3.	Sandstone and shale	41½	101
2.	Slaty shale	1	102
1.	Coal	3	105

CLAY PIT OF DAVENPORT BRICK AND PAVING COMPANY, BUFFALO.

		THICKNESS.	DEPTH.
8.	Loess, middle and upper phases	7	7
7.	Till, red, brownish-yellow, clayey, pebbles plentiful but small, few exceeding 2 inches, and only one seen reaching 5 inches	5	12
6.	Shale, weathered, gray and ocherous yellow, readily disintegrating, joints and seams and spaces between laminæ filled with ocherous accumulations	5	17

		THICKNESS.	DEPTH.
5.	Shale, black, finely laminated	12	29
4.	Shale, gray	3	32
3.	Shale, dark drab and black, brittle, fine-grained, containing ferruginous nodules and nodular layers	42	74
2.	Shale, gray, disclosed in shaft below bottom of pit	26	100
1.	Rock very hard (limestone?) dip of shale 4° W., 20° N at		100

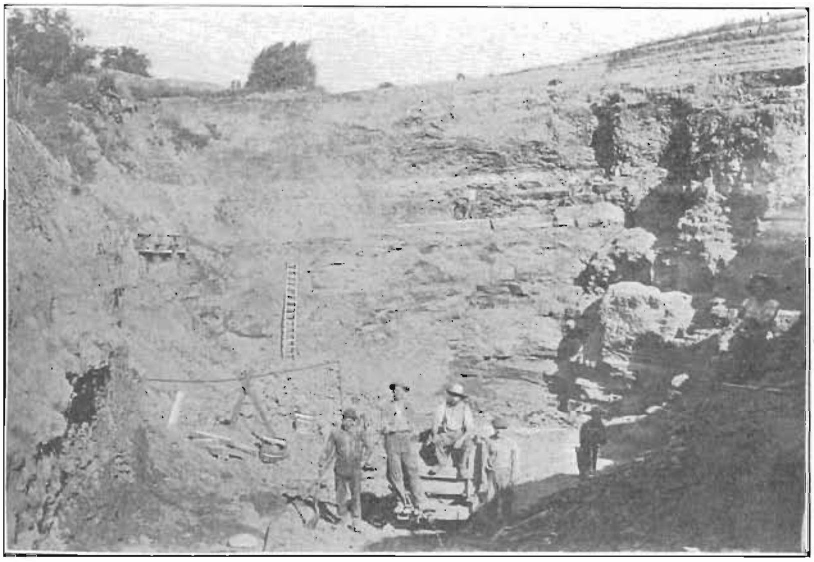


FIG. 50. Clay pit of the Davenport Brick and Paving company, Buffalo, Iowa.

C. ROWAN, SEC. 10, SW. QR , NE. ¼. RECORD OF COAL SHAFT.

		THICKNESS.	DEPTH.
7.	Yellow clays	35	35
6.	Blue clays	30	65
5.	Potters' clay, Carboniferous	4	69
4.	Sandstone	5	74
3.	Slaty shale	3	77
2.	Hard, black rock	3	80
1.	Coal	3	83

RECORD OF WELL, BUFFALO TP., SEC 16, SE. QR., SE. ¼.

		THICKNESS.	DEPTH.
9.	Yellow clay	20	20
8.	Soapstone	25	45

		THICKNESS.	DEPTH.
7.	Slate	2½	47½
6.	Coal	½	48
5.	Fire clay	2	50
4.	Shale	20	70
3.	Coal	2½	72½
2.	Fire clay	1	73½
1.	Limestone, Devonian	66½	140

RECORD OF WELL OF M. SARGENT, LE CLAIRE TP., SEC. 5, SE. ¼, CURB 700 A. T.

		THICKNESS.	DEPTH
9.	Soil	7	7
8.	Blue shale	67	74
7.	Gray sandstone	10	84
6.	Darker shale	10	94
5.	Dark caprock	3	97
4.	Coal	5	102
3.	Fire clay	12	114
2.	Shale	105	219
1.	Limestone at		219

CLAY PIT OF LE CLAIRE BRICK AND TILE CO., ISLAND CITY, LE CLAIRE TP.

		THICKNESS.	DEPTH.
7.	Loess and till, unmeasured.		
6.	Cannel coal	2	2
5.	Potters' clay	4	6
4.	Coal	1	7
3.	Fire clay	4	11
2.	Shale, gray	2	13
1.	Shale, black, to bottom pit	20	33

WELL RECORD OF LE CLAIRE BRICK AND TILE CO , ISLAND CITY.

		THICKNESS.	DEPTH.
6.	Shale, dark	90	90
5.	Sandstone, fine, white, hard	6	96
4.	Shale, blue	70	166
3.	Sandstone, as No. 5	9	175
2.	Shale, blue	25	200
1.	Limestone, with water vein beneath shale under sufficient pressure to rise within four feet of surface	26½	226½

CLEONA TOWNSHIP, SEC. 7, SW. ¼.

A small outcrop of fine yellow sandstone, unfossiliferous, rests on Niagara limestone on the shoulder of a hill 36 feet above the level of the creek below. No ledge was found at this height on the hillside. Fragments and disintegration bowlders occur for a few rods, and a small pit marks the site of a long disused quarry.

CLEONA TOWNSHIP, SEC. 4, SW. ¼.

WELL RECORD, FARM OF WM. RHEIMS.

		THICKNESS.	DEPTH.
4	Pleistocene deposits	144	144
3.	Slate	1	145
2.	Coal	1	146
1.	Limestone at		146

ELDRIDGE, RECORD OF CREAMERY WELL.

		THICKNESS.	DEPTH.
2.	Pleistocene deposits	180	180
1.	Shale, gray, fine grained	20	200

LINCOLN TOWNSHIP, SEC. 2, SW. ¼.

RECORD OF WELL ON FARM OF DETLER ARP.

		THICKNESS.	DEPTH.
3.	Pleistocene deposits	113	113
2	Shale	7	120
1.	Limestone	10	130

LIBERTY TOWNSHIP, SEC. 22, NE. QR., SW. ¼.

Here a road cutting on the side of the hill descending to Walnut creek, exposes some 30 feet of Le Claire limestone of the massive Le Claire type. Midway up the hill occurs a large cavity, 3 feet deep, broadly open above, with extensions into the rock on either side filled with greenish, plastic, gritless clay, entirely similar to that at Davenport, Clinton and many other localities in this region of the state.

GEEST.

The indurated rocks of the Silurian, Devonian and Carboniferous systems record that inconceivably long lapse of time during which the area now occupied by Scott county was covered with the waters of the Paleozoic ocean. At last the sea retired wholly from the area, and for countless ages a land surface was exposed to the disintegrating and dissolving action of the weather. The rock surface was thus everywhere roughened. Wherever the root pried apart the layers of limestone, or where by any cause a way was made for the downward passage of water, there the ground water charged with humic acids and carbon dioxide took up the rock into solution and opened pipes and chimneys and pits and cavities of various shapes and dimensions. Slight though it may be, there is yet in all limestones an insoluble residue of fine quartzose, argillaceous and ferruginous matter. Left behind after the carbonates of lime and magnesia were dissolved and carried away to the sea, these insoluble ingredients remain as fine, plastic, unctuous, gritless clays. The ferric oxides which were able to color the bulk of limestone to which they originally belonged only a faint tint of buff, when concentrated in the thin residue of clay give it the deepest shades of red and brown. These products of rock decay, known as geest, have in places been wholly removed by glacial scour, but for the most part the rock surface and the geest upon it remain much as they were at the beginning of the invasion of the ice. Deeply and firmly frozen, they resisted the slight erosive action of the glaciers whose chief function in these regions seems to have been the deposition of material excavated elsewhere.

In Liberty and Cleona townships the preglacial decay of rocks is especially well marked. Pits of weathering descend as much as 12 feet from the rock surface. These are lined with geest, but are usually filled with glacial clays. The section given of Steffen's quarry p. 431, exhibits the common condition of the rock surface under the Kansan drift. A typical exposure of geest is also seen in a road cutting in the north half of section 22, Liberty township, on the side of a hill descending to Walnut creek. The rock surface slants with the slope of the hill, showing the valley here to be preglacial. On this surface lies from 1 to 2 feet of geest, a dark, reddish-brown, jointed clay, graduating upward by reassortment into a lighter loam, which in turn passes into 2 feet of true loess. In the geest are found sparse pebbles of glacial drift even to its base, showing a slight rehandling of the geest by the overriding ice. Along the Mississippi river, in the region covered with Illinoian drift, the rock surface is less deeply weathered and pitted.

PLEISTOCENE.

TAXONOMIC RELATIONS.

In the diversity and interest of its deposits of glacial drift, Scott county is hardly surpassed by any area of equal size in the United States. Lost pages of Pleistocene history are here recoverable, and evidence is at hand which may help to solve questions of long dispute in glacial geology. The drift deposits of the county will be described under the categories now in use by the Iowa Geological Survey, which recognizes the following sequence of events in Iowa during the age of the Great Ice:

First.—An invasion by glacial ice from the north, perhaps an extension of the Kewatin ice sheet, whose center of dispersion lay west of Hudson bay. Little is known of the till deposited by this invasion and it is termed for the present the pre-Kansan drift sheet.

Second.—A stage of deglaciation, the Aftonian, during which the glaciers retreated, probably beyond the limits of the state.

Third.—A second and more formidable invasion by the Kewatin glacier, which pushed the ice front south to the Missouri river. This stage and the drift sheet then deposited are known as the Kansan.

Fourth.—A second stage of deglaciation, the Yarmouth, during which the land left bare by the retreat of the ice far to the south, weathered into rich soils of prairie and forest.

Fifth.—A third ice invasion, the Illinoian, entering Iowa from the east, and occupying a narrow strip of country along the Mississippi extending from the Wapsipinicon south nearly to the Des Moines.

Sixth.—A third stage of deglaciation, the Sangamon, during which the drift sheet left by the retreat of the Illinoian ice weathered into soil, and was covered with peat swamps, savannas and forests.

Seventh.—A fourth ice invasion, the Iowan, coming from the north and extending on its eastern margin as far south as Scott county. Southward from the front of the Iowan ice was laid down in some manner, at present undetermined, a silt called the Iowan loess.

Eighth.—A fourth stage of deglaciation and soil formation, the Peorian.

Ninth.—A fifth ice invasion, the Wisconsin, confined in Iowa to the central portions of the state, and extending as far south as Des Moines. Of the nine stages just enumerated records of all are believed to exist in Scott county with the exception of the last two, the Wisconsin and the Peorian.

CONSPECTUS.

STAGES OF GLACIATION.	STAGES OF DEGLACIATION.
9. Wisconsin.	
7. Iowan.	8. Peorian.
5. Illinoian.	6. Sangamon.
3. Kansan.	4. Yarmouth.
1. Pre-Kansan.	2. Aftonian.

PRE-KANSAN.

No exposure of this drift has so far been discovered in Scott county. As described in its typical outcrops in the southern part of the state by Bain, its discoverer in Iowa, it is physically a dense, flaky, bluish-black till. It can be recognized with certainty only where it is separated from the overlying Kansan till by a weathered zone, an ancient soil, or a forest bed. The pre-Kansan appears in evidence in the following records of the wells of the county, and these present little except its attitude, color and local thickness.

CLEONA TP., SEC. 4, SW. ¼, FARM OF WM. RHEIMS.

	THICKNESS.	DEPTH.
3. Clay, blue, hard, pebbly, Kansan	50	50
2. Ancient soil, "smelling like ground," emitting gas, making it difficult for diggers to stay in the well more than half an hour at a time, containing wood, of which the largest piece was about one inch thick, Aftonian	1	51
1. Clay, blue, hard, pebbly, pre-Kansan, penetrated to depth of	19	70

No water was found, and a well was drilled near by and on the same level. In this no record is at hand of the ancient soil, but the number 1 was found to continue to a depth of 146 feet, giving the pre-Kansan here a thickness of 95 feet. The well is situated in the area of Kansan unreached by the Illinoian or Iowan.

CLEONA TP., SEC. 19, NW. ¼, HEINRICH GOETTSCH.

	THICKNESS.	DEPTH.
5. Clay, yellow } 4. Clay, blue }	102	102
3. Clay, black, ill smelling, Aftonian	45	147
2. Clay, blue, hard, pre-Kansan	50	197
1. Quicksand, mostly fine	134	331

This well penetrates the bed of a preglacial river which passed northeast through Cleona township, and which we may refer to conveniently as Cleona river. It is in such deep valleys, where glaciers must deposit and where they can least erode, that ancient tills may be expected to be best preserved.

ALLEN GROVE TP., SEC. 26, NE. ¼, HENRY ROH.

	THICKNESS.	DEPTH.
6. Clay, yellow above and blue below	100	100
5. Quicksand	25	125
4. Clay, blue, stony.		
3. River sand	70	
2. Clay, blue, stony.		
1. Gravel	25	300

There are apparently three distinct tills here penetrated, the combined thickness of the two lower being eighty feet.

The lowest of these we may refer to the pre-Kansan. Still less conclusive is the evidence of the next section, which seems to lie in a tributary to Cleona river.

HICKORY GROVE TP., SEC. 19, NW. QR., NW. ¼, JOHN FRAUEN.

		THICKNESS.	DEPTH.
7.	Clay, yellow. Loess?	20	20
6.	Sand, yellow	10	30
5.	Clay, yellow	120	150
4.	Clay, blue	10	160
3.	Sand	20	180
2.	Clay, blue	50	230
1.	Gravel	3	233

This well, like the preceding, is situated in the area of Illinoian drift, and it is hardly safe to say more than that the No. 2 may represent the pre-Kansan drift sheet.

AFTONIAN.

As has been seen from the above sections, the pre-Kansan till is sometimes separated from the overlying Kansan by an old soil or forest bed. At the typical localities in Afton county, it is separated by heavy layers of gravel and sand. Such have not been found in Scott county except in the channels of Cleona river and its branches. Deposits of muck and peat, soils mingled with vegetal detritus, and old forest beds are of much more consequence as evidence of interglacial stages, since they imply a freedom from ice for times sufficiently long for the accumulation of the deposits in question. Of the flora and climate of the Aftonian, nothing is known from the evidence at hand in Scott county. Indeed, so far as the county alone is concerned, the scanty data at hand upon which the Aftonian and pre-Kansan are based, could as readily be explained by local and temporary advances and retreats of a single ice sheet. But meager as are the data, they agree with a large body of evidence from other counties which consistently witnesses the hypothesis here used.

KANSAN.

In the northeastern areas of the county designated as the Kansan upland and the Kansan plain, the Kansan till lies immediately beneath the superficial water-laid clays; but many exposures occur in other parts of the county in areas marked as Illinoian and Iowan. Like any till, it is an unstratified mixture of bowlders, cobbles, pebbles, sand, rock meal and clay. Of these the finest grindings of the glacial mills, rock meal and clay largely predominate. Bowlders are neither plentiful nor large, and cobbles are comparatively rare. As in other glacial tills the larger stones are generally granitoids. Of erratics one foot and over in diameter counted in the Kansan drift exposed in the cut of the Burlington, Cedar Rapids & Northern railway west of Davenport, 51 per cent were granitoids, 37 per cent Carboniferous sandstone and limestone, 10 per cent greenstones and 2 per cent quartzites. In other exposures quartz porphyry is not rare. Four bowlderets of this rock were noted in the ravines on the farm of Mr. D. Snyder, section 1, Liberty township. On an adjoining farm two nuggets of copper have been found, whose home was probably the Lake Superior region. A group of bowlders from this till lie by the roadside in Liberty Tp., Sec. 6, Se. qr., Nw. ¼. They are from two to four feet in diameter; four of them are granites, one a diorite. Three bowlders of coarse, pinkish granite are found in a slough in Cleona Tp., Sec. 7, Sw qr., Ne. ¼, which measure each more than three feet in diameter. In Reim's quarry, Cleona Tp., Sec. 7, Nw. ¼, eight bowlders were noticed, of which three were granites, three Carboniferous sandstones, and one a quartzite.

Of the smallest stones and pebbles to about half an inch in diameter, greenstones prevail over granites, and still more numerous is local material—cherts of the Niagara, limestones of the Devonian, and shales and sandstones of the coal measures. The following list was made of 186 pebbles taken at random in the lower five feet of unaltered Kansan till, in the Burlington, Cedar Rapids & Northern railway cut west of Davenport:

	PER CENT
Greenstone	24
Granite	15
Jasper	6
Quartz and quartzite	5
Miscellaneous	1
Limestone	29
Cherts	6
Sandstone	5
Shale	2
Coal and coaly shale	7
Limonite	½

Several tallies of pebbles were made, with like results, from Kansan till in various parts of the county, and a classification of more than 500 pebbles from unaltered Kansan near Mt. Vernon, Linn county, gave about the same general ratios; greenstone, 33⅓ per cent; granite, 16½ per cent; limestone, 26⅓ per cent; chert, 6 per cent; but naturally showed a less number of coal measure shales and sandstones.

Thus it appears that while granites prevail over greenstones among the bowlders, the reverse is true among the smaller stones. This is readily explained by the structure and weathering of the two classes of rocks. Granite weathers normally into immense bowlders of disintegration and these are not readily ruptured into smaller masses. But when granite is once broken into small fragments these soon crumble into sand by the decomposition of feldspar and mica. On the other hand several of the rocks popularly known as greenstones readily break up into angular chipstones. But their small fragments are exceeding obdurate. Their large numbers in the Kansan are an example of the survival of the hardest.

Bowlders, sometimes, are beveled and faceted, and scored pebbles are common, especially greenstones and limestones. Even pebbles less than an inch through have been thus set in the ice and cut in the glacial lathe. The Kansan till is therefore a ground moraine, accumulated beneath the Kansan ice sheet, largely derived from its erosion of the geest and rocks of the state, and compacted into a dense tough mass by the pressure of the ice.

That the Kansan is largely derived from the rocks of the state, ground fine in the glacial mill, is shown by the quantity of undecomposed flour of limestone which it carries in its clay. The unaltered Kansan till never fails to effervesce briskly when touched with a drop of strong acid.

In color the Kansan is normally a bluish-drab. In texture it is exceedingly hard and compact. It is often seen to be traversed by vertical reticulating joints which part it into polygonal blocks up to 3 feet in diameter. These cracks are often filled with thin, ocherous crusts, and on either side the till is stained brown up to 1 or 2 inches. Such are the effects of percolating waters on the deeper Kansan. Near the surface it is universally weathered, and exposures of normal Kansan, as it has been described, are very rare. To a depth which varies, reaching sometimes 12 and 15 feet, it has been so profoundly altered that the weathered zone has been supposed to be genetically distinct from the unweathered till, a product of a later ice invasion, or deposited in a different manner. The lime has been leached out, so that the clay no longer responds to a test with acid. In places the lime has gathered into hollow concretions. The texture has been loosened by frost and decay, so that the till crumbles readily into small particles near the surface, while further down its jointed structure appears in larger and larger rhombic blocks.

Still more striking is the change in color. From a fraction of a foot to 2 feet or more from the surface the Kansan is rusted to a reddish-brown, a terra cotta red, or a deep purplish-red, by the oxidation of its iron compounds and by the accumulation of iron salts brought down by percolating waters from the soils above. This zone has been designated by Bain, the *ferretto*, a verbal short cut whose superiority to the well worn phrase of "zone of ferruginous accumulation" is obvious. The ferretto changes downward to a lighter and less reddish-brown, to brownish-yellow, and to a yellow distinctly brighter than the buff of the loess. So deep have these changes extended that seldom is one privileged to see the yellow merge into mottled gray and at last into the unaltered blue of the Kansan till. Where the Kansan is overlain by the Illinoian the ferretto may be placed in the Yarmouth inter-glacial stage.

YARMOUTH.

The lobe of ice from the great Kewatin glacier, beneath which the Kansan drift sheet was moulded, at last retreated from Iowa. In counties farther to the north it is supposed that at this time of rapid melting of the ice, heavy deposits of gravels were laid down in swift, glacial streams, and these have been termed by Calvin the Buchanan gravels. These gravels are not known to exist in Scott county; they are found in force a few miles north of the county line, near DeWitt, and it is from pits in the paha-like hills which they there form that the gravel is obtained which is being largely used for road making in Scott county. A sand and gravel at Dixon, beneath the loess and deeply stained, may perhaps belong to this formation. Just south of the county line the Durant cut of the Chicago, Rock Island & Pacific railway discloses a gravel, almost wholly made up of local materials, overlying Kansan till and covered with a ferretto; and similar gravels no doubt exist in the adjacent hills across the line. With these possible exceptions, the retreating Kansan glacier left behind it no gravel trains in Scott county, but only the barren, clayey waste of its ground moraine, the blue till. Barren and blue it could not long remain; gradually it became clothed with vegetation; forests and savannas of grasses, we may conceive, grew upon its level plain. Meanwhile its surface became deeply weathered, leached of its lime, comminuted into finer clay, and reddened with accumulations of iron. Where local conditions favored, it is believed that deep soils rich in humus were formed on prairie and in peat bog. These soils and the interglacial time of their making have recently been termed the Yarmouth by Leverett. Such buried soils have been noted in Scott county by several glaciologists. Thus McGee* describes a subsoil bed in the bluff at the corner of Harrison and Sixth streets, Davenport, intercalated between a blue till (the Kansan) some thirty feet thick, and fifteen feet of till (the Illinoian), upon which rests the loess. This ancient soil, which is not now visible, is described as "jet-black in color, weathering brownish, light, friable, of peaty appearance, with a maximum thickness of two feet." At a ravine in Crow creek, Pleasant Valley Tp., Sec. 14, Se. qr., Se. ¼, a stiff, gray, gumbo-like clay, two feet thick, with many bullet-shaped, calcareous nodules, underlies a till supposed to be Illinoian, and may be referred to the Yarmouth, although it is water-laid.

In exposures in Davenport an ashen, gummy clay, with black streaks apparently of humus, is taken to be of Yarmouth age by Leverett, since it rests upon the Kansan and is overlain by the Illinoian. Forest beds appear in a number of the well records of the county; and although these records are seldom complete enough for certitude, in several instances there is a fair presumption that the forest horizon is the Yarmouth. About Eldridge, it is reported by two drillers that quite generally a forest bed is struck at from twenty to forty feet beneath yellow clay, which may include Illinoian with the loess, and above blue clay, which may be Kansan. Another driller reports that wood is often struck at about twenty-five feet in the vicinity of the adjacent station of Mount Joy. The following is perhaps a typical section of the Pleistocene in this region:

SHERIDAN TP., SEC. 4, SW. QR., SE. ¼. WELL OF CHAS. MEIER.

	THICKNESS.	DEPTH.
4. Soil, black	5	5
3. Clay, yellow, loess and Illinoian (?)	20	25
2. Forest bed, Yarmouth (?)	10	35
1. Clay, blue, stony, Kansan, to rock	65	100

* Pleistocene History Northeastern Iowa, 11th Ann. Rep., U. S. Geol. Surv., p. 493.

BUFFALO TP., SEC. 3., SW. ¼. WELL OF S. JAMES & SON.

		THICKNESS.	DEPTH.
3.	Yellow clay, loess, and Illinoian (?)	22	22
2.	Ancient soil, with wood, Yarmouth (?)	4	26
1.	Blue clay (Kansan) to rock	11	37

ILLINOIAN.

It has been recently discovered that Iowa was invaded by glacial ice from the east, in a narrow belt stretching along the Mississippi from the Wapsipinicon to Ft. Madison. To Leverett belongs the honor of working out the cumulative and concordant evidences which attest the hypothesis. Some of the proofs found in other counties are not seen in Scott, such as westward bearing striæ and the presence of bowlders of jasper conglomerate, whose parent ledges lie northeast of Lake Huron. But here, as elsewhere, the evidence of the Illinoian invasion has been left in a topography differing alike from the Iowan and the Kansan, and in a till of somewhat different physical characteristics. The Illinoian drift is intermediate in its leaching and weathering between the Iowan and the Kansan, from which it is sometimes separated by horizons of weathering and ferric and humic accumulations. It contains a large number of pebbles of local derivation. It is thin in the county, wherever it has been seen, and over much of the Illinoian area the drift encountered in natural sections is either Kansan, or at least has not been discriminated from it. The topography and limits of the Illinoian have been described. We append a few typical sections.

DAVENPORT, EIGHTH AND MARKET STREETS.

		FEET
6.	Humus layer	½
5.	Clay, brown, jointed, sandy	2
4.	Till, bluish-gray, mottled with reddish-brown, clayey, jointed, with many small calcareous concretions, pebbles small (Illinoian)	3
3.	Clay, stiff, whitish pebbly, non-calcareous	3

2. Till, clayey, calcareous, brownish-yellow mottled with gray; jointed, breaking in rhombic blocks about 1 inch in diameter, weathers on outside to thin crust of yellow clay which crumbles under fingers to small particles and dust. Clay grows finer and more plastic above and less pebbly. Kansan...... 14
1. Till blue, or slate colored, pebbly, with gravel largely of limestone and chert and less than an inch in diameter, jointed, with reticulating cracks from a few inches to 3 feet apart, filled with fine yellow sand and with limonite crusts. On each side of these cracks, till is oxidized to brown for 2 or 3 inches, a few larger pebbles, up to 6 inches noted, all of limestone, fresh and scored. Near base and outer edge of hill veins up to 7 inches thick occur of coarse sand and gravel, discontinuous, dipping outward 13

SIXTH AND HARRISON STREETS.

		FEET.
8.	Loess, light buff, pulverulent, fossiliferous, with small loess-kindchen, superficially indurated	8
7.	Loess, ashen, pulverulent, calcareous, horizontally laminated	2
6.	"Soil black, Sangamon."*............................	1
5.	Till, reddish, leached for 2½ feet from its surface, with calcareous concretions for 4 feet from surface, "with traces of horizontal bedding at bottom, but with few vertical fissures or seams, a characteristic Illinoian till"*	7
4.	Till, yellow, calcareous, limestone and chert pebbles abundant, jointed, oxidized (Kansan), passing into No. 3...	9
3.	Till, mottled, blue and buff, transitional in color and texture between Nos. 2 and 4......................	2
2.	Till, bluish-gray, tough, hard, compact, jointed; pebbles small, few bowlders; calcareous; about 20 feet from base occurs a horizontal zone about 3 feet wide in which occur several thin seams of fine sand and of fine silt; these seams are highly oxidized and in places cemented by ferric oxides, Kansan.........	33
1.	Sand fine, gray and yellow, passing upward into yellow silt, stratification horizontal and undisturbed. Fragments of this silt occur in the till immediately above	5

*From notes of Mr. Frank Leverett.

The two following sections are kindly furnished by Mr. Leverett:

DAVENPORT, EIGHTH STREET, BETWEEN MYRTLE AND VINE.

		Feet.
5.	Iowan loess	30
4.	Reddish-brown surface of Illinoian till sheet, leached and stained during Sangamon interglacial stage	2½–3
3.	Brown, calcareous till, crumbling readily, a characteristic Illinoian	15
2.	Ash colored, gummy clay, with black streaks apparently of humus, representing the Yarmouth interglacial stage	2–3
1.	Brown till, calcareous, fracturing in cubical blocks, color changing to bluish-gray at 12–15 feet. Characteristic Kansan till	25

One to two miles south of Blue Grass the ravines expose the following beds:

		Feet.
4.	Loess	15
3.	Yellow till (Illinoian)	8–10
2.	Gummy, gray clay	3–6
1.	Brown, sandy till (Kansan), exposed a few feet	

Similar sections are found in the ravines about one and one-half miles northwest of Blue Grass.

SANGAMON.

This interglacial stage is recorded in the weathered surface and the ferrettos of the Illinoian drift, and the old soils and forest beds formed upon it. These are overlain by Iowan loess. Several examples of Sangamon deposits have already been cited. It is probable that the widely published section of W. H. Pratt of a cutting near Davenport* discloses, in its ancient soil and peat, the same formation. A number of well sections in eastern Scott county include beds of peat and old soils which may be Sangamon in age. The exact position of these beds is difficult to find out, the yellow clay of the drillers' record including not only the loess but also all weathered and oxidized tills beneath. But where quicksand

*Proc. Davenport Acad. Sci., vol. I, p. 96. Geology of Iowa, White, vol. I, p. 119. 1870.

is given beneath yellow clay of not more than the usual local thickness of the loess, it may be assumed that the yellow clay is wholly the loess.

About Porter corners, west of Le Claire, it is reported that yellow clay twenty or thirty feet thick is underlain by quicksand, and that beneath this is sometimes found an old forest bed, several feet thick.

LINCOLN TP., SEC. 23, E. ½, WELL OF MRS. MARY JONES.

		THICKNESS.	DEPTH.
6.	Yellow clay	30	30
5.	Quicksand	12	42
4.	Forest bed (Sangamon)	6	48
3.	Clay, bluish	20	68
2.	Clay, yellow, pebbly	40	108
1.	Clay, blue, pebbly, to rock	12	120

A generalized section of the Pleistocene in Le Claire township is given by Mr. Clark, well driller at Le Claire, as follows:

		FEET.
6.	Yellow clay	25
5.	Quicksand, fine, bluish	6-20
4.	"Rotton wood."	
3.	Clay, thin, hard, smooth, without pebbles.	
2.	Yellow clay, stony.	
1.	Blue clay, stony sometimes, with bowlders near bottom.	

IOWAN.

The last glacial invasion of Scott county hardly more than crossed its northern boundary. Its track is found only east of the great elbow of the Wapsipinicon, and not more than 2 to 3 miles south of its flood plain; and yet within these narrow limits are found perhaps all of the characteristics by which Calvin has proved its existence as a separate drift sheet of a distinct ice invasion. The peculiar topography of the Iowan in Scott county has already been noted. The drift, compared with the Kansan, is more sandy and contains more large pebbles, cobbles and bowlders. While the latter do not strew the fields with the profusion seen in Delaware and

Buchanan counties,* yet they are sufficiently common to form a distinct contrast with the loess-covered areas to the south. Pinkish granites are especially noticeable, and of the rarer rocks, quartz porphyry may be named. Deep cuttings are uncommon in the Iowan area, and none was found which reached through the unleached till. The deep red ferrettos of the Kansan are lacking, oxidized surfaces having a brownish tint. The Iowan area as here mapped includes the loess moraine of pahoid hills, even though these may in part rest on earlier drift.

Iowan Loess.—With the exception of the Iowan drift plain and the alluvial bottom lands, all of Scott county is covered with a mantle of fine silico-argillaceous silt known as the Iowan loess. It presents three phases due largely to alteration since it was laid down. Lowest of these lies the ashen loess. This is a bluish-gray silt, sometimes laminated obscurely, usually more pervious than the loess above, and retaining its original calcareous constituents. These may be uniformly distributed, but near the edges of outcrops they are segregated into calcareous nodules known as loess kindchen, loess puppen and loess manchen. These are the "clay dogs" of the brick maker, to whom they are an unmitigated nuisance, burning into quick lime within the bricks in the kiln, and bursting them by the expansion of the lime when hydrated by the absorption of water.

In this zone there is also a concentration of ferruginous constituents forming brown ocherous pipes and tubes sometimes 3 feet long, and concentric nodules of the same material. These "bulls eyes" occasionally reach a diameter of 6 inches, and, although soft while remaining in place, rapidly harden when exposed to the weather on the surface of a bank. Limonite crusts also occur, following lines of lamination and water movement. Occasionally such a crust, or a band of ocherous stain, divides the ashen loess from the main body of loess above. This ferretto is not taken to indicate an old

*Calvin: Iowa Geol. Surv., vol VIII., pp. 172-173, 244-245.

weathered surface, but merely the place of deposit of iron salts by the movement of ground water in the entire mass of the loess. Often it is impossible to draw any line of separation between the two lower phases, the one grading inperceptibly into the other.

The main body of the loess is a light buff loam, often mottled or streaked with gray where it has either escaped oxidation or has been deoxidized by the penetration of water containing organic matter in solution. Vertical cleavage is a notable characteristic. Lime occurs in minute, branching tubules, in kindchen and in small fossils, but the two latter are much less numerous than in the ashen loess below. Oxidation has often affected the entire mass of the loess, so that the lower phase is absent.

The loess weathers superficially into a brown clay to a depth of from zero to four or five feet, according to the activity of agents of erosion. This phase differs from the main body in its higher oxidation, seen in its deeper color and the still darker narrow bands of ferruginous stain which often traverse it parallel with its upper surface, in its general induration, in its fineness of particles due presumably to disintegration, in its complete leaching, in the absence of fossils, and in its tendency to break down into a slope of crumbling fragments.

Other differences in the loess are due to circumstances of deposition. On the Iowan frontier loess graduates vertically and laterally into sand, while a few miles distant to the south sand is for the most part absent. Over the drift plains of the interior of the county, the thin mantle of loess forms a somewhat finer and more plastic loam. This is due in part to the deposition of the coarser material within short distance of the periphery of the Iowan ice, and in part to the alteration of the material by prolonged weathering. The latter cause is conceived as specially effective on level tracts where erosional agents are comparatively inoperative, where a heavy humus layer continually generates acids which effect disintegration, and where the level of ground-water stands high.

The loess rests here and there on unmodified till, the line of demarkation being of necessity sharp between the deposits of ice and of water. More often it passes into clays intermediate in texture and color, as in the Kansan area, or as within the limits of the Iowan by interlamination into stratified sands.

Red Loam.—Outside the Iowan area hillside gullies which cut through the loess, often show beneath it a reddish, loess-like loam, often laminated, sometimes jointed, more clayey than the loess, and yet like it readily friable even when dry. No distinct line separates the red loam from the loess, and, beneath, it merges into a more plastic clay which in a few inches becomes pebbly and passes into the red ferretto of the till. So seldom is a section found on the summits of the hills and uplands that little can be said as to its occurrence at high levels. It is seen on the bluff at Division street, Davenport, four feet thick, and in places it here is black with humus. It is near the bottom of hill slopes that it usually is disclosed by gullies, and in the Mississippi valley, where it often outcrops between Le Claire and Princeton, it descends to within ten feet of the water of the river. Here it is more deeply stained with ferric oxides and reaches the greatest measured thickness—some nine feet—which is three or four times what seems to be its average thickness elsewhere.

At Theilman's quarry, Le Claire, the red loam is seen to rise along the slope of the rock from about the level of the flood plain of the river, till here being practically absent, and thinning as it rises to merge into the loess. On the river bank, a few rods distant, the red loam is nine feet thick, is slightly laminated, but not so distinctly as is usual in lake clays. Physically it resembles a loess composed of a somewhat wider range of particles, the siliceous particles being larger than in normal ashen loess. Toward the base it becomes slightly gravelly.

SECTIONS OF THE RED LOAM.

LE CLAIRE TP., SEC. 26, SW. ¼, ON BANK OF MISSISSIPPI.

		FEET.
3.	Humus	½
2.	Yellow loam	¾
1.	Red loam, non-calcareous above, jointed, weathering into fragments a fraction of an inch in diameter; below more friable. Near upper surface rare pebbles occur up to 2 inches in diameter, to road	5

LE CLAIRE TP., SEC 14, NW. ¼, ON BANK OF MISSISSIPPI RIVER.

		FEET.
2.	Red loam, with rare pebbles	4
1.	White clays, with horizontal, interbedded sand and gravel, to high water beach of river	4

LINCOLN TP., SEC. 1, EAST ½, HILL SLOPE.

		FEET.
4.	Loess to hill summit	30
3.	Loess, lower phase, slightly reddened, separated from buff loess above by slight ferretto and ocherous stain 2 inches wide	4
2.	Loam, reddish, laminated, non-calcareous, siliceous, particles indistinguishable in size under the microscope from those of ashen loess at Davenport, readily friable beneath fingers	3½
1.	Kansan till, ferretto	2½

BLUFF, DIVISION STREET, DAVENPORT,

		FEET.
5.	Loess, upper and middle type. This grades into ashen loess below, but in places a ferretto of 3 inches separates them. This ferretto is also seen in places below the upper surface of the ashen type	10
4.	Loess, ashen, fossiliferous, with calcareous tubules and kindchen. Limonite casts, more or less spherical, occur up to 2½ feet in diameter, which, on a horizontal section, simulate contorted laminæ	11
3.	Red loam, transitional, laminated, calcareous; mottled here and there with dark humus which in one place becomes a black humus layer	4
2.	Ferretto of till, leached free of lime, darkened	3
1.	Till, calcareous to within a foot of the ferretto, a stiff, stony, yellow clay without cobbles or bowlders, but with many small pebbles, of which limestones and cherts predominate; exposed	8

Numbers 1 and 2 slope back into the hill and toward Duck creek. To the south, down the hill, the till is broken by two depressions, each some two and a half rods wide, extending below the cutting, separated by a steep-sided mound of till six feet wide, and filled with fossiliferous loess crowded with limonite tubules, bull's eyes and crusts obscurely laminated, dipping downward with the hill.

DIXON, BANK OF WALNUT CREEK.

		FEET.
6.	Loess, light buff, pulverulent	22
5.	Loess, mottled, gray and buff, with rare and small kindchen, passing by interlamination into No 4	8
4.	Loess, light brownish-buff, of much the same texture as above, but slightly more clayey, with rare and small kindchen, readily friable	1
3.	Loam, light reddish-brown, obscurely laminated, with some sand, more plastic than above, grading into No 2	¾
2.	Sand, clayey, with an occasional pebble, bright terra-cotta red	2½
1.	Till (?), purplish-red, predominantly sandy, with numerous pebbles, all small, no stratification lines seen; pebbles mostly cherts and greenstones. Till dips with slopes of hill in both directions	8

The intimate association of the red loam with the loess, the gradation between them, and the loessial texture of the loam indicate that the two silts were laid down in the same waters. The color of the loam and the wider range in size of its constituent particles, associate it with the ferretto of the tills on which it rests and show that, in part, it is derived by wash therefrom.

Loess Sands.—The absence of sand and gravel over the larger part of Scott county is a striking fact, and one in strong contrast with the abundance of these coarser deposits of running water in the counties a little north and northwest, where the Iowan ice had full play. Beyond a short distance south of the Iowan frontier, even in the immediate vicinity of the channel of the Mississippi river, there were no currents in Pleistocene times, so far as the superficial deposits show, capable of carrying heavier sediment than the fine silt of the loess. North of that frontier sand is plenty, and its relations to the Iowan loess are so close that it seems best described in connection with it.

In the great ridge of hills in Princeton township, which overlook the flood plain of the Wapsipinicon, heavy beds of sands are superior and peripheral to the loess. In many road cuts in this district typical loess is seen to pass outward into sands by gradations which show that the two deposits were contemporaneous. The loess is often seen also to pass downward into beds of sand by intercalation in tortuous, irregular, discontinuous layers, showing conclusively the genetic identity of the two deposits.

A few typical sections are appended.

BUTLER TP., SEC. 20, EAST $\frac{1}{2}$.

		FEET.
2.	Sand, stratified	3
1.	Loess, buff, fossiliferous, graduating outward into fine yellow sand, and toward the margin overlying stratified sand of same color	6

BUTLER TP., SEC. 19, SECTION OF EAST END OF PAHA.

		FEET.
3.	Soil, passing into loess	2
2.	Loess, buff, fine	3
1.	Sand, fine, stratified, yellow, passing upward into true loess by interstratification	5

On the margin the loess passes under reddish, clayey sand, with purer sand from 1 to 3 feet thick.

WINFIELD TP., BETWEEN SECS. 14 AND 20.

		FEET.
2.	Soil	$\frac{3}{4}$
1.	Loess, upper and middle phase, graduating downward into fine stratified sand which, on the north side of the hill, dips outward and downward	5

These sections transect the margins of paha, and it is probable that, as in some more thoroughly studied paha in Linn county, a complete section would show the sand to thin from the margin invaded, and to be absent in the central portions of the hills.

The following sections indicate something of the structure of the massive sand hills northwest of Princeton. It must be remembered that these sections are not vertical, but are descriptions of exposures along the slope of the hills. Thus the lower members which appear to underlie the upper may only abut upon their flanks.

NORTH SIDE OF HILLS ON ROAD IN SEC. 29, PRINCETON TP.

		FEET.
3.	Unexposed or with small outcrops of yellow sand.....	62
2.	Loess, typical light buff, floury in fineness, interstratified with very thin and distant, parallel, and fairly continuous veins of finest sand dipping 6 degrees with slope of hill..........................	28
1.	Sand, light gray, merging inward into sandy clay and loam and buff loess, to base of hill...........	20

The section on the south side of the same hill is more complete.

		FEET.
10.	Grass-covered, sandy slopes, with an occasional bed of somewhat clayey sand.............................	25
9.	At 85 feet from base, fine yellow sand, dipping with the hill, south 4 degrees, graduating downward by intercalation of bands of maximum thickness of 2 inches, into typical loess.	
8.	At 73 feet, typical loess.	
7.	At 68 feet, typical loess, fossiliferous.	
6.	At 63 feet, loess, fine.	
5.	At 58 feet, loam, loess-like, a fine clayey sand with many kindchen, thickening down hill and merging downward and laterally inward into loess 7 feet thick.	
4.	At 46 feet, loess, typical, light yellow-gray, with kindchen and fossils, 5 feet thick.	
3.	At 43 feet, sand, yellow and somewhat clayey.	
2.	From 25–38 loam, brownish buff, fine, sandy.	
1.	From 1–25 concealed, probably sandy.	

A deep gully on the same range of hills, section 23, Princeton Tp., shows clearly the same relations of the loess and the sand, the latter overlying the former and spread along its sides. This gully, the largest in the county, some 75 feet deep and several hundred feet wide, has been cut out in the last 15 years. Before that time the hillside could be driven across at any point. At the head of the gully, at the height of about 10 feet, black soil passes down into brownish, slightly sandy loam, and this into light buff, pulverulent loess.

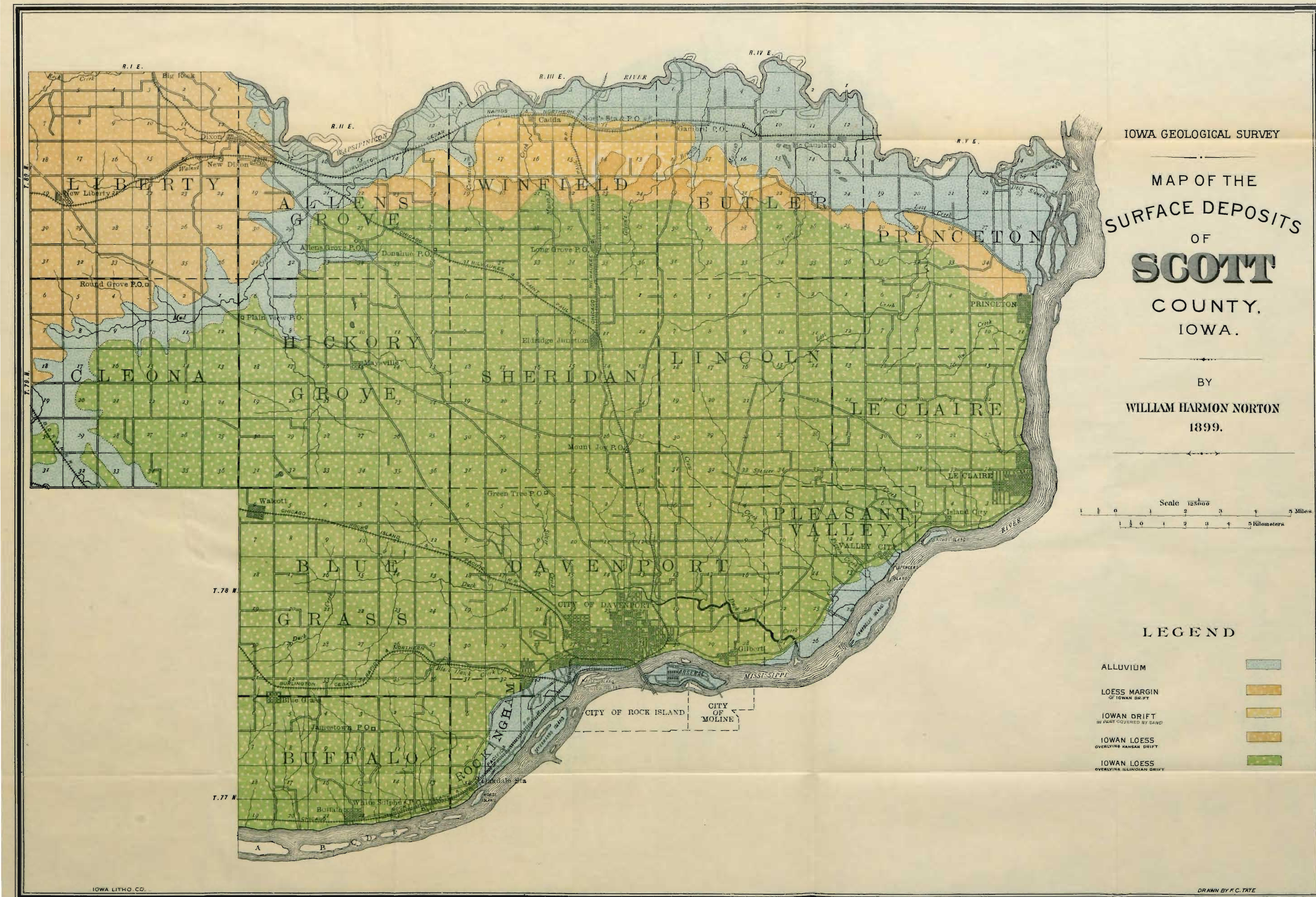
Within a few rods from its head the ravine has cut well down toward the base of the hill, and here, within 5 feet from the bottom of the gully, stratified reddish-yellow sands, dipping 4 degrees south, pass downward by interbedding into loess. The transition is effected in about 2 feet, within which measure the sand grows finer and its laminæ more narrow from top to bottom, with a corresponding increase in the width of the interbedded loess. At the same level, a few feet distant to the south, the loess is succeeded outward by fine, and finely laminated, horizontally bedded, light yellow sand, including thin, darker bands of clayey sand and grading upward into coarser and redder sand. The relation between the loess and the fine sand cannot be seen; but they probably grade into one another as they are known to do elsewhere in the Wapsipinicon valley. The aspect of such gradations strongly suggest that the deposit of loess was here made in currents retarded by hills of glacial till, while sand was being laid down in the more rapid currents along the open channel of the river valley.

It is difficult to estimate the thickness of the loess with any degree of accuracy. Road cuttings seldom give a measure of the thickness, since it folds down over pre-existing hills like a blanket. Well records do not discriminate between this and yellow glacial clays. All the evidence at hand goes to show a considerable thickening of the loess in the vicinity of the Iowan margin, where it may attain the measure of 40 or 50 feet. Along the Mississippi the loess reaches 25 or 30 feet at Davenport, but is considerably thinner than this in Buffalo township. Over the interior of the county the yellow loess can hardly be conceded more than 15 or 20 feet.

The loess we have described is that intimately associated with the invasion of the Iowan ice and laid down as a result of conditions, at present not well known, in the glacial waters attending its melting.

Preglacial Surface.—A very slight investigation suffices to show that the preglacial topography was widely different from that which meets the eye to-day. Rivers ran hundreds of feet below the present surface. Hills relatively high stood where the level prairie now stretches to the horizon. Were the cover of drift removed from the underlying rocks, their surface would be found rugged and hilly, deeply scored with manifold ravines, and trenched by river valleys deeper than that of the Mississippi, and as wide. But it is scarcely practicable to draw the details of that ancient surface. For the most part we must rely on the records of the wells which have been sunk in the past few years. It is a familiar fact that the well driller finds the distance to rock far from equal even from the same level. In one section, the drill grinds on the native rock within fifty feet from the surface; a mile or so away, rock is only found within 300 feet from about an equal elevation. These deep depressions, now plastered over with glacial mud, were cut by running water. They are not local discontinuous pits. They join and form continuous valleys, cut out by ancient rivers. Accordingly, the deepest drift wells are not found in clusters but in lines.

The best defined of the old channels thus marked out, lies parallel, for the most part, with the valley of Mud creek, from which it is nowhere more than two miles distant. In Cleona township the course begins in section 14, not in the immediate valley of Mud creek, but across the crest of a low swell on the left bank. Udden, the discoverer of this ancient river valley, has traced it southward from here into Muscatine county, and its course therein is described in his report upon that county in the present volume. In section 21, the


IOWA GEOLOGICAL SURVEY
MAP OF THE
SURFACE DEPOSITS
OF
SCOTT
COUNTY,
IOWA.
BY
WILLIAM HARMON NORTON
1899.
Scale 1/125000
5 Miles
5 Kilometers
LEGEND
ALLUVIUM
LOESS MARGIN OF IOWAN DRIFT
IOWAN DRIFT IN PART COVERED BY SAND
IOWAN LOESS OVERLYING KANSAN DRIFT
IOWAN LOESS OVERLYING ILLINOIAN DRIFT
LIBERTY
ALLENS GROVE
WINFIELD
BUTLER
PRINCETON
CLEONA
HICKORY GROVE
SHERIDAN
LINCOLN
LE CLAIRE
PLEASANT VALLEY
BLUE GRASS
DAVENPORT
BUFFALO
ROCKINGHAM
CITY OF DAVENPORT
CITY OF ROCK ISLAND
CITY OF MOLINE
MISSISSIPPI RIVER
WAPSIPINICON RIVER
IOWA LITHO. CO.
DRAWN BY F.C. TATE

old valley lies two miles south of the creek, along the main divide of the region. Thence it bends northward, and in section 15 of Cleona township, reaches within a mile of Mud creek; the hills here which overlie the old channel still being some fifty feet above the present valley. Trending northwest, it crosses Mud creek at Plain View, and recrossing, bends again northeast to Allen Grove and north by Donahue to the Wapsipinicon.

Several well sections have been given showing the nature of the deposits which have filled this old valley, which we may conveniently designate the Cleona channel.

Another buried channel, not so plainly marked, is traced by deep wells from the northeast corner of Blue Grass township, north along the east line of Hickory Grove township. It either runs north to join Cleona channel, or turns eastward along the north line of Sheridan township, and thence to Long Grove and the Wapsipinicon valley.

North of Davenport, in Tp. 78 N., R. III W., Sec. 12, are several deep wells whose apparent isolation is due to the incompleteness of our data. In some instances of deep wells, investigation shows that the apparent great depth to rock was due to the fact that heavy Carboniferous shales were reckoned as "blue clay" instead of as rock. Such wells also indicate buried channels, but of such vast antiquity that they were filled with the silts of the Des Moines stage of the Carboniferous.

The list of wells which is appended to the report, exhibits data gathered mostly from the well drillers of the county. In several instances it was made from written records, in others, from the memory of the driller. No high degree of accuracy attaches to the records of the materials through which the drill passed; though they no doubt represent at least a composite of mental impressions derived from long experience in the region. The distance to rock is believed to be, in most instances, reliable.

ECONOMIC PRODUCTS.

Coal.

In several of the Carboniferous outliers of the county, as at Black Hawk and Island City, there occur thin seams of coal, but the only seams thick enough for profitable working are found in the large Carboniferous area of Buffalo township. Here mining operations have been carried on for nearly half a century; and along Stillwater creek, and about Jamestown, their record is left in the numerous heaps of refuse which mark the places of prospect shafts and abandoned workings. In 1897 three mines were reported in active operation, all near Jamestown. The Williams company mine, leased by T. E. Anderson, reports the number of days worked at 225, and an output of 4,500 tons. The mine of James & Son reports 130 days' work, and an output of 2,572 tons. From the Clipper mine Mr. S. Long took a few hundred tons, and some was mined from a "bank" on the farm of Mr. E. Pahl. The small output is in part due to the discouragement of a slack market and low price. The coal was sold in 1897 at the "banks" for $1.50 per ton. Several prospect shafts were being sunk at the time of the survey about Jamestown, Buffalo and Stillwater.

The seam worked by the Jamestown mines lies in a trough about two miles long and 200 yards wide, trending from northwest to southeast, and reached at a depth of about ninety or 100 feet from the surface. In the center of this "swamp," as it is termed, the coal has a thickness of from four to six feet, but it thins as it rises to either side of the trough, where it lies some ten feet higher than in the center. In the James mine it is worked on each side for 100 yards from the central axis, and at this distance it is reduced to a thickness of two and a half feet. The trough rises from each end gently toward the center. Thus, at the James mine, the dip is toward the northwest at the rate of eight feet in 300 yards. Slight faults, rolls and pinch-outs occur on each side of the axis, with the down throw on the swamp side, but nowhere do these seriously interfere with mining. The farthest point toward the northwest to which this seam has been traced is Blue Grass Tp., Sec. 33, Se. ¼, where coal two feet thick is said to have been found, but to be unworkable because no roof overlies it. At the Williams mine, which has been worked for thirty years, the swamp is reached at a depth of 102 feet, and coal has been worked to 150 yards to each side. The swamp here sinks to the southeast. Detailed sections of these mines are given elsewhere in this report.

South of Jamestown there is an area where the coal is said to lie in a comparatively flat and uniform seam. It has been mined on the farm of Mr. Charles Rowan, Buffalo Tp., Sec. 10, W. ½, about eighty feet from the surface. Several seams, two and three inches thick, occur above the one mined. Wells show that coal is underlain with fire clay sometimes to a depth, as is reported, of twenty-five or thirty feet, and at from 175 to 200 feet from the surface the drill passes into Devonian limestone. Toward the northwest coal is reported one and one-half miles south of Blue Grass, Buffalo Tp., Sec. 8, Nw. ¼, where a well record gives it a thickness of twenty-one inches at a depth of 114 feet from the surface.

In the Stillwater district, west of Buffalo, no mines were found in operation. Here the coal is said to lie in "swamps" with a maximum thickness of four feet, and to be reached by shafts at a depth of about fifty feet below the creek bottoms. A full description is given by Keyes* of these mines as he found them in operation in 1893.

Mining in Buffalo township is carried on with little difficulty or expense. Coal is found within easy reach of the surface, and in workable seams, well roofed with hard carbonaceous and argillaceous limestone or firm gray shale. No serious dislocations occur and all engineering problems are at their simplest. While the main swamps may be worked out in the near future, there are apparently large amounts of coal in

*Iowa Geol. Surv., vol. II, pp. 472-473.

thinner seams, which will much longer yield a moderate return to the industry of the miner.

All coal of the region is of the ordinary bituminous type, and, in its comparative freedom from injurious impurities and small per cent of ash, it compares well with the leading coal mines of the state, as is shown in the following chemical analysis* of a typical seam:

FRIEDLY & HOYT, BUFFALO.	Moisture.	Total combustibles.	Ash.	Volatile combustibles.	Fixed carbon.	Coke—fixed carbon plus ash.	SULPHUR.		
							In sulphides	In sulphates	Total.
Top of seam.......	3.48	89.79	6.73	41.32	48.47	55.20	4.99	.54	5.53
Middle of seam....	3.66	87.46	8.88	41.44	46.02	54.90	3.72	.15	3.87
Bottom of seam....	2.89	82.03	15.08	38.09	43.94	59.02	7.80	.38	8.18

Building Stone.

Superior building stone is well distributed throughout the county. *The Silurian* in the Anamosa type of the Gower, furnishes cut stone unsurpassed in quality in the state, and, in its heavier layers of coarser grain, a stone practically indestructible for bridge piers, culverts and heavy masonry generally.

The quarries about Le Claire are the best developed of any using the Anamosa stone. Detailed sections of the quarries of F. H. Thielman and of Velie and Nason have been given together with several others of less economic importance. In all these quarries the light buff dolomite runs in even courses about 1 foot in thickness, traversed by vertical joints so distant that stone can be taken out in dimensions far in excess of any possible demand. No channelers are used, but the stone is uniform of texture and can be broken with fairly even fracture along the lines desired. The color is slightly warmer than obtains in the Anamosa quarries. The rock can be easily dressed or sawed when green, and it contains no

*Keyes: Iowa Geol. Surv., vol. II. 1894, p. 508

injurious constituents, such as quartz or pyrite. At the Rock Island arsenal it has been laid in dressed stone, but rock-faced ashlar will usually be found the most pleasing cut. The overlying stripping of glacial clays is rather heavy and seriously increases the cost of working some of the quarries at present. But if railroad facilities were offered, encouraging the development of the industry, all this stripping could be handled at slight expense by hydraulic machinery. The localities where the Anamosa stone occurs are without railways, and for this reason the quarry industry is but little developed. In no quarries has modern machinery been introduced. The strippings are moved with spade and barrow, and the rock is quarried by means of the jump drill, the wedge and the crowbar.

The strength of the stone is more than adequate to any strains it is likely to bear. Sample blocks from F. H. Thielman's quarry tested by Prof. A. Marston,* Iowa Agricultural college, withstood 1,200 pounds per square inch, proving it a stronger stone than such well-known stones as the Berea sandstone and the Bedford oolite.

The heavier, coarser grades of the same type are nowhere found near enough to railways to warrant any working of the quarries beyond the supply of local needs. Much of this stone lies in layers about 2 feet thick, with moderately smooth surfaces, and, while highly vesicular, its cavities do not injure the stone for purposes of heavy masonry. As a dolomite it is more resistant to the chemical attacks of the weather than is ordinary limestone, and it endures frost, as many stones of finer grain cannot do. The quarries of this group are described in the preceding pages.

The Devonian furnishes some very good building stone, the most durable being that from the Upper Davenport beds. This stone is rough and hard and not easily brought to desired shapes and sizes. On the other hand it is exceedingly tough and durable, of a beautiful color, and where properly dressed

*Iowa Geol. Surv., vol. VIII, p. 402.

and set, rock-faced ashlar is most pleasing; it leaves little to be desired. Trinity church, Davenport, is an example of the architectural capacities of the stone. The geological section of the Davenport quarries supplying this stone, which is used to a considerable extent about the city, has already been given. The only quarry reported is that of Mr. H. G. Schmidt, whose output was for 1897, some 3,000 perch, quarried chiefly for rough and rubble and road work.

The Lower Davenport beds, in their lower layers as exposed between Davenport and Gilbert, afford a very fair and durable building stone. It is of this stone that the cathedral of the Protestant Episcopal church was built. Most of these beds are of no value for masonry, soon breaking up into thin calcareous plates and chipstone, on exposure to the weather. The chief quarries are Louis Gomel's and Boland Andre's near Camp McClellan, which supply a large amount of excellent crushed stone for roads and streets.

The Cedar Valley limestones are for the most part too argillaceous to afford building stone of good quality. Several layers of the lower beds constitute a fair stone, and large quarries are now worked in them near Buffalo, chiefly, however, for rough and rubble and road work. The sections of the largest of these are given elsewhere. L. E. Dutcher's quarry, about two miles east of Buffalo, worked when visited about thirty men, besides teamsters. The rock is easily handled. Scarcely any stripping is necessary. The stone is blasted out of the ledges, broken up with the sledge, and carried on wagons a few rods to the bank of the Mississippi, where it is loaded on barges for government use in rip rap and on dams. Some also is used for road material in adjacent townships.

At A. C. Walker's quarry, one-half mile east of Buffalo, the same kind of rock is quarried and for the same purposes. About thirty-six men and fourteen teams are employed. In 1897, 25,876 cubic yards were quarried, valued at $13,782.

Lime.

The Le Claire beds of the Gower stage offer an inexhaustible supply of a stone unsurpassed in the United States for the manufacture of lime, but the industry remains almost wholly undeveloped and largely for want of facilities for transportation. Thus the lime quarries of Le Claire are unworked, while across the Mississippi lime burned from the same rock has made the name of Port Byron a familiar term to architects and builders.

Mr. H. Schmidt has supplied local needs, for a number of years, from a very pure lime rock quarried near Dixon. At Gilbert, Mr. H. Kuehle & Son burn the Lower Davenport beds, whose freedom from clay, quartz and iron insure a lime of great purity. As a non-magnesian limestone it produces a hot, quick lime admirably adapted for many manufacturing purposes. Several paper and straw mills have been supplied with it in the three adjacent cities. A new draw kiln is now building. In the pot kilns in use in 1897, $675 worth of lime was burned.

Clays.

CARBONIFEROUS.

The shale clays of the Carboniferous strata of the county form a source of wealth which has only begun to be drawn upon. At two points, Buffalo and Island City, these clays are utilized for the manufacture of brick. Both sites are well chosen, since the shale at each place is deep, with little refuse, and can be worked in open pits. The Island City plant is somewhat handicapped for want of railway transportation for its product. Both plants have the great advantage of wharfage on the Mississippi.

The Davenport Brick and Paving company operates an extensive plant at Buffalo, consisting of eight down draft kilns, capacity 440,000; an auger brick machine for end or side cut paving brick, capacity 35,000 per day; large drying sheds; an iron clad steam drier, capacity 25,000 per day; an 80 H. P.

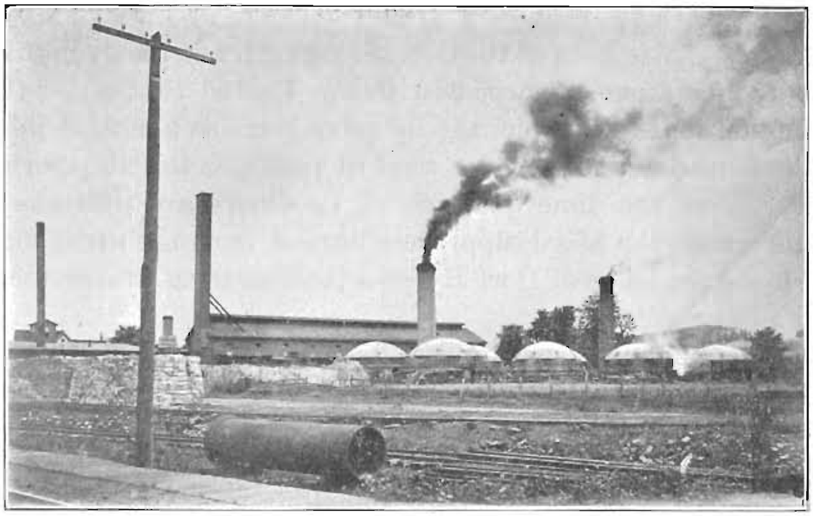


FIG. 51. Plant of Davenport Brick and Paving Company, Buffalo.

engine; an Eagle clay crusher and the usual pit machinery. Fire brick for the kilns are made from the lower 26 feet of the pit. Sidewalk brick are burned chiefly from the glacial clays. For pavers the shale is used mingled with a certain amount of the loess. Fuel is obtained at the coal mines at Jamestown three miles distant. The excellent quality of the pavers is shown by the following tests made by E. P. Boynton, C. E., Cedar Rapids:*

Paving brick, common. Abrasion and impact, per cent of loss, average	14.85
Porosity, absorption, per cent of gain	.93
Transverse strength, modulus of rupture, average	2,056.00
Comparative rating by formula	61.88

Draintile and sewer pipe are manufactured to a limited extent. The output for 1897 is reported as follows:

Common building brick	10,000
Paving brick	2,153,000
Draintile	3,000

The large plant of the Le Claire Brick and Tile company is situated three miles below the town, on the banks of the Mis-

*Iowa Geol. Surv., vol. VII, p. 379.

sissippi. It consists of a Chambers stiff-mud machine, capacity 50,000 per day; a Brewer tile machine, capacity 15,000 per day; a Chicago steam drier, double tunnel, capacity 50,000 brick per day; two round down draft kilns, capacity 70,000; and a sixteen furnace, Eudaly patent, down draft kiln, capacity 250,000. Common building brick and drain and sidewalk tile are manufactured. The pit is conveniently situated just back of the works, and its whole face is used. Fire brick are made for the kilns from the fire clay found on the ground. The building brick are of excellent quality, hard, tough, ringing and of even texture. Like the stone and lime quarries at Le Claire, the industry is seriously handicapped for want of a railroad. The brick sell chiefly to the cities along the Mississippi river, in Scott and adjacent counties.

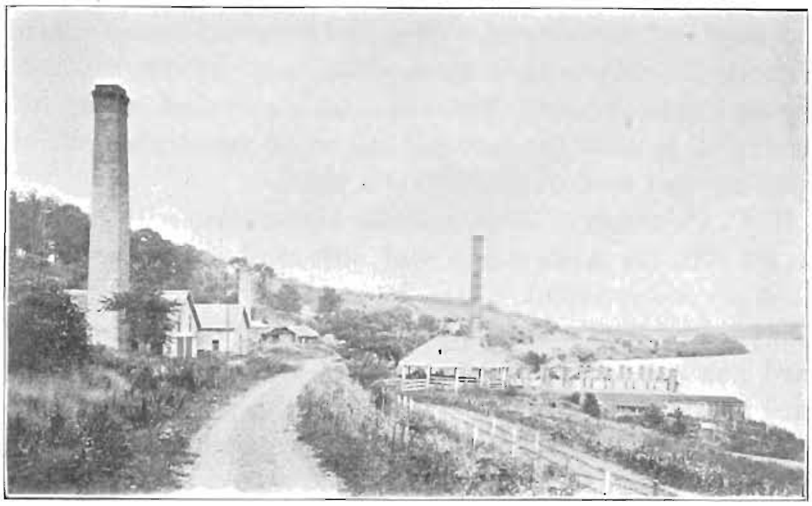


FIG. 52. Plant of Le Claire Brick and Tile company, Island City.

LOESS.

The loess supplies a good and abundant brick clay, easily manipulated and distributed well over the entire county. It is naturally manufactured most largely at Davenport, where there are four large yards in and adjacent to the city. The clay banks of the different plants are geologically identical, consisting of the three phases of the loess; the stiff joint clay of the weathered loess above the middle buff, and the lower and more sandy ashen loess. The whole face of the banks is worked, but the whole thickness of the ashen loess is not always used, since it gives too large a proportion of sand. Either on account of some hidden quality in the Davenport loess, or on account of skill in its manipulation, the brick from these yards are distinctly better than the average of loess brick. At all the yards brick for outside walls are moulded with a fine ocherous sand, found beneath the loess near Black Hawk. The iron, in which the sand is rich, oxidizes in the kiln and gives the surfaces of the brick a pleasing deep cherry-red color. The average weight of the brick is about 4,800 pounds per M.

The Black Hawk Brick company's plant is situated west of the city and consists of a new Anderson soft mud machine, capacity 25,000 per hour; three kilns, capacity 600,000, and ten drying sheds, capacity 250,000. All sand used is dug in the yard; coal is used for burning and wood for drying off. The sales amount to about 2,000,000 a year.

H. P. Pohlman & Bros. operate three kilns with a capacity of 480,000, an Anderson Chief soft-mud machine, capacity 2,500 per hour, and adequate drying sheds. The output from this yard in 1897 was 900,000. The Otter & Pohlman brick yard has substantially the same plant and output, and the yard of Mr. J. Ruch, similarly equipped, produced in 1897 a somewhat smaller quantity. The three yards last mentioned are situated on the bluffs in the northwestern part of the city.

The only plant that remains to be mentioned is one recently built for the manufacture of pressed brick at Long Grove. This place was selected for the reason that it is the first station coming north from Davenport on the Chicago, Milwaukee & St. Paul railway where the sub-loessial sands appear, being near the Iowan margin. Both sand and clay are taken from the same pit in the yards, conveniently situated adjoining the railway tracks. The plant consists of a U. S. dry press, capacity 20,000 per day, an Alsip up and down draft kiln, capacity 106,000, and the necessary engines, sheds, etc. At the time of inspection the first kiln of bricks was not through burning.

Road Material.

The supervisors have recently shown an exemplary enterprise in the making of good roads throughout the county. In the Kansan upland steep grades are being reduced by cuts and fills, and in every township road metal is being laid down where roads are difficult in wet weather. Most of the material is brought from a pahoid kame of the Buchanan gravels south of De Witt. Some is taken from the Devonian quarries of the Cedar Valley stage near Buffalo, and a better quality from the quarries of the Wapsipinicon stage at Davenport. The still harder Le Claire stone will no doubt be utilized in the future, and the Carboniferous shales and other clays offer inexhaustible mines of clay ballast wherever it is deemed expedient to burn it for this purpose.

Soils.

The soils of the county are of several distinct kinds. Those developed upon the Iowan drift are very limited in extent, since the Iowan area is small and much of it covered with aqueous deposits. The soils developed on the loess, wherever the land is level or gently undulating, are exceedingly fertile, and from them the larger part of the enormous agricultural wealth of the county has been drawn. But where the hillsides are steep, as on the Kansan upland, humus is rapidly removed, and the soil soon depleted of its nitrogenous constituents. Such hillsides, with their deep, porous loess mantle, are admirably adapted for forest culture, for orchards and vineyards, and are largely used for fruit raising about Davenport. The soils of the sandy hills of the Iowan frontier are light and poor, while those on the silts of the broad bottom lands of the Wapsipinicon and Mississippi are among the most fertile in the county.

Water Supply.

From almost any point of view in the county the wind engine is a conspicuous figure in the landscape, and its presence not only attests the prosperity of the farming community, but it suggests the significant fact that the ground water of the region has lowered since the settlement of the county. The earlier shallow wells are mostly dried up, and of recent years the well driller has been busy mining for that most valuable of minerals — water. The shallow veins just beneath the loess still occasionally afford a domestic supply. Water is found near the surface on the alluvial bottoms and sandy terraces. On the Wapsipinicon flood plain drive wells are commonly used, but generally the driller has been compelled to go for permanent and adequate supply through the heavy mantle of drift to the country rock. Here a well-defined water horizon is often found in sand and gravel, but not infrequently the rock itself must be penetrated until a vein is found in the strata. In the districts where the coal measures form the country rock, the water problem becomes particularly serious, since these shales and sandstones are either wholly dry or contain a little water of undesirable quality. The driller is compelled, therefore, to go through these shales to the limestone beneath, and wells sometimes more than 300 feet in depth are necessary.

The sands and silts interbedded with tills in the buried channel of Cleona river, contain water in large quantities. So fine are these sediments that they pass through the driller's sieves, and it is only with great care and skill that he can sink his well to coarser sand and gravels, often 250 or 300 feet beneath the surface.

Coming from considerable distance below the surface, and protected by heavy sheets of dense glacial clays, the water supply of the county at large may be assumed to be free from any bacterial contamination. The few small towns on alluvial bottoms should exercise constant care to prevent the pollution of their shallow wells and the ravages of disease which inevitably ensue. Wells in rocks are usually safe wells in this region, but it must be pointed out that where the strata dip more or less steeply, their bedded planes furnish open waterways from the surface downward, and ready access of superficial contaminations of any kind to the deeper veins. If we mention the town of Le Claire as occupying such a site it is not from any evidence or ground of suspicion of any impairment of the purity of its present water supply, but only because the high dip of the strata on which the town is built makes such an impairment possible at any time. An artesian well would insure an abundance of pure and wholesome water, and could be drilled at small expense.

ARTESIAN WELLS.*

Few local artesian basins of the United States have been so thoroughly studied as has the district of Davenport, Moline and Rock Island, by Prof. J. A. Udden, of the latter town. Before Professor Udden's paper appeared in the seventeenth annual report of the United States Geological Survey, he very generously placed in our hands the notes upon which his manuscript was based. We are also indebted to the owners of several wells for information, and to Mr. A. S. Tiffany, who loaned his set of drillings from the Kimball house and the city park wells.

In number of artesian wells Davenport slightly outranks any other town in the state. The exploitation of the field is comparatively recent. Nine of the fourteen wells were drilled during the present decade. This extension of the use of artesian water has taken place in the face of the fact that the city water supply, drawn from the Mississippi river, passes through one of the largest mechanical or rapid filtering plants in the United States. The preference for artesian water on the part of large consumers is probably due in part,

*Norton: Iowa Geol. Surv., vol. VI, p. 272, et seq.

in the majority of instances, to its relative cheapness. In one instance a well was put down simply "to bring the water company to terms."

TABLE OF ARTESIAN WELLS AT DAVENPORT.

OWNER.	Depth.	Diameter in inches	Elevation of curbs A. T.	Original head A. T.	Present head A. T.	Original discharge.*	Present discharge.*	Water horizons A. T.	Temper'tre.	Date of completion.	Driller.†
Witts' Bottling Works	780	....	575	657	634	300	....	....	.....	1891	...
Woolen Mills	1053	3½	564	651	....	......	....	479 ft.; -136 ft.; n.bo'm	.....	1890	2
Crystal Ice Co	1067	6-4	590	605	602	250	240	-10 ft. and St. Peter.	60° F	1893	2
Malt and Grain Co	1076	5	592	627 631	602 607	....	.....	-108ft ;-464 to -474.	.....	1892	2
Kimball House	1100§	8-4	579	637	599	......	.....	-131 ft. and St. Peter.	.....	....	2
Tri-City Packing & Provision Co.	1100	8-5	564	610	610	250	250	-236 to bottom.	....	1893	1
Gas company, two wells	1200	5-4	564	612	612	.....	....	....	.....	1891	2
Schmidt building	1200	4	576	600 606	....	45 28	.....	....	.....	1892	2
City park	1797	....	704	682	670	‡125	.....	....	....	1888	1
Glucose Manufacturing Co.	1500	5	562	.....	620	......	230	....	60° F	1880?	...
Glucose Manufacturing Co.	2101 2105 2107	5	562	.....	643	....	380 400 400	....	60° F	.... 1889 1892	1

*In gallons per minute. †1, J. P. Miller & Co.; 2, A. K. Wallen. ‡By pumping. §Approximately.

The first flow of the wells of this district rises from about 479 feet A. T., near the base of the Devonian. This may represent the natural springs which rise from the Independence shale in other counties, and indeed the shale near this level of the Kimball house record, preserved by the Davenport Academy of Science, may be the Independence rather than a cavern filling as held by Udden. The water is corrosive in quality and insignificant in quantity. A second flow is obtained in the Galena limestone, at depths from -108 A. T. to -242 A. T. This is the so-called "upper water," and is impregnated with sulphureted hydrogen. To enjoy the characteristic taste and odor of the gas, the water must be taken immediately from the well. Aeration and relief from pressure permit an escape of the gas so rapid and so complete that chemists rarely find traces of its presence in samples sent to their laboratories for analysis. The water is usually separated by tubing from the lower flows. The yield is generous, amounting in the Witts' well to 300 gallons a minute, and at Carbon Cliff, Ill., to 400 gallons. At Davenport the head is reported somewhat lower (less than ten feet) than that of the water from the Saint Peter. At Carbon Cliff the reported pressure equals a head of 684 feet A. T.

The third water horizon lies in the Saint Peter sandstone, whose depth is variously reported in different wells at from –376 feet A. T. for the summit to –577 feet A. T. for the base. This flow has furnished so far most of the discharge of the Davenport basin. Other flows unspecified in the extant records, occur in the Oneota and the sandstones of the Saint Croix, and under greater pressure and with heavier discharge if we may judge from the wells at the city park and the glucose factory.

ANALYSES.

The following analyses indicate the qualities of the waters from their different horizons, excepting that from near the base of the Devonian. The first of the Witts' well is from the Galena. The second, of the Crystal Ice Co.'s, is from the Saint Peter only, all upper waters being shut off by tubing 1,067 feet in depth. The analyses from the glucose factory well probably represent admixtures with the deeper waters below the Saint Peter.

WITTS' BOTTLING WORKS.

	GRAINS PER U. S. GALLON.	PARTS PER MILLION.
Calcium carbonate	2.1480	36.80
Magnesium carbonate	1.6034	27.47
Iron carbonate	.4488	7.69
Sodium carbonate	16.4457	281.75
Sodium sulphate	23.4069	401.01
Sodium chloride	26.1753	448.40
Silica	.4377	7.50
Total	70.6658	1212.50

Analyst, E. T. Burghausen, chemical works, Cincinnati. Authority, J. A. Udden.

CRYSTAL ICE AND COLD STORAGE CO.

	GRAINS PER U. S. GALLON.	PARTS PER MILLION.
Silica ($Si O_2$)	.497	8.571
Alumina ($Al_2 O_3$) / Ferric oxide ($Fe_2 O_3$)	.182	3.143
Lime (Ca O)	1 624	28.000
Magnesia (Mg O)	.530	9.143
Potash ($K_2 O$)	......	....
Soda ($Na_2 O$)	31.834	548.857
Chlorine (Cl)	15.859	273.429
Sulphur trioxide ($S O_3$)	13 282	229.000
Carbon dioxide ($C O_2$)	9.139	157.571
Water in combination ($H_2 O$)	.829	14 286
Free (CO_2)	[1.110]	[19.143]

UNITED AS FOLLOWS.

	GRAINS PER U. S. GALLON.	PARTS PER MILLION.
Calcium bicarbonate ($Ca H_2 (CO_3)_2$)	4.690	80 857
Magnesium bicarbonate ($Mg H_2 (CO_3)_2$)	1.922	33.143
Ferrous bicarbonate ($Fe H_2 (CO_3)_2$)	.406	7.000
Sodium carbonate ($Na CO_3$)	12.667	218.571
Sodium sulphate ($Na_2 SO_4$)	23.705	408.714
Potassium chloride (K Cl)	......	....
Sodium chloride (Na Cl)	26.266	452.857
Alumina ($Al_2 O_3$)	Trace.	Trace.
Silica ($Si O_2$)	.497	8.571
Oxygen replaced by chlorine (O)	3 613	62.287
Solids	73.776	1272 000

Analyst, Dr. J. B. Weems, May 27, 1896.

The waters of the Wagner brewery well at Rock Island, Ill., the paper mill well at Moline, 1,628 feet deep, and of the East Moline well, 1,340 feet deep, are similar in chemical composition to those of the Witts' well and the Crystal Ice Co.'s. If the "upper water" is not mixed with the lower in all these wells (excepting, of course, Witts'), this marked similarity, closely approaching in some instances practical identity, strongly suggests that the upper water from the crevices of the Galena really rises from the horizon of the Saint Peter or even from still lower veins, and this assumption is reinforced by the volume and head of the Galena water. On the other hand, the presence of sulphureted hydrogen in the upper water supports the assumption that it is native to the Galena.

GLUCOSE FACTORY (WELL UNKNOWN).

COMPOUNDS.	GRAINS IN U. S. GALLON.
Calcium bicarbonate	5 132
Magnesium bicarbonate	4.770
Calcium sulphate	5.540
Sodium sulphate	16.096
Sodium chloride	28.080
Alumina	0.361
Silica and unsoluble residue	0.216
Total	60.195

Analyst, Chemist of Co. (?). Authority, D. W. Mead, Hydrogeology of Illinois, Table X.

GLUCOSE FACTORY (WELL UNKNOWN).

COMPOUNDS.	PARTS PER MILLION.
Calcium carbonate	202 0
Magnesium carbonate	110.0
Sodium carbonate	7.0
Sodium sulphate	364.0
Sodium chloride	833.0
Insoluble	226.0
Total	1,742.0

Analyst, E. Guteman, Davenport. Authority, J. A. Udden.

PERMANENCE OF THE PRESENT SUPPLY.

The original head of the earlier wells, from 1,000 to 1,200 feet deep, is exemplified in that of the Kimball House and of the Woolen Mills wells—a head of from 637 to 651 feet A. T. The wells drilled in 1891 and 1892 show no original head higher than 631 feet, and in two wells the head was only 600 and 612 feet A. T. From 1893 to 1895 the water rose in new wells of this depth to from 606 to 615 feet A. T. In old wells it is impossible to state how much of the loss of pressure is due to leakage from various causes. The well at the woolen mill, for example, lost 62 feet of head in the first three years after it was drilled. About 300 feet of casing was then taken out, much corroded and in places perforated. When new tubing to that depth was adjusted, the water rose to a tank 10 feet higher than the head before repairs were made. How much higher it would rise was not tested. That any overdraft is local, is shown by the fact that in 1894 the village well at Milan, three miles south of Rock Island, headed at 635 feet A. T. In Davenport, at least the deeper wells, from 1,800 to 2,100 feet deep, maintain nearly their original pressures.

In summation, we may say that the supply available to wells less than 1,200 feet deep is being overdrawn. All wells should be kept in thorough repair. Any considerable increase in the number of the wells in the district will probably make pumping necessary in all the wells of this depth. But the larger reservoirs below the Saint Peter show little or no signs of exhaustion, and the limit of their supply may be far from being reached.

GEOLOGICAL SECTION.

The first attempt to interpret the relations of the deeper strata at Davenport was made by Mr. A. S. Tiffany.* This was based upon samples obtained by him from the well at the city park. As an illustration of the pains sometimes needful to secure these valuable data, it may be said that the trips which Mr. Tiffany made to the well involved some 300 miles of travel. Abridged and slightly rearranged, and the elevations A. T. being added, Mr. Tiffany's section is as follows:

FORMATION.	THICKNESS.	DEPTH.	ELEVATION A. T.
Drift	100	100	604
Coal Measures	30	130	574
Corniferous	390	520	184
Lower Helderberg (Le Claire)	80	600	104
Niagara	175	775	-71
Cincinnati and Trenton	300	1,075	-371
Saint Peter, Calciferous	100	1,175	-471
Other groups, Calciferous	622	1,797	-1,093

*American Geologist, vol. III, pp. 117-118.

The samples from this well and from that at the Kimball house were kindly placed by Mr. Tiffany at the service of the writer and have been described by him in detail.* It was found impracticable to reconcile the records of the two wells, and a large part of each section was left undetermined as to the age of the strata. For example, the horizon of the Maquoketa shale, although 242 feet thick at the Kimball house well, was represented in the samples of the Park well only by several samples of non-argillaceous dolomite. The presence of interbedded layers of dolomite in the Maquoketa is not strange, but the absence of any shale, or record of shale, is singular. The following was the author's section based upon these data:

FORMATION.	THICKNESS.	ELEVATION A. T.
Pleistocene or recent	13	566
Devonian	115	451
Upper Silurian	320	131
Maquoketa	242	-111
Galena-Trenton	425	-536
Saint Peter sandstone	90	-626

Thus the great body of the strata referred by Tiffany to the Corniferous was placed with the Niagara, the base of the Devonian being lifted 267 feet.

Since the publication of the author's paper, Prof. J. A. Udden, of Rock Island, has collected and most skillfully collated a large amount of data from the three adjoining cities, including some well records and series of drillings from the Illinois towns that are specially complete and reliable. The general geological section which he has constructed from these must be a close approximation to the fact.

*Iowa Geol. Surv., vol. III, pp. 200-202.

	FORMATION.	THICKNESS.	ELEVATION A. T.
14	Devonian	55	500
13.	Niagara	340	160
12.	Maquoketa	223	-63
11.	Galena	244	-307
10.	Trenton	100	-407
9.	Shale	41	-448
8.	Sandstone	76	-524
7.	Shale	66	-590
6.	Lower magnesian	800	-1,390
5.	Sandy shale	35	-1,427
4.	Arenaceous limestone	27	-1,452
3.	Sandstone	145	-1,597
2.	Calcareous shale	75	-1,672
1.	Sandstone	97	-1,769

Nos. 1-5 are referred by Professor Udden to the Potsdam and Nos. 7-9 are included in the Saint Peter.

After a close examination of all the facts in the case, involving the conflicting records of about a dozen wells, we find few changes to suggest, and these in points of minor detail. We should incline to place the base of the Devonian at about 475 A. T., relying upon the recorded samples of the Kimball house well, and other data, and would follow these same sources of information and the records of the Davenport Academy of Science in placing the limits of the Maquoketa at 131 A. T. and 109 A. T. The records of the Saint Peter are singularly conflicting. The reported top of this sandstone varies from -376 A. T. to -485 A. T., and its base from -456 A. T. to -577 A. T. It will be noted that while we limit the Saint Peter to the sandstone, Professor Udden joins with it the shales immediately below and above, which we have allotted to the Trenton and to the Upper Oneota. Below the Saint Peter the section rests upon the records of three wells.

GLUCOSE FACTORY, DAVENPORT, 562 A. T.

STRATA.	THICKNESS.	DEPTH.	A. T.
Surface material	52	52	510
Limestone, bluish	...	410	152
Shale	...	635	- 73
Limestone	...	970	-408

STRATA.	THICKNESS.	DEPTH.	A. T
Shale	30	1,000	-438
Sandstone, Saint Peter	42	1,042	-480
Limestone, sandy	530	1,572	-1,010
No record	258	1,830	-1,268
Shale	40	1,870	-1,308
Limestone, sandy	20	1,890	-1,328
Sandy rock	160	2,050	-1,488
Shale	50	2,100	-1,538

MOLINE PAPER CO., 564 A. T.

STRATA.	THICKNESS.	DEPTH.	A. T.
Sandstone (Saint Peter)	65	1,141	-577
Red marl and limestone	316	1,457	-893
Sandstone	121	1,578	-1,014
Limestone	50	1,628	-1,064

MITCHELL & LYNDE'S BUILDING, ROCK ISLAND, 558 A. T.

STRATA.	THICKNESS.	DEPTH.	A. T.
Sandstone, Saint Peter	145	1,104	-546
Limestone	811	1,915	-1,357
Sandstone, compact	30	1,945	-1,387
Limestone	35	1,980	-1,422
Sandstone	130	2,110	-1,552
Shaly limestone and shale	75	2,185	-1,627
Sandstone	97	2,282	-1,724

According to these records, the base of the Lower Magnesian cannot well be below -1,357 feet A. T., and may more probably be placed not below -1,268 feet A. T. with the glucose factory record, which is more exact in other details than that of the Mitchell & Lynde's boring. Nor will these records allow us to extend the section below -1,724 A. T. In the absence of frequent samples showing the true nature of the different strata from the base of the Saint Peter to -1,268 A. T., in view of the character of the strata of Magnesian series, which often causes even a geologist to hesitate as to whether to call them limestones, sandstones or shales, and in view of the 121 feet of sandstone included in the record of the Moline Paper Co., it seems preferable to leave indeterminate the base of the Oneota, or Lower Magnesian, and to place the base of the entire Magnesian series, including the

Saint Lawrence, at 1,328, the base of the last limestone in the glucose factory record. The sandstone and shales below this will fall in with the Basal sandstone of the Saint Croix.

At White Sulphur Springs, a beautiful park overlooking the broad Mississippi (Buffalo Tp., Sec. 24, Nw. ¼), there still flows one of the pioneer artesians of the state. It was drilled over thirty years ago and its depth is 800 feet. The hotel, which was once one of the chief health resorts of the state, was burned in 1893, and has not been rebuilt. The water is strongly sulphurated and it retains all the qualities which have made it sought after for medicinal purposes.

ACKNOWLEDGMENTS.

The assistance is greatfully acknowledged which was rendered during the survey of this county by all to whom opportunity offered, by owners of mines and quarries, deep wells and kilns, and by the persons engaged in well drilling. Our indebtedness is especially great to the director and members of the Survey for very many suggestions; to Dr. Calvin, to Professor Udden, and to Mr. Leverett, the privilege of whose counsel was enjoyed in the field, to Dr. Barris and the Davenport Academy of Natural Sciences, to Capt. C. D. Townsend of the Upper Mississippi Improvement Commission, and to Mr. J. W. Brown, division engineer, Burlington, Cedar Rapids & Northern railway.

APPENDIX.

The record of wells mentioned on page 493 follows. As has already been stated, these records are not absolutely accurate, but are offered as the best at hand and for the purpose of preserving them for future use.

RECORD OF WELLS IN SCOTT COUNTY.

OWNER.	Section.	Quarter.	Quarter.	Depth — rock not reached.	Depth to rock.	Depth in rock.	Total depth.	Curb A. T.	Bottom A. T.	Rock surface A. T.	Authority.	
Liberty Township —												
L. Riefe	2	SE	SE	...	100	...	...	...	...	...	..	
Z. Parker	7	NE	NW	....	93	...	113	...	...	...	2	Yellow clay 18, blue clay 75.
J Stoltenberg	7	SE	......	....	60	30	90	...	...	...	..	
J. L. Andre	8	NE	NE	....	150	...	...	...	...	...	1	Yellow clay 35, yellow sand, blue and yellow clay to bottom.
Klahn	8	NW	......	....	60	58	118	...	...	...	..	
G. Parker	8	SE	SE	....	143	...	143	...	...	...	2	Yellow clay 40, sand, remainder blue clay.
J. Hickson	10	NE	NW	....	112	...	...	...	...	...	..	
Dixon City Hotel	12	SE	SE	....	23	50	73	680	...	657	1	Nearly all fine blue, silty quicksand.
J. Holt	13	SE	SE	....	60	...	108	...	...	...	1	Yellow clay 25, black muck 35.
J. Flinker	15	NW	......	....	60	75	135	...	...	...	1	
J. Killian	16	SW	......	....	60	...	...	...	...	...	..	
P. Mohr	17	NE	NW	....	60	...	...	800	...	740	..	
....	18	SE	SE	....	81	...	...	...	...	...	..	
A. Paustian	9	NW	NE	....	18	...	...	800	...	782	..	
Town of NewLiberty	20	SW	......	....	90	...	...	...	...	...	..	
Town of NewLiberty	20	SW	......	....	108	...	...	800	...	692	1	Yellow clay 16, yellow sand 3, blue clay 89.
Town of NewLiberty	20	SW	......	....	50	...	...	...	...	...	..	
A. Weise	20	NW	NE	....	100	...	...	...	...	...	1	Yellow clay 16, quicksand 10, blue clay 74.
W. M. Lensch	20	SE	SW	....	90	...	...	...	...	...	..	Yellow clay 20, sand 3, blue clay 67.
W. M. Lensch	20	SE	SW	....	60	30	90	...	...	...	1	Little blue clay.
H. Schmidt	22	SW	SE	....	50	65	115	...	...	...	1	Yellow clay 25, red clay 25, boulders on rock.
M. Smallfield	24	SW	NW	....	105	...	165	...	...	...	13	
J. Flinker	24	SE	......	....	140	...	...	...	...	...	..	
H. Quistorf	25	SE	SW	42	...	...	...	...	...	...	1	Hard, blue clay from 12 to 40, stopped in sand.
E. Moeller	32	SW	SW	....	60	...	72	...	...	...	..	Yellow clay 20, sand 2, blue clay 38.
H. Arp	33	SW	SW	....	...	...	150	...	...	...	..	
T. Ketelson	35	NE	NW	...	128	22	150	810	...	672	..	
T. Killian	16	Sn	SE	....	8	...	64	...	...	...	2	
J. Killian	16	....	......	....	120	...	125	...	...	...	2	
T. Ketelson	26	SE	NE	....	70	...	74	...	...	...	13	Thick, yellow clay throughout.
Cleona Township—												
D. Boll	1	NE	NE	222	...	...	...	730	500	...	..	
C. Gimm	4	NW	NE	....	42	...	72	...	...	...	..	
W. Rheims	4	SW	......	....	162	...	163	...	...	...	2	
W. Rheims	7	NW	NW	....	121	...	...	...	...	...	..	
J. Schroeder	7	SW	SE	....	80	...	108	...	...	...	..	
H. Kroeger	9	SW	SW	....	45	...	113	740	...	595	4	All yellow clay.
H. Hein	10	SW	SE	265	...	...	...	...	...	...	..	
F. Kardel	11	NE	SW	....	...	...	...	...	...	...	..	
J. Rathjen	12	SW	SW	242	...	...	...	...	...	...	4	Yellow clay 35, blue clay 205, sand 2.
H. Speth	13	NW	......	275	...	...	...	...	...	...	4	Yellow clay 10, blue clay 116, quicksand 150, ends in gravel.
A. Franz	13	SE	NE	....	193	...	...	...	...	...	..	
H. Hein	14	NW	SE	282	...	...	...	750	468	...	..	
G. Paustian	14	NE	NE	280	...	...	...	740	460	...	4	Yellow clay 10, blue clay 268, sand and gravel 2.
Juergen Mumm	14	NE	SW	280	...	...	...	...	...	...	..	
M. Hoersch	15	SE	SW	167	...	...	...	...	...	...	..	
Johann Mumm	15	SW	......	188	...	...	...	...	...	...	4	Yellow clay 15, blue clay, stony, 171, gravel 2.
P. Paulson	16	NE	NW	....	58	...	122	...	...	...	3	
P. Paulson	16	NW	SW	....	111	...	137	...	...	...	3	
H. Goettsch	19	NW	NE	331	...	...	331	730	399	...	3	
Lena Mumm	21	NE	NE	278	...	...	...	740	462	...	4	Yellow clay 12, blue clay 236, sand and gravel 30.

RECORD OF WELLS IN SCOTT COUNTY—CONTINUED.

OWNER.	Section.	Quarter.	Quarter.	Depth—rock not reached.	Depth to rock.	Depth in rock.	Total depth	Curb A. T.	Bottom A. T.	Rock surface A. T.	Authority.	
H. Mumm	22	NW	SE	306				760	454			
J. Theil	22	NE	NE	146							4	Yellow clay 15, blue clay 129, sand and gravel 2.
H. Wessel	23	NW	SE	133							5	Yellow clay 20, sand 10, blue clay 100, gravel 3.
J. Reimer	30	SW	SW	32								
W. Rhelms	4	SW			146		161					
J. Tesrow	24	NW		144							5	Yellow clay 7, red sand 7, sand 21, gravel 25.
Durant											3	Yellow clay 25, sand 5, blue clay 109.
Near Durant, on cr'k											9	To rock, 100-150 feet.
Allen Grove Township—												
E. Snyder	7	NW	NW		50		2					
C. Rohwer	13			137							13	Ends in 25 feet of sand.
D. Yale	29	NW	SW		99		111				1	Yellow clay 20 feet, blue clay stony 70, hard pan 9.
E Gallegher	20	NW	SE		155							
M. King	20	SE	NW	75			75				1	Yellow clay 20, blue clay 50, hard pan dry 5, no water.
E. Richardson	20	SE	SE		100		118					Blue clay 70, sand 30.
* * *	24	NW		300								
O. H. Walton	24			320				750	430		13	Yellow clay, blue sticky clay, quicksand, stopped in 50 feet of river sand.
Wm Blythe	25	SE	NW		246						1	
H. Rohwer	26	NE	NE	300				740	440		7	Stopped in gravel.
Gilmore	27	SE	SE		228			700		472	L	
J. Hasenmiller	28	NW	SE	165								Stops in sand.
E. O'Neil	28	SE	NE		312		323	760		448		Yellow clay 50, 50 feet of sand, mostly blue clay, coarse gravel.
J. Carter	28	SW	SE	300				720	420			
H. Ketelson	30	NE	SE	46								
C. H. Brockmann	31	SW	NW	275				740	465			
H. Schultz	33	SW	SE		113							Yellow clay 16, quicksand, blue stony clay to 50, sand and gravel 2, blue clay 61.
H. Stahft	33	NE	SW		240		250	680		440	11	Mostly quicksand, 100 feet of sand in one bed.
H. Latrode	33	NW	NE		212			720		508		
R. O. Curtis	34	SE	SE					80				Struck rock.
H. Weise	35	NE		113								
Town of Donahue	36	NE			100						10	
Town of Donahue	36	NE			157	3	160					Yellow clay, blue clay, quicksand 15.
Chas. Middlemass	24	NW	SW	300				730	430		7	Mostly fine sand.
Hickory Grove Township—												
H. Klindt	2	SE	NW		71		81				13	
C. Rock	4	NE	SW		72							
F. Rock	4	SE	NW		150	6	150				13	
P. Burmeister	4	NW	NE		70		74				10	
M. Spelletich	5	SE	SE		69		77				6	
D. Wunder	5	SW	SE	180								
Joseph Vort	6	?	?		215							
Plainview	7	NW	NW	225				730	475		4	
Plainview	7	NW	NW		232						4	
M. Spelletich	7	NW	SE	293				740	447		4	
M. Spelletich	7	SE	NW		245						4	
M. Spelletich	7	SE	SE		55			720		665	4	
J. Soutter	8	NE	SE		30	47	77				6	
P. Burmeister	9	NW	NW		70	75					10	
P. Burmeister	9	SW	NE		80	85					10	
H. Arp	9	SE	SW		50	53					13	
J. Kerker	9	SE	SE		40	64					12	
P Meyer	10	NW	SE		80	95					13	
C. Meyer	11	SW	SE		67		81				12	
B. Painter	12	NE			215			740		525	U	

RECORD OF WELLS IN SCOTT COUNTY—CONTINUED.

OWNER.	Section.	Quarter.	Quarter.	Depth—rock not reached	Depth to rock.	Depth in rock.	Total depth.	Curb A. T.	Bottom A. T.	Rock surface A. T.	Authority.	
Ira Burch	12	SW	SE		190		191	740		550	12	Yellow clay 40, blue till 150.
Hans Joens	13	SE	NW		155		157				13	Water on rock.
J. Steenbock	13	SW	SE		208		212	710		502	13	
Maysville	15				78							
Maysville	15				120		130				9	
W. Koberg	15	NE	SW		105							
A. Lage	16	NW	SW		85		91				13	All yellow clay.
H. Klindt	16	SW	SW				74				10	Ends in rock.
G Golinghast	17	SE			50		78				4	
M. Spelletich	18	SW	SE		270			780		510		
J. Frauen	19	NW	NW	233						1	5	Ends in gravel.
J. Paustian	19	SE	NE	137							5	Yellow clay 20, sand 5, blue clay 105, gravel 7.
J. Hamann	20	NE	NW		110							
Th. Karbel	21	SE	NE	88								
M. Gries	22	SW	SW		165		170	720		555	13	From 100 feet down all quicksand and sticky clay.
J Plambeck	23	NE	SE	280				720	440		13	Mostly blue clay.
W. Fry	24	NE	SE		206		208	740		534	9	Yellow clay 17, blue clay hard 60, sand 138.
Schoolhouse	26	SE	SE		215		250	740		525	9	Ends in gravel.
E. Sindt	27	NW	NE	88							13	Yellow clay 15, blue clay 15, quicksand, ends in gravel.
C. Haller	29	NE	SE	116							4	
P. Riessen	29	NW	NW	126								
C. Paustian	30	NE	NW		130		143				5	Yellow clay 20, sand 5, blue clay 105
Geo. Dietz	31	SW	SE	55							5	Yellow clay 15, quicksand 5, blue clay 30, gravel 5.
Schoolhouse	32	NW	NW	115							5	Ends in gravel.
A. H. Lamp	33	NW	NW	86							5	Yellow clay 20, sand 6, blue clay 58. gravel 2.
Maysville creamery.	15	NW	SE		90		90	740		650	1	Yellow clay 16, quicksand 10, greenish clay 64.
Geo. Dietz	31	SW	SE	70							5	Yellow clay 16, sand 5, blue clay with bowlders, gravel.
J. Plambeck	36	SE			230		240	740		510	9	Quicksand 60 feet, on rock.
J. Soutter	8	NE			80		90				13	Yellow clay 40. blue clay to rock.
Blue Grass Township—												
S. R. Miller	1	NW		117								
S. R. Miller	1	SW	SW	275				760	485		12	Yellow clay 35, blue, hard clay to bottom, did not cave, no
S. R. Miller	1	SE	NE	113							14	Ends in gravel
S. R. Miller.	2	NE	NW	102							14	Ends in gravel.
S R. Miller	2	SE	SW	117								
W. Arp	3	SW	SW		100			760		660		
G Muhl	5	SW			40	64	104				5	Soft, white limestone.
H. F Strohbeen	5	SW	SW		47	43	90				5	
Walcott	6				50						5	Yellow clay 14, sand 5, blue pebbly clay 31.
T. Giese	7	SW	NE		26							
J. Franz	8	NE	NW		86		89					
H. Goering	10	NW			91		101				14	
H. Goering	10	SW	SW		90		118				14	
H. Meyer	12	NW	NE		235		253	740		504		
Eggert Puck	12	SE	NE		204		210	740		536	14	
A. LeBuhn	16	NE	NE	90							5	Yellow clay 20, sand 5, blue clay 50, gravel 5.
H. Wiese	19	NW	SW		78							
H. Schlichting	23	SE	NE		110		120				14	
Schoolhouse No. 3	19	NW			78	122	200				5	Yellow clay 20, sand 10, blue clay 48, white limestone 122.
Buffalo Township—												
E. James	3	SW			35		316				12	Limestone 160.
L. Daurer	8	NW	NW		50		270					
C. Rowan	10	SW			60							
Barnwick	16	SE	SE		20		144					

RECORD OF WELLS IN SCOTT COUNTY—CONTINUED.

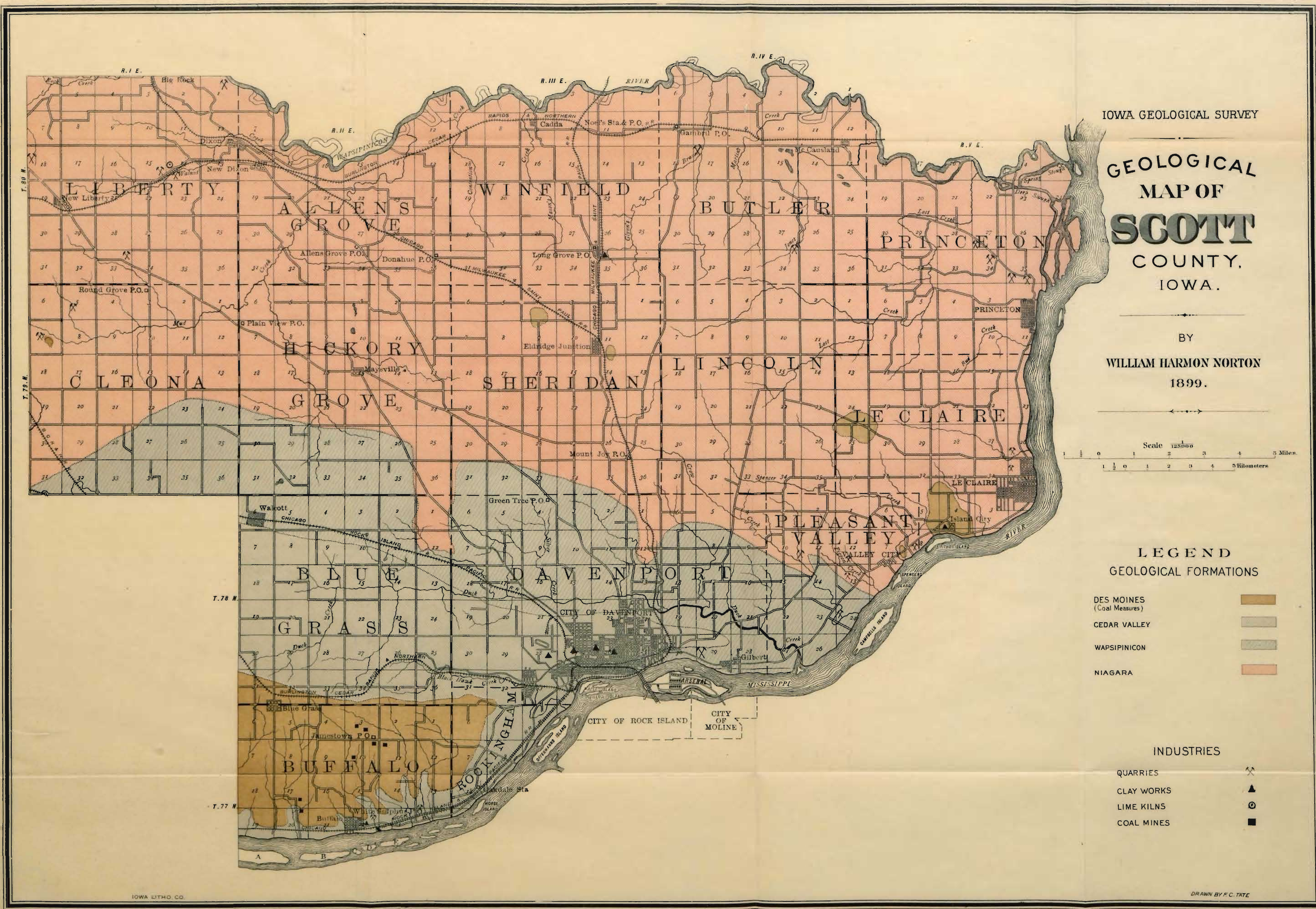
OWNER.	Section	Quarter.	Quarter.	Depth—rock not reached.	Depth to rock.	Depth in rock.	Total depth.	Curb A. T.	Bottom A. T.	Rock surface A. T.	Authority.	
F. Bell	18	NE			80		261				12	Limestone 161 feet.
J. Murray	10	NW			35		305				12	No coal, limestone 160.
Winfield Township—												
J. Ennis	11	SW	SW	70								All sand.
C. Gillian	7	SE	SE	150							8	Sand 20, hard, blue, pebbly clay 120, sand 5, gravel 5.
School No. 4	14	NW			125							
St. Ann's Church	14	SE	SW		64	36	100				9	Sand 15, yellow clay 10, blue clay, a little sand.
P. Jones	15	NW	NW		190			720		530		
School No. 3	16	NW	NW	94							8	Sand 70, blue clay 20, gravel 4.
N. Schallmeier	18	SW	SE	200							8	
N. Denklau	19	SW	NW		153		173				13	
A. Brownlee	26	NW	SE		220			725		505		
J. Robertson	27	NE	NE		120		121				8	Yellow clay 50, hard, blue, stony clay 70, sand and gravel thin.
J. Grill	30	SE	SE	115								
C. Preston	31	NE	SE		180							
J. Neil	35	SW	SW		225			780		555		
Hotel Long Grove	35	NW		54							8	Ends in gravel.
Sheridan Township—												
C. Clapp	2	SW	NE		122		128				9	
J. Lensch	2	SE	SE		114		118				8	
C. Meier	4	SW	SE		100		199				8	Yellow clay 25, old soil 10, blue clay 65, coal 2, shale 97.
J. Baustian	5	NE	SW		200		237	760		560	13	Shale 37 feet.
J. T. Cooper	5	SW	SW		140		145				12	Yellow and blue clay, gravel on rock.
S. Burmeister	6	NW	SE		120							
E. Rohwer	6	NE	SW		140							
L. Husted	7	SE	SW		166							
Eldridge	11	SW			127		135	7			6	Yellow clay less than 20, mostly blue clay, ends in limestone.
Eld. Creamery	14	NW	NE		180		201	780		600	1	
Chas. Erhsam	20	NW	NE		72			730		658		
J. L. Seaman	27	NW	SW		90						L	
H. Stoltenberg	28	NW	SE		100						L	
W. Hughes	33	NW	SE		170		180				14	
Claus Lamp	19	SW	SW		270		285	740		470	6	Mostly hard, blue clay.
Davenport Township— (Range 3, E.)												
Chas. Murray	1	SE	NE		105							
W. Untiedt	7	NE	SW	120							14	Ends in gravel.
School No. 2	7	NE		122							5	Yellow clay 30, sand 10, blue clay 80, gravel 2.
Capt. Stahr	7	NW	NW		160							
J. Carlin	10	SW	SE		115		140				14	
G. Conklin	11	SW	NW		90		106					
E. Daugherty	12	SW		212				700	488		14	
R. Clay	12	NE	SW	230				680	449			
M. Boyle	13	NW	SW		85		94				14	
*J. Armel					202		245				9	
*Dr. G. P. Maxwell					100		130				9	
†Schuetzen Park					160		240				14	
J. Hever	21	SE	SE		155		200				14	
Thos. Sindt	7	NW	NW		160		167				14	
Davenport Township— (Range 4, E.)												
I. Barr	4	SE	NW		100		150				13	
C. Van Evera	4	SW			90		115				14	
R. Schaefer	4	SW	SW		80		85				14	
J. Barnholdt	5	NW			88		98				14	
H. Wiese	6	NE			79		94				14	
J. Barr	7	NE	SW		142		157				13	
F. Thomas	9	NW	SW		150		163				14	
C. Carstens	17	SE	SW		120		138				14	
H. Woodford	18	NE	NW		176							
A. J. Partridge	18	NE	NE		90		106				14	

RECORD OF WELLS IN SCOTT COUNTY—CONTINUED.

OWNER.	Section.	Quarter.	Quarter.	Depth — rock not reached.	Depth to rock.	Depth in rock.	Total depth.	Curb A. T.	Bottom A. T.	Rock surface A. T.	Authority.	
I. Barr	18	NW			70		90				14	
J. Barr	18	SE	NE		58		65				14	
Wm. C. Schaefer	19	NE	SW		80		93				14	
J. L. McCullough	20	SW			90		160				14	
E. S. Kellog	18	NW	SE		90		105				14	
Butler Township—												
J. Henry	22	NE	SW		100						U	
J. Henry	22	NE	SE		62						U	
J. McCausland	23	NE		67							U	
	25				65						U	Sandstone at 65.
D. Holst	26	SE	NE	175				740	765		U	
E. Mueller	35	NW	NW		60						6	
Lincoln Township—												
D. Arp	2	SW	NW		120		130				6	Ends in limestone.
C. Schneckloth	7	SE	SE		140							
I. Barr	7	NE	NE		101		121				13	
J. H. Barr	22	NE	SW		190			740		550		
Thos. Criswell	23	NW	SW		160						13	
M. Jones	23	SE			120		150				15	
M. Thompson	27	NE	NE		175		182				14	
H. Schroeder	33	SW	SW		55		75	720		665	14	
M. Barr	26	SW	SW		86		116				14	
Benj. Criswell	23	NW			190						15	
Princeton Township—												
J. Carroll	30	NW	NE		60							
C. Fulmer	4	NW	NE		80						16	
C. Like	4	NE	SE		100						16	
O. Peaslee	9	SW	SW		169			720		551	16	
W. Florence	5	SW	SW		70		82	700		630		
Le Claire Township—												
J. Brown	17	SW	NE		100							
J. Wilson	21	SE	NW		100							
G. Leamer	25	NW	NE		210		381	740		530	14	Shale from 210-375, ends in limestone.
J. C. McGinnis	30	SE	NW		170		250				15	
W. H. McGinnis	30	SE	NE		120		150				15	
J. Stafford	36	SE	NW		150		246					
H. Stafford	36	NE	SW		100		121					
H. Whitson	25	SE	NE		120		15				15	
M. Miller	31	SW	NE		150						15	
M. Wilson	32	NE			60		150				15	
T. Taylor	32	NE			55		75				14	
H. Stone	32	SW			61						15	
J. Suiter	33	NW	SE		35						15	
J. McCaffry	4	NW			40						15	
A. Schurr	4	NW			50		78				12	Yellow clay 25, blue clay to rock, shale.
G. Hyde	36	SW	NW		80		100				15	Lime rock 20 feet.
Porter's Corners	35	NE	NE		175		305				13	Yellow clay 30, quicksand, blue till, 100 feet of shale, 30 feet of limestone.
(Rockingham)												
F. J. Shaeffer	5	NW			40		216				14	Shale from 40 to 206 feet.
Walnut Hill school	5	NE	NW		40		225				14	Shale from 40 to 206 feet.
J. A. Punt	5	NW	NE		30		186				14	Shale to 10 feet of bottom.
Fairview school	7	NE	SE				110				14	Shale and blue clay in alternate layers.

*City of Davenport, Gaines St.
†City of Davenport.
U Prof J. A. Udden, Rock Island.
L Mr. Frank Leverett, United States Geology Survey.
1 M. Crownwick, Dixon.
2 S Spitler, Bennett.
3 H. Voss, Durant.
4 J. P Buhrmeister, Plainview.
5 J. Strueben, Walcott.
6 C. Cook, Mt. Joy.
7 E. M. Buhrmeister, Eldridge.
8 H. Meyer, with Tieple Bros., Wilton.
9 Tieple Bros., Wilton.
10 M Burmeister, Donahue.
11 J. W Hoover, Wheatland.
12 H. Stoltenberg, with J. C. Buck, Davenport.
13 C. C. Buhrmeister, Davenport.
14 J. W. Buck, Davenport.
15 Stone & Clark, Le Claire.
16 M. L. Conrad.

Records for which no authority is named are given by the owner.


IOWA GEOLOGICAL SURVEY
GEOLOGICAL MAP OF SCOTT COUNTY, IOWA.
BY
WILLIAM HARMON NORTON
1899.
Scale 1/125000
5 Miles
5 Kilometers
LEGEND
GEOLOGICAL FORMATIONS
DES MOINES (Coal Measures)
CEDAR VALLEY
WAPSIPINICON
NIAGARA
INDUSTRIES
QUARRIES
CLAY WORKS
LIME KILNS
COAL MINES
LIBERTY
ALLENS GROVE
WINFIELD
BUTLER
PRINCETON
HICKORY GROVE
CLEONA
SHERIDAN
LINCOLN
LE CLAIRE
PLEASANT VALLEY
BLUE GRASS
DAVENPORT
BUFFALO
ROCKINGHAM
CITY OF DAVENPORT
CITY OF ROCK ISLAND
CITY OF MOLINE
MISSISSIPPI
RIVER
WAPSIPINICON
IOWA LITHO. CO.
DRAWN BY F.C. TATE

ARTESIAN WELLS

OF THE

BELLE PLAINE AREA.

BY

H. R. MOSNAT.

REPORT OF THE ARTESIAN WELLS OF THE BELLE PLAINE AREA.

BY H. R. MOSNAT.

INTRODUCTION.

About forty miles east of the geographical center of the state of Iowa, is an area of about 100 square miles occupying a portion of the valley of the Iowa river, and nearly all of the valley of Salt creek, a tributary of the river from the north. This area is apparently like the adjacent country. Its surface is the same—flood plains, valleys and rolling hills, as that of the surrounding territory. However, by drilling to a depth of 110 to 360 feet within this area, artesian wells to the number of about 135 have been struck. Non-flowing artesian wells were secured in the high, rolling land to the northeast of Belle Plaine, Benton county, Iowa, as early as 1882. Four years later a strong flow was struck in the city of Belle Plaine, and later in the same year, 1886, the famous "Jumbo" was allowed to break loose. Thus, for historical reasons, this has been called the Belle Plaine artesian area. The exploration of the basin has not altered the appropriateness of the name, as Belle Plaine is approximately in the center of the basin.

The general trend of the Belle Plaine artesian area is from northwest to southeast. The southwestern margin probably runs a short distance north of Gladstone, thence southeast through Chelsea. Continuing in the same general direction, the line runs to a point three and one-half miles south of Belle Plaine, where its course appears to change to almost due south, passing through Victor.

The northeastern margin runs in a southeasterly direction a short distance east of Elberon, passing about a mile east of Irving, and goes almost to Luzerne. Before reaching Luzerne it changes its course to due south, running to a point about three and one-half miles south of Luzerne, where the direction changes to due southeast, passing through Marengo.

In general, the width of the area is about six miles. About three and one-half miles southeast of Belle Plaine the width diminishes to half of that, and from this point it rapidly increases to twelve miles, which width it maintains as far south as the area has been explored. The field, as far as explored, extends from northwest to southeast, from Vining to Ladora, a distance of twenty miles, diagonally crossing the present valley of the Iowa river.

The wells are most numerous in the flood-plain of the Iowa river, and particularly in the Salt creek valley and westward of it. In all, there are 124 flowing and 11 non-flowing wells. In addition to these there are a few old wells, now filled up. The water supplying all of these wells comes from the same water-bearing vein or aquifer, making very apparent the reasonableness of Professor Norton' definition* of the word "artesian." The very case there supposed actually occurred to the previously flowing wells in the Belle Plaine area, when "Jumbo" broke loose; that is, the other wells ceased flowing and became "deep wells," "deep borings," etc. After "Jumbo" was controlled the wells which had stopped flowing began to flow again. In the present report the word "artesian" is used in the sense defined by Professor Norton: "a vertical

*"Artesian Wells of Iowa," Iowa Geological Survey, vol. VI, p. 124-6.

well in which water rises near to or above the surface by natural hydrostatic pressure, consequent upon certain structural conditions."

The Belle Plaine artesian area is one of the most important in glacial drift in Iowa. It contains about one-tenth of the whole number of artesian wells so far drilled in glacial drift in the state. In the accompanying lists on the map, and in the diagrams, Arabic numerals are used to designate artesian wells belonging to the Belle Plaine area; capital letters are used for artesian wells in rock and adjacent to the Belle Plaine area; Roman numerals are used for various non-flowing and weak-flowing artesian wells in rock and adjacent to the Belle Plaine area; small letters are used for various shallow artesian wells in drift, in or near the Belle Plaine area.

HISTORY OF THE BELLE PLAINE ARTESIAN AREA.

As remarked above, the Belle Plaine artesian area was discovered about 1882, in the elevated, rolling country two to four miles northeast of Belle Plaine. Numbers 1, 2, 3 and 46 on the map were the first wells drilled. The water in these wells rose to within twenty-five or fifty feet of the surface. These wells made first class deep wells, and nothing more was thought of it. They were wholly in blue clay, and so were easily drilled and not expensive. It was noticed that the water had a peculiar mineral taste, that it left a red sediment and stain and, after a time, it was observed that the water rapidly corroded iron pipe. No one took the trouble to have the water analyzed. The supply of water was inexhaustible and constant. Live stock liked the water after becoming accustomed to the taste. It, therefore, made a good water for stock, and was used for that purpose only, being pumped usually by windmills.

Hilton Bros., of Boston, needed an unlimited supply of water for their creamery at Belle Plaine. In April, 1886, a 2-inch well was drilled which proved a pleasant surprise. At a depth of 215 feet, after passing through blue clay, water was struck which rose from the well curb with a pressure of more than thirty-five pounds per square inch, or to a height of about seventy-seven feet from the surface. This well (No. 6) is located at the eastern edge of Belle Plaine. Immediately other wells were drilled. The flow secured varied with the elevation of the surface, the water in all the wells rising to the same head, about 915 feet A. T. This figure is fairly accurate. A well was drilled on top of a hill in the northern part of Belle Plaine, at an elevation of 918 feet A. T. This well (No. 4), of course, did not flow, but it was a much more reliable indicator of the head than the strong flowing wells. The head of water rose to within three feet of the surface, showing the head to be, at that time, 915 feet.

Shortly after the last mentioned well was completed, the most famous of all Iowa artesian wells was drilled. This well, for its brief day, attracted a popular notice almost as wide as the Charleston earthquake, which occurred about three days later, and with which the outburst of water from this well was connected by a romancing newspaper reporter.* Professor Chamberlin remarks that the only similitude of seismic disturbance, as the cause of this well, was in the moral faculties of said reporter. Renewed geyser activity in Yellowstone park, a seismic movement on the opposite hemisphere, the Charleston earthquake and this runaway well at Belle Plaine, were at once connected as factors in a common disturbance of the earth's crust. A relation between the first three may have been possible, but connecting the well with them was as ridiculous as many of the theories advanced as to the source of the water supply.

"The notoriety of 'Jumbo,' of Belle Plaine, was strictly that of a member of the criminal class, and began with his resistance to control, and lasted only until his final imprisonment."† The accounts of the well given in newspapers were

*Note by Professor Calvin in the "Report on the Charleston Earthquake," U. S. Geol. Survey, Ninth Ann. Rep., p. 443; and Professor Chamberlin's "The Artesian Well at Belle Plaine Iowa," Science, vol. VIII, p. 276, Sept. 24, 1886.

†Norton, "Artesian Wells in Iowa," Iowa Geol. Survey, vol. VI, p. 350.

in many instances most sensational, their extravagance "increasing according to the square of the distance" from Belle Plaine. European papers published accounts of the water spouting hundreds of feet into the air, with a roar that could be heard for miles, and even pictured people being rescued by boats from the third and fourth stories of houses!

During the summer of 1886 six flowing wells had been drilled in drift at Belle Plaine; numbers 4, 5, 6, 7 and 10 on the map. The record of the strata of the seventh well, number 9, "Jumbo," as given by Professor Chamberlin, and quoted by Call and Norton, is as follows:

	THICKNESS.	DEPTH
6. Soil with humus	4	4
5. Sandy clay	12	16
4. Gravel and sand	8	24
3. Yellow clay	13	37
2. Blue clay, with layers or pockets of sand and gravel	172	209
1. Gravel and sand, water bearing, at		209

As Professor Chamberlin remarks, the record lacks detail, and possibly precision. But inaccurate as the record no doubt is, it is the most careful that has been kept, and satisfactorily shows the geological structure which will be considered under that heading. This well is a typical well on low ground. The elevation of the curb is 811 feet A. T. A local history of the well is entitled: "A Complete History of the Jumbo Artesian Well of Belle Plaine, Iowa, Known as the Eighth Wonder of the World," second edition, by A. C. Huston.

Professor Norton's account of the history of "Jumbo" is accurate, and is repeated below with some additional facts.

"The seventh well, 'Jumbo,' was drilled on lower ground than any of the others, and reached the water-bearing stratum of sand and gravel at 193 feet." (A. T. 811.)

"The beginning of the trouble lay in the fact that the driller attempted to use the force of the flow in reaming out the two-inch bore, which he had put down for want of a larger drill, to three inches, the dimension specified in the contract. This task the water speedily accomplished in the unindurated clays and sands, but not stopping there went on and soon enlarged the bore to over three feet in diameter." When the driller saw the result of his inexcusable carelessness, which result he ought to have foreseen, he hastily decamped and was not heard of until the popular excitement had subsided.

The force of the water was sufficient to throw out two-bushel sacks filled with sand. "Through this three-foot shaft the water boiled up in a fountain five feet in height"—see illustration—"the press reports giving several hundred feet as the height of this fountain, were exaggerated—flooding streets and lawns, and covering them with sand. It was estimated that from 500 to 1,000 carloads of sand were discharged from the well. The quantity was certainly so great that only with the greatest effort could the ditches be kept open to carry off the water. Gravel and small pebbles of northern drift, representing a great variety of northern rocks, were thrown out."

The writer has a flint bowlder weighing two and one-fourth pounds which was thrown out by "Jumbo." There may have been others even larger. It is not necessary to suppose that these larger stones came from the bottom of the well, as bowlders are occasionally encountered in drilling through the till sheets. Pieces of fossil wood, some of them two or three feet long and four or five inches thick, were thrown out. These, no doubt, came from the forest bed which represents the Aftonian interglacial stage between the Kansan and sub-Aftonian till sheets. Small boys, of which the writer was one, put fossil wood, pebbles and sand into bottles and sold them to visitors to the well during the few days of its fame.

"The maximum flow of water was variously estimated at 5,000,000 to 9,000,000 gallons per day, 30,000 to 50,000 gallons per minute. Two weeks after the well was drilled Professor Chamberlin, of The University of Chicago, calculated its discharge at 3,000,000 gallons per day; 2,000 gallons per minute.

The enormous flow rapidly drew down the head until the other wells ceased flowing.

"The attempt to case and control the well continued from August 26, 1886, the date when the water was struck, to October 6, 1887, when the task was successfully accomplished. During this time the well, 193 feet deep, devoured, as the local historian recounts, 163 feet of 18-inch pipe, 77 feet of 16-inch pipe, 60 feet of 5-inch pipe, an iron cone 3 feet in diameter and 24 feet long, 40 carloads of stone, 130 barrels of cement, and an inestimable amount of sand and clay."—*Norton.*

After "Jumbo" broke away, the head of water in the the other wells fell rapidly until those on Main street—elevation 848 and 846 feet A. T.—ceased to flow on August 30th; 4 days after "Jumbo" began his escapade. The head diminished 67 feet in four days, an average of almost 17 feet per day. By September 7th the water had dropped to 838.5 feet A. T., a fall of 1.3 feet per day. From that time until September 20th the head diminished at an average of 3 inches per day, or to 835 feet A. T. The head remained at this point for about 3 days — 24 feet above "Jumbo"— and then began to rise until, on November 22d, it was within 5 inches of the surface at Main street, or an average rise of .6 foot per day. The well was then closed for the winter. The head continued to rise until about the present level was reached. About 1890 well No. 88 was allowed to break away by careless drilling, and a second "Jumbo" occurred. This one did not act just like the first one. Instead of coming out in one stream, the water flowed from every gopher hole over several acres. It probably spread out in an underlying bed of sand. This well again drew down the head. Little was done to shut it off. It was allowed to run until it had choked itself up, and all the other wells had again ceased flowing. Within two or three years the head had risen to about what it is at present, 864 feet A. T., 51 feet below its original level. At present the flow is gradually growing weaker.

Up to 1890 about 50 flowing wells had been drilled. Now there are about 124 such wells. The owners of many of the wells are very careless and let them run much more than is necessary.

GEOLOGICAL STRUCTURE.

The record of strata passed through in drilling "Jumbo" has been given above. The well is a typical well on low ground. The record with the geological interpretation is as follows:

		THICKNESS.	DEPTH.	INTERPRETATION.
6.	Soil with humus	4	4	Recent.
5.	Sandy clay	12	16	Loess.
4.	Gravel and sand	8	24	Loess.
3.	Yellow clay	13	37	Weathered Kansan till, or loess.
2.	Blue clay, with layers or pockets of sand and gravel and occasional hard bowlders	172	209	Kansan till.
1.	(b) Leaves and wood of an old forest bed.			Aftonian interglacial stage.
	(a) Gravel and sand, water bearing, at		209	Aftonian interglacial stage.
0.	Pre-Kansan till.			

Stratum number 6 is composed of vegetable mould, soil, etc. It is of about maximum thickness in this well, as the well is one of those within the flood plain of the river. In the wells on higher ground this stratum is about two feet thick.

About three miles directly north of Belle Plaine runs the line which marks the southern limit of the Iowan drift. This line has been traced as far west as the western line of Johnson county, and has been located again at Toledo, but it has not been traced across Benton county and the eastern half of Tama. From the topography of the county it seems probable that the explored portion of the Belle Plaine area lies almost, if not quite, entirely outside of the margin marked by the Iowan ice, in which respect this field differs from other artesian areas in Iowa in which the wells penetrate only the glacial drift. But it is certain that the intake area is somewhere inside the margin of the Iowan drift sheet.

The margin of the Iowan ice sheet not being yet definitely known in the area under consideration, it is not possible to say whether any of the wells of the Belle Plaine area are within the moraine of the Iowan glacier. The Belle Plaine artesian area, as far as known, is of Kansan topography, except where modified by the valleys of the Iowa river and Salt creek.

The line of the Iowan ice probably coincides with a portion of the northeastern margin of the Belle Plaine area, shown on the map. The margin of the ice probably ran about two miles north of Luzerne, and thence followed the line of the margin of the Belle Plaine area running west. About a mile east of Irving the Iowan margin turns to the northwest and north and runs to a few miles north of Elberon, where it probably turns westward, passing several miles to the north of Vining, thence in a western and southerly direction, crossing the Belle Plaine area and running through Toledo, where it has been traced for a short distance. This hypothesis makes every well in the Belle Plaine area without the margin of the Iowan glacier. There is no reason to doubt that where the elevation is not too great, flowing wells in this aquifer will be found within the Iowan area. Many artesian wells are within the Wisconsin moraine in northern Iowa. Such wells are less common in the Iowan drift. Fifty to seventy-five miles to the northwest are numerous shallow flowing wells in glacial drift. These, however, are within the moraine of the Wisconsin ice sheet. It is not probable that the aquifer is the same as that in the Belle Plaine area.

Strata Nos. 5 and 4 belong to the loess. Stratum No. 3 may be loess, but it seems more likely that it is partly weathered Kansan, which was not differentiated from the loess. The loess deposits in the neighborhood of Belle Plaine are rather heavy, so a total thickness of twenty to thirty feet of loess, in its thick places, is not excessive. Stratum No. 2 varies with the altitude from about eighty-three feet in thickness in No. 40, to 322 feet in No. 29. This glacial till is the Kansan. It has the characteristic pockets or layers of sand and gravel, and occasional bowlders. At forty to fifty feet from the base of the till, leaves and sticks are often encountered, which are from the Aftonian interglacial stage, just below the Kansan, and have been mixed with the clay during the grinding-up process to which the till was subjected. The same phenomenon is well shown in the cut at Oelwein*, where wood from the Aftonian forest bed is found twenty feet above the base of the Kansan till.

Sometimes bowlders are encountered by the drill. With the light apparatus used it is almost impossible to go through these hard bowlders, and they are apt to be struck slantingly, which bends the pipe out of line and interferes with further drilling. Accordingly, when a bowlder is struck, it is usual to pull up the casing and drill another well near by. A move of four or five feet usually avoids the bowlder in the second drilling. It is cheaper to dig a new well than to drill through one of these hard bowlders.

Stratum No. 1 is the aquifer. It is of the Aftonian interglacial stage. In the Belle Plaine artesian area it is composed of—

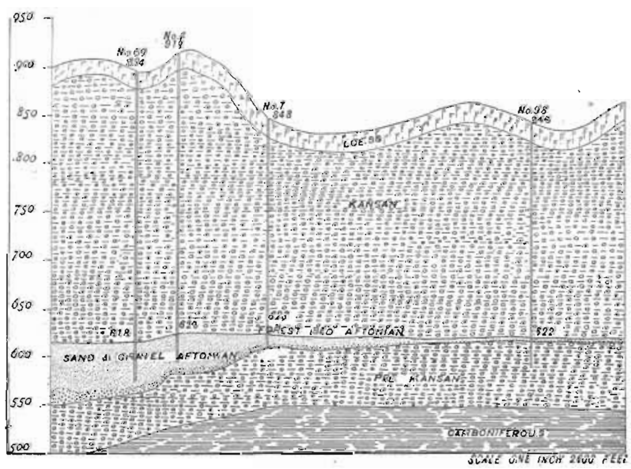


FIG. 53. Section showing variation in Aftonian gravels at Belle Plaine. Northwest to southeast.

(b) An old forest bed — mention of which is omitted from Chamberlin's record. The maximum thickness is about two feet. The wood appears to be from conifers.

*Proc. Iowa Acad. Sciences, vol. IV, pp. 54-69.

(*a*) Sand and gravel, forming the aquifer. This stratum varies from two feet in thickness, as in No. 93, to more than forty-six feet, as shown in Nos. 60 and 4. Again, at Ladora, the aquifer is thirty to forty feet in thickness. (See figures Nos. 53 and 54.)

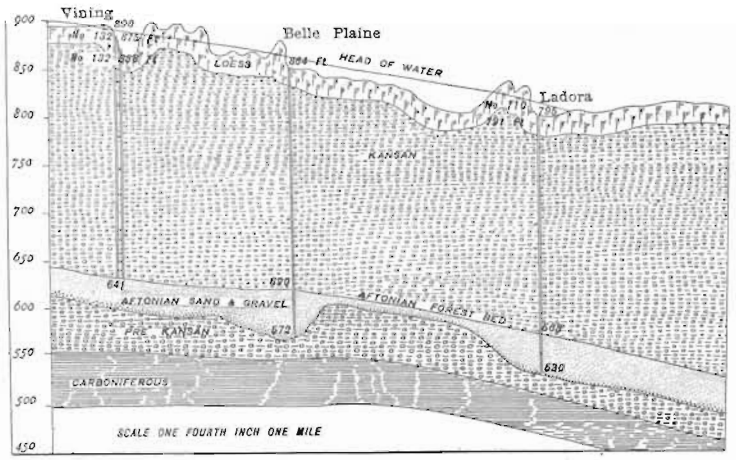


FIG. 54. Section northwest to southeast—Vining to Ladora.

At some places, as at Afton Junction, the gravel and sand is found above the forest bed. At Belle Plaine the gravel and sand is below the forest bed. At Afton Junction the gravel and sand may have been deposited by water flowing from the front of the advancing Kansan ice; at Belle Plaine the gravel and sand were probably laid down by streams attending the retreat of the pre-Kansan ice invasion. It may be asked how the great Kansan glacier passed over this unindurated deposit of gravel and sand instead of carrying it away. The answer is that the sand and gravel was full of water, which, upon the near approach of the glacier, was frozen. Thus the ice passed over the frozen sand and gravel without disturbing it any more than it would disturb hard rock.

The wells vary in depth according to surface elevation. The altitude of the aquifer is fairly constant. At Vining it is 641 feet A. T. At Belle Plaine, eight miles to the southeast, its elevation averages 620 feet A. T. At Ladora, eleven miles farther towards the southeast, its elevation is 565 feet A. T., a fall of 76 feet in 19 miles, or an average of 3.5 feet per mile. The elevation of the aquifer diminishes relatively faster toward the southeast. From Vining to Belle Plaine the average fall is 2.6 feet per mile; from Belle Plaine to Ladora, 5 feet per mile. The well diggers claim that they can tell within a few feet the depth at which the aquifer will be struck, provided they know the height of the point at which the well is to be bored. The upper surface of the aquifer is more regular than the base, showing that the gravel and sand were laid down on an uneven surface. The tendency, of course, was for the gravel to be deposited over the lowest places, leveling them up. For example, in number 7 the altitude of the base of the aquifer is 615 feet A. T., elevation of the surface is 620 feet A. T. In number 4, about 60 rods north, the base is less than 590 feet A. T., the surface is 615 feet A. T. In number 60, about 15 rods farther north, the base is less than 582 feet A. T., the surface is 618 feet A. T. In well number 98, which is about half a mile southeast of number 7, the elevation of the base of the aquifer is 620 feet A. T., the surface is 622 feet A. T. Thus within about three-quarters of a mile the base of the aquifer varies more than 38 feet, while the surface varies only 7 feet.

The aquifer consists of fine sand at the top, changing to gravel at the bottom in the thicker places. In number 6, where it is 5 feet 3 inches thick, there is a little gravel at the bottom. In number 98, where the aquifer is only 2 feet thick, there is no gravel; the whole thickness is sand. In number 4, 25 feet of sand were penetrated before encountering gravel. In number 60, 46 feet of sand were passed through before reaching the gravel. The thickness of the gravel at these points is unknown. At Ladora the drill penetrated 30 to 40 feet of sand before reaching the gravel. The whole thickness of the aquifer has not been penetrated in any of the thick places, so it is impossible to give its maximum thickness. It was found to be composed of 46 feet of sand in number 60, with gravel of unknown thickness below.

In drilling the wells the casing is kept full of water during the boring to prevent the sand from rushing up and filling up the pipe when the aquifer is penetrated, and preventing the water from flowing. Where this is not done it may take days to pump out the sand with a sand pump. In fact, it may be cheaper to dig a new well, and avoid the mistake. Several wells have become stopped up by sand. To prevent this a strainer is usually put at the bottom of the casing. Wherever possible it is seated in gravel. Where the vein is very thin, as in number 98, only fine sand is found, and the well drillers have trouble in seating the strainer.

The aquifer thins out toward the margins of the artesian area, causing wells near the margin to have a relatively weak pressure. It seems probable that to the northwest of Belle Plaine the aquifer is thicker, and contains more gravel than south and east of Belle Plaine. As in the first mentioned portion of the field, with the exception of wells near the margin of the area (as numbers 83 and 2), all the wells are normal in their flow. In the latter mentioned portion of the field there are two groups of wells where the head is abnormally weak. In numbers 83, 40, 41, 89 and 58 the weak flow is caused by the fact that the wells are near the margin of the area; but numbers 143, 142, 118, 152 are apparently well towards the center of the field. The explanation of their weak flow is considered later.

The dip of the aquifer to the southeast is about 3.5 feet per mile, which seems slight. From Chelsea to Marengo, eighteen miles in an air line, the Iowa river falls 150 feet, or eight feet per mile. But the aquifer was laid down under very different conditions from that of the flow of a river in a regular channel. It is also possible that there have been changes in level since it was laid down, which have reduced its dip. The limits of the aquifer are, of course, the same as the boundaries of the Belle Plaine artesian area, which are traced above. The opinion has been advanced that this extensive subterranean hydrographic basin is an immense preglacial river valley, now entirely filled up and obliterated. It must be remembered that the present drainage of this portion of the state has little or nothing in common with its preglacial drainage.*

Of the Belle Plaine artesian field, Call says that "there are indications which point toward the existence in this area, either, first, of a great preglacial valley which has become filled with morainic materials, or second, to the existence of a great fault." † Reference to figure 55 will show that no

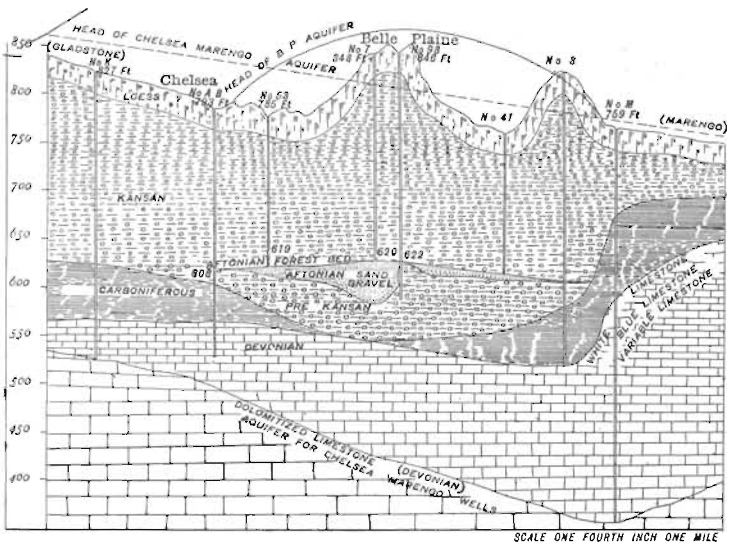


FIG. 55. Diagonal cross-section—Gladstone to Marengo.

such geological structure as a great fault need be supposed to explain the Belle Plaine area. Call suggests, further,‡ "that the water may be derived from the Cedar river," which he considers may be tapped below Waterloo, the water finding its way southward through a very wide and deep channel, from which it rises at Belle Plaine. This point will be brought up again in considering the source of the water.

*Call: "Iowa Artesian Wells," Weather and Crop Service, vol. III, March, 1893, p. 4.
†Ib., p. 4.
‡Ib , p. 7.

Professor Norton* "regards the Belle Plaine area as a normal artesian basin in glacial drift, and does not sympathize with any view of the derivation of its waters through a great fault or by the subterranean diversion of a river." With a better knowledge of the area it seems conclusive that the artesian basin occupies a preglacial river valley, now completely filled up and obliterated.

There is positive evidence of a glacial till below the aquifer. In one boring, well No. 98, eighteen feet of blue clay were penetrated below the aquifer. It is not known how much thicker this lower till may be. In well No. III the elevation will not explain the 240 feet of drift there found. To the west, in Nos. 41, 40, 89, the glacial till is but eighty to 120 feet in thickness; to the east are wells, Nos. M and L, with only eighty feet of blue clay; to the north is No. II, with about the same thickness of drift. It is possible that No's. I, II, III, and No. C, penetrate the same aquifer, the white Devonian limestone just below the Carboniferous shale. The altitude of No. II is too great for a flow, and it seems that the well should be deeper, but it may lie more distant from the margin of the Belle Plaine basin than Nos. I and II, and the conditions in it may be similar to those at Marengo. (See figure 56.) No. III is included in the Belle Plaine field, because of the great thickness of the drift there shown. The record of well No. III is very brief: "305 feet deep, last fifty feet in shale." The elevation is such that the Belle Plaine vein would not flow, and it is very likely that the Belle Plaine aquifer was penetrated without its being noticed. The well was drilled in 1886, or about the time the Belle Plaine flow was struck at

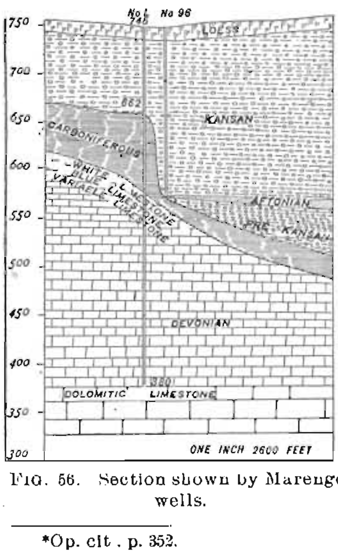


FIG. 56. Section shown by Marengo wells.

*Op. cit. p. 352.

Belle Plaine. It was not then known that the latter area was so extensive and the well digger was not expecting to encounter the Belle Plaine aquifer at Marengo. The head of the Belle Plaine aquifer would, even at that time, have been a few feet below the surface, and it is probable that the well digger did not notice the vein, if it was struck.

Number III shows 240 feet of drift, which seems excessive for this point. About four miles northward, within the Belle Plaine field, are several wells at a greater elevation of curb, which show only 20 to 230 feet of drift above the aquifer, which is perfectly normal, considering the elevation. This well shows an excess of thirty-five feet of blue clay. The explanation seems to be given by well number 98, where the drill was stopped in blue clay, eighteen feet *below* the Belle Plaine aquifer, in a glacial till of sub-Aftonian or pre-Kansan age. Number III gives some not very satisfactory evidence as to the probable thickness of this lowest glacial till, which here appears to be about thirty-five feet.

The pre-Kansan drift sheet has been discussed by Mr. Bain,* who remarks that the pre-Kansan shows evidences of erosion. The inequalities of the base of the Aftonian gravels at Belle Plaine point to an irregular pre-Kansan surface. If the gravels were laid down during the retreat of the pre-Kansan ice, by streams produced by the melting ice, there could have been but little erosion of the surface on which the gravels were spread. It is not necessary, however, to suppose that the upper surface of the till, as left by the ice, was perfectly level.

Over the territory of the Belle Plaine artesian area the evidence of a depression in the surface upon which the Aftonian rests is that in the borings, even when not much beyond the margin of the Belle Plaine area, much less glacial till is penetrated than in the wells within the Belle Plaine area. Number I penetrates a few feet of shale and has a total depth of only 185 feet, while neighboring borings penetrating the

*"The Aftonian and Pre-Kansan Deposits in Southwestern Iowa." Proc. Iowa Academy of Sciences, vol. V, p. 37. 1898.

Belle Plaine aquifer, with a lower altitude of curb, show thirty-four to forty feet more depth, though passing through only a portion of the aquifer. Number 32, which is about a mile southward and west, has a depth of 220 feet, while the altitude is less by perhaps twenty feet. Numbers 80, 81, 82 show the same fact. The same condition of things towards the west and northwest is proved by numbers 83, 84. About six miles towards the southeast is the next boring, a short distance outside the Belle Plaine area. The curb of number II has an elevation of about 850 feet A. T., and, although the boring is only 100 feet deep, a few feet of shale were penetrated, making it probable that the margin of the Belle Plaine area is at some distance. The thickness of the glacial till at this point is about eighty feet. Two or three miles to the west are borings, partly penetrating the Belle Plaine aquifer, where 80 to 120 feet of till is shown; the altitude being 770 to 810 feet A. T., as wells numbers 40, 41, 89 show.

About two miles farther south is number III, having an elevation of about 830 feet A. T. Like numbers I and C, the flow is weak. There is no strong flow from this vein, which is in the white Devonian limestone, just below the Carboniferous shale. Proceeding eastward, numbers M and L show only forty-five feet of glacial till before encountering shale. At Marengo number 96 is but a few rods south of number L, but has about 100 feet more of glacial till. Along the entire line traced there is within the Belle Plaine area a greater thickness of glacial till than outside that area. At Marengo the excess is about 100 feet within a few rods; in other places the change is not known to be as sudden or extensive. A corresponding relation of till and shale can be shown along the western margin of the Belle Plaine area.

The wells in Richland and Otter Creek townships (numbers F, G, H, I, J, K) vary from 250 to 320 feet in depth, with an average altitude of 827 feet A. T., and about 163 feet of glacial till above 80 or 100 feet of Carboniferous shale and a few feet of Devonian limestone and dolomite. Number 29 has an elevation of about 975 feet A. T., and 323 feet of Kansan till, making the upper surface of the aquifer about twelve feet below the base of the glacial till one or two miles westward. As has been remarked, the aquifer appears to be thick in this portion of the field. Farther southeast, at Chelsea, two wells, numbers A and B, have been drilled into the same aquifer as F, G, H, I, J, K, L and M. In these two borings glacial till to the thickness of 163 feet was penetrated. A very weak vein of water was struck just above the shale. This vein flowed a stream about the size of a straw. The well drillers believe that this is the Belle Plaine vein. This is not probable, however, because its depth is too great. Below the shale, which is here only thirty feet thick, a very strong flow was struck in number A. Number B is a weak flow, because it was never well opened up into the aquifer. In A it seemed that a fissure was penetrated. The drill dropped several inches. The altitude of the curb of A and B is 793 feet A. T. Number 53, two miles eastward, has an altitude of 785, and it penetrates 123 feet of Kansan till. The base of the till is 619 feet A. T.; in numbers A and B the base of the till is 608 feet A. T., or eleven feet lower than in number 53, which is a typical well of the locality in this respect. This is probably due to gravel not being deposited at Chelsea, the Kansan till lying directly above the pre-Kansan at that point. Wells V, VI, VIII have an elevation of about 838 feet A. T. They show about thirty feet of shale, above limestone, in which the aquifer occurs. These wells show about sixty feet of till, its base being about 740 feet A. T. In numbers IX and XII no shale is reported. The drill passed directly from the till to Devonian limestone. The elevation of these wells is about 830 feet A. T. The base of the till is about 620 feet A. T. The elevation of number 31, which is a mile or two miles north and west, is 770 feet A. T. The base of the till has an altitude of 615 feet A. T. From number IX the line of the western limit of the Belle Plaine aquifer can be no farther traced until it appears again at Victor, which is as far south as the wells have as yet been drilled. The flow here becomes too weak from friction to flow strongly.

It is unnecessary to believe that this great trough is the result of a great fault, or a broad syncline. An obliterated river valley is the most natural and reasonable explanation. The variation in the thickness of the shale and the limestone point towards that conclusion, and all the known facts are perfectly consistent with it and with no other.

This increased thickness of the drift means that the altitude of the floor upon which it was laid down was lower than the surrounding land. That floor is the Aftonian gravels. It has already been shown that these gravels are laid down on an uneven surface of glacial till. It is reasonable to suppose that the streams produced by the melting of the ice during the advance of the Kansan followed, in a measure at least, the pre-existing river courses. The pre-Kansan till sheet, as has been noted, appears to be thin; at any rate it was not thick enough to fill the depression. The condition of the valley at the close of pre-Kansan was probably similar to that of the interglacial valley at Mason City, which belongs to the interval between the Kansan and Iowan ice invasions,* where the Iowan till was not sufficient to fill the valley. The rocky bluffs on either side still rise to a height of forty feet. The valley at Belle Plaine was much wider, averaging about six miles, while the depth is at present unknown.

Probably the valley was first a great preglacial river valley cut in the Devonian. The stream was revived after the Carboniferous, and was afterwards partially filled up by the pre-Kansan glacial till. Then the Aftonian forest grew, and possibly a river again occupied the region. Finally the great invasion of the Kansan ice completely filled up and obliterated the river valley, blocking it with till, through which an entirely new and distinct valley has been cut by the Iowa river. This present river valley obliquely crosses the old valley; their coincidence is wholly accidental.

*Iowa Geol. Survey, vol. VII, p. 125.

A letter from Professor Beyer informs the writer that a thesis by "Mr. Leverett gives records of certain wells in Story county which appear to indicate depressed areas in the old surface, and suggests that these depressions may be one and the same." Mr. Call† takes this as evidence of a preglacial river valley. If there is a preglacial river valley there it does not seem likely that it is the same as that found in the Belle Plaine area. Shallow flowing wells are very common within the territory covered by the Wisconsin glacier, and similar preglacial drift-filled valleys are not uncommon. Flowing wells in glacial till are much less common in the region occupied superficially by the Iowan drift, and the Belle Plaine area is so far the only one in Iowa known to be outside the margin of the Iowan ice. To this exception must be added the small area in Honey Creek township and mentioned below.

Wells numbers dd, ee, ff, gg and hh—the first two of which flow five feet—form a local artesian area, explained by local conditions. It is remarkable in being wholly out of the Iowan drift—and of course the Wisconsin as well—both as to basin and intake area. The source is probably in the elevation to the south. The area is purely local, and probably does not extend over an area of more than three or four square miles.

The non-flowing wells to the southwest of the Belle Plaine area are of interest in showing that the general dip of the country rock is towards the southwest. This is the normal dip for this portion of the state. The wells outside the Belle Plaine area, at and near Chelsea and Marengo, show that below the pre-Aftonian glacial till is thirty to eighty feet of Carboniferous shale. Just below this shale weak flows were found in numbers I, III, C and XII, probably in Devonian limestone. Below this shale is six to twelve feet of white Devonian limestone, then twelve to fifteen feet of blue limestone, also Devonian, then a few feet to 250 feet of variable stone, described as gray, pink, brown, etc. This last is also

†Op cit, March, 1892, p. 12.

Devonian. Norton* states that the Devonian "probably somewhat exceeds 300 feet immediately west of its outcrop in central Iowa." Wells numbers L, M would seem to verify the statement. The Chelsea group appears to contradict it. The water comes from a so-called "white sandstone." It is hard to explain the occurrence of sandstone at this elevation and in this section of the state. It is most likely a granular dolomite which is broken up by the drill, giving it the appearance of sandstone. It is probable that it is the dolomitic phase which changes, and not the thickness of stratum. In several of the Chelsea wells the flow appears to be found in a crevice in rock. Crevices are characteristic of dolomite. A few of the Chelsea wells, as number B, do not flow strongly. "Shooting" these weak-flowing wells with nitroglycerin, as gas wells are shot, might increase their flow by opening up crevices in the rock, thus giving less impeded channels for the water. The head from this aquifer conforms to Professor Norton's map, showing isopiestic lines for head above sea level of water in Iowa artesian wells not in drift.† The head at Chelsea is about 860 feet A. T.; a little stronger than might be expected. At Marengo the head is about 750 feet A. T.; not quite as much as it theoretically should be. The flow is reported as sixty gallons per hour, which would indicate a head of only a few inches. A head of one foot, from a three-inch pipe, will flow 4.44 gallons per second. The flow of this well would probably be increased by "shooting."

Belle Plaine is one of the few cities of more than 4,000 population in Iowa which have no system of waterworks. By drilling to a depth of about 450 feet a moderate artesian flow would be obtained on low ground. But the water would be but little better than the Belle Plaine vein, as the analysis of the Marengo well shows. At a depth of about 1,300 feet, however, a moderate flow of excellent water will be found in the Saint Peter sandstone.

*Artesian Wells of Iowa, Iowa Geological Survey, vol. VI, p. 148.
†Op. cit., Plate viii.

THE FLOW OF WATER FROM THE BELLE PLAINE AREA.

The phenomonal flow of "Jumbo" has already been mentioned. The average head of the 124 flowing wells is 38 feet, that figure being the result of the sum of heads divided by 124. This is the head from the curb, or surface of the ground. A head of 38 feet equals a pressure of almost 17 pounds per square inch.

The velocity of flow from curb, in feet per second may be represented by v. According to the well known formula for the flow of water from an orifice, v equals the square root of $2\ gh$, where g equals the acceleration due to gravity; or 32.16 feet, and where h equals the head in feet, in this case 38. The square root of $2\ g$, or 2 times 32.16 is about 8.02 and the square root of 38 is about 6.15.; 6.15 times 8.02 equals 49.32, the velocity of the flow in feet per second. This does not take friction into account. The solid contents of 1 foot length of a 3-inch pipe equals .3672; 49.32 times by .3672 equals 18.11 gallons theoretical flow per second; 1,086.6 gallons per minute; 65,196 gallons per hour, or 1,564,704 gallons per day.

The wells are nearly always shut off to about 15 gallons per minute. As nearly as can be determined that is the average actual flow per well. This gives a total flow from the whole aquifer of 1,860 gallons per minute; 111,600 gallons per hour; 2,678,400 gallons per day; 977,616,000 gallons per year, and in the twelve years since the wells have been discovered the total amount of flow has been about 11,731,392,000 gallons. The two periods during which the water flowed little, are more than compensated for by the excessive flows causing those diminutions. The total amount of water is equal to about two-thirds the average monthly discharge of the Wisconsin river.*

This water comes from the rainfall somewhere to the northwest of Belle Plaine, probably not more than fifteen to twenty-five miles distant.

*Greenleaf, "Report on Water Power of the Mississippi River," p. 20, vol. XVII, Tenth Census U. S.

The rainfall in this portion of the state is slightly below the average. The average rainfall for Iowa is 34.88 inches per year. The early records show a higher average but this is probably due to the fact that the earlier observers were stationed at points since proven to have more than the normal rainfall for the state.

It would seem that thirty inches per year is a conservative estimate for the locality under consideration. Of this amount it may safely be assumed that one-fourth finds its way to the aquifer. Professor Norton* quotes DeRance's estimate that one inch of rainfall per year equals a daily average of 40,000 gallons per square mile. One-fourth of this, or 10,000 times 30=300,000 gallons per day per square mile—640 acres—reaching the aquifer. The intake area in square miles equals the flow per day divided by 300,000 gallons, the estimated daily intake; 2,678,400 divided by 300,000 equals 9, nearly. The supply area, then, need not be more than about nine square miles in extent. Professor Chamberlin made an estimate that the area of intake "need not exceed 400 acres in extent." His estimate was based upon "a discharge of 5,000,000 gallons lowering the head five inches per day, and taking no account of inflow — the reservoir indicated has a clear surface of less than forty acres. A mixture of sand and gravel may easily contain one-fourth its volume in water, as may be shown by experiment; but assuming one-tenth, the upper stratum need not exceed 400 acres in extent." The total normal flow is a better basis for calculation than "Jumbo's" abnormal flow, as the former more nearly shows the real amount of water supplied to the aquifer. Professor Carpenter's table of velocity of underground waters, given below, shows that the flow of underground water is very much slower than it has been supposed. The apparently rapid drawing off of the head after "Jumbo" broke loose, was due to the draining of the aquifer locally, and its inability to supply water fast enough on account of friction, rather than

*Op. cit. p. 153.

to drawing off the head, over the entire basin. The promptness with which the head began to rise — only about two months after Jumbo broke loose, and while still uncontrolled, appears to confirm this opinion. The head has lowered slightly, for the last four or five years, showing that the maximum number of wells has about been reached, and that many more wells, or letting those now drilled flow an unnecessary quantity of water, will reduce the head, injure all the wells in the area, and cause the wells on higher ground to cease flowing.

Besides the amount of water discharged from the runaway wells, thousands of gallons have been wasted by letting the wells run more than necessary. This has not yet become serious enough greatly to injure the wells. The deep wells drilled before Jumbo have since been useless, the water being too deep to be pumped easily.

Call mentions a well (No. 28), in Iowa county, range 80 N., 12 W., section 12, with a flow of 1,500 gallons per hour. No other data are given. The location puts the well near Ladora. The writer has not heard of an artesian well near Ladora dug before 1891. The flow is about correct for the Belle Plaine vein. On his map of artesian wells in Iowa, Call locates a well (No. 108) about fifty miles west and north of the Belle Plaine area — the nearest in that direction. But this well is omitted from the continuation of the list of wells.*

The flow from the wells is not apparently affected by the rainfall. This is no doubt due to the slow movement of water in the aquifer. The head does vary, but not more than a few inches. It is difficult to keep an accurate record of the variation of the head. A decrease may be due to over draft instead of diminished head; or it may be in the individual well, so that the sources of error are too numerous to be guarded against, except in a very general way. Water flows much more readily through gravel than through sand, and where the aquifer is gravel below and sand above, it may be assumed

*Call, Op. cit., p. 19, March, 1892.

that the water flowing through the gravel rises to reinforce that in the sand above.

In the Belle Plaine artesian area, the irregularities of the aquifer account for certain irregularities of flow. At the edges, where the flow diminishes and the head of water becomes lower with unusual rapidity, as Nos. 58, 83 and 41, for instance, the aquifer is probably a thin vein of fine sand, with no underlying bed of coarse gravel near by. Probably a similar condition obtains at Marengo in No. 96. A group of wells towards the southern portion of the field, wells Nos. 143, 142, 118, 152, ought to have a head of about thirty-five feet, instead of six feet. The same thing occurs in a number of other wells in the southern portion of the field, Nos. 40, 41, 89. In isolated wells of abnormally weak head, the weakness may be due to the well being not properly drilled, but in the group of four mentioned, Nos. 143, 142, 118, 152, which average about a quarter of a mile apart, improper drilling will not explain the diminished head. These wells are not so close together as to interfere with one another's flow, and they are ranged *across* the aquifer about at right angles to it. If these wells were ranged in a line *parallel* to the trend of the aquifer the case would be very different. Elevations being *equivalent*, in that case the well nearest the source of water would rob those more distant. The well nearest the source of water would flow with normal pressure, while the more distant wells would flow with a pressure less than normal. These wells are not near enough together to affect one another's flow. Improper drilling will not explain a *group* of wells acting in this way, so it seems reasonable to believe that their peculiar behavior is due to something in the source of supply. There is no doubt that the water comes from the Belle Plaine vein. It appears reasonable to ascribe the diminished flow to some change in the character of the aquifer. The aquifer is changeable in thickness, varying from two feet to more than forty-six feet in thickness, and that within less than a mile. It is changeable in character also; varying from coarse gravel at the bottom in its thick places, to fine sand at the top. Suppose that the aquifer here is two feet of fine sand as in No. 98, and that it persists as such for a half mile to the northward; reference to the table will make it apparent that this state of things would easily account for the diminished flow and head.

The narrowing of the aquifer to about three miles, two miles to the northward towards the source of supply, probably diminishes the amount of water which flows into the portion of the field to the south and east of the constricted point. If this constriction affects any, it affects all the wells to the south and east of it, and influences them all alike. This may partly account for the fact that elevation of head diminishes faster proportionately, from Belle Plaine to Ladora, than from Vining to Belle Plaine. (See diagram No. 3.)

As to the part played by friction in the flow of underground water, Professor Carpenter of the Colorado experiment station has made interesting observations on the seepage or return waters from irrigation, from which he has prepared the following table.

TABLE FOR FINDING APPROXIMATE VELOCITY OF FLOW OF WATER THROUGH SOILS. BY PROF. L. G. CARPENTER:*

Value of "k" in formula:

$$\text{Velocity (in feet)} = k \text{ times } \frac{\text{fall (in feet).}}{\text{distance (in feet).}}$$

KIND OF MATERIAL.	Size of grains in inches.	Voids—proportion of.	VALUE OF K TO GIVE VELOCITY IN FEET.			
			Per second.	Per hour.	Per day.	Per year.
Minute gravel	.08	0.41	.024	86.47	2075.0	757.520
Coarse sand	......	0.38	.0026	9.33	224.0	81,730
Fine sand	.008	0.35	.00047	1.69	40.5	14,777
Sandy soil	......	0.30	.00022	.79	18.9	6,897
Sandy clay	......	0.25	.00012	.42	10.2	3,725
Clay	......	0.20	.00003	.12	2.8	1,035
	......	......	.00008	.295	7.1	2,587

*Bulletin No. 33 on Seepage Waters, of the Colorado experiment station, Fort Collins, Col., January, 1896, p. 47.

Illustration of use of Table: What distance will water pass through coarse sand in a year, with fall of fifty feet per mile?

Here, fall divided by the distance is 50 divided by 5,280, or 1–106; close enough, considering the approximation in the data, to call 1–100. If the sand averages 1–10-inch in diameter, without finer particles, it might be classed as minute gravel. Then from the table, "k," for velocity per year, is 757,520, and distance is 757,520 times 1–100, or 7,575 feet, or about 1½ miles.

If in coarse sand, same fall, distance in a year is 81,730 times 1–100 equals 817 feet. If movement is straight downward, the fall may be the same as the distance.

By this table, with a fall of 3.5 feet per mile, as in the Belle Plaine aquifer, in coarse sand, the water has a velocity of about 5.70 feet per year; in minute gravel, 53 feet per year. But in places where the vein is thick there is coarse gravel below, much coarser, indeed, than .08 of an inch in diameter. The largest grains are as much as .5-inch in diameter, and perhaps larger. In the coarse gravel the water moves with comparative freedom, the velocity may be as much as one mile per year. Professor Carpenter observes: "When the passage takes place through the interstices of the soil the movement" (of underground water) "is very slow, much slower than is ordinarily supposed by those first encountering the subject. It is faster as the material is coarser. Where there are perceptible channels the movement may be relatively rapid."*

Referring to the table for finding approximate velocity of flow of water it is curious to note that, calculating that the water in the aquifer flows one mile per year, it would take eight years for water to flow from Vining to Belle Plaine, in a *direct line*, and nineteen years for water to flow from Vining to Ladora; seven years longer than the time since the wells were discovered! Or it will be 1905 before water which was

*"Bulletin Colorado Experiment Station," No. 33, p. 4.

at Vining when Jumbo was struck in August, 1886, will flow from the wells at Ladora. If the Ladora wells about that time show an otherwise unaccountable decrease, it may be taken as a verification if the above. However, the effect of the drain may be minimized by (1) the constriction of the area southeast of Belle Plaine, (2) the apparent thinning out of the aquifer southwest of Koszta, and (3) the storage capacity of the thirty-foot vein at Ladora. The velocities given in the above table very graphically show (1) the vast importance of *friction* in the aquifer and (2) the variation produced by changes in the character of the latter.

The head of the Belle Plaine aquifer at Belle Plaine was 915 feet A. T. when first discovered. At present the head is 864 feet A. T. at the same point.

THE SOURCE OF THE WATER.

As has been mentioned above, the intake ground or catchment basin, from the general trend of the Belle Plaine area, appears to be towards the northwest. It is at whatever place or places, at present unknown, erosion of the glacial tills has exposed the Aftonian gravels. This locality need not be very far away. It may be near Wolf creek, in Tama county, but at present so little is known about the geology of this portion of the state that nothing definite can be said. The area of intake is not in the immediate vicinity to the north of Belle Plaine, as wells in the same aquifer have been drilled at Vining, eight miles to the northwest. The intake area is possibly in that direction, five or ten miles beyond Vining.

Professor Chamberlin says: "It is not, therefore, necessary to suppose any unusual subterranean source, either in area or kind, nor is it necessary to suppose a distant origin. The head is not greater than could be supplied by the country adjacent on the north, which is the probable supply ground. It is simply a flowing drift well, run rampant for want of control. It has its phenomenal feature in its magnitude, and its lesson in its expensive and destructive career through injudicious handling."*

When Jumbo was struck some persons thought the aquifer was a solid vein of water, and were fearful lest this water escaping, the ground would cave in! "The well was supposed by many to tap an aqueduct leading from some large and distant body of water, but with such vagaries the reader will have little patience."† Some connected the lowering of level in certain lakes in northern Iowa, particularly Storm lake, with these wells. True, the lakes have lowered, but the wells have been in no way related to that phenomena.

"The life history of a lake, the conditions of its existence, show that it cannot be the reservoir of artesian water. If the depression which the lake occupies is due to secular rock decay, residuary clays, the produce of such decay, may cover the bottom with an impervious mantle. Though the depression may be due to other causes, it becomes an area of sedimentation on account of its relatively low relief. The floor is built up of layers which include, if they do not consist of, water-tight clays. Nor do lake beaches of sand, or sandy bottoms, afford subterranean outlet. Even if clayey layers do not occur immediately beneath, yet the pressure of the ground water from the higher levels of the surrounding land will usually prevent leakage. Such sandy layers thus become the conduits of sublacustrine springs, and replenish instead of deplete the waters of the lake. For reasons much the same it is not to be supposed that rivers contribute to artesian supply, except under special circumstances."‡ Mr. Call§ believed that the Cedar river was tapped below Waterloo, and the water conducted by a wide and deep channel to Belle Plaine. If this were true the volume of the Cedar should diminish below that point. The writer has not found any evi-

*Science, vol. VIII, p. 276.
†Norton, op. cit., p. 352.
‡Norton, p. 159. See, also, Chamberlin, "Requisite and Qualifying Conditions of Artesian Wells." Fifth Ann. Rept. U. S. Geol. Surv., p. 132. (1885.)
§Iowa Weather and Crop Monthly, March, 1892, p. 7.

dence confirming this. Mr. Call suggests, also, that there may be "at least two, and possibly three, water-bearing strata, one of which is coincident with the forest bed of Iowa." There is, however, only one aquifer penetrated in the Belle Plaine wells. "Certain it is," says he, "that some unusual and abundant water supply prevails in that section. The rainfall is not above the mean of the state, and no other subterranean source seems probable." These arguments have been sufficiently refuted above.

CHEMISTRY OF THE WATER.

ANALYSIS OF THE BELLE PLAINE ARTESIAN WATER.

Silica	1.6
Bicarbonate of soda	....
Alumina	Traces
Sulphate of lime	1427.8
Sulphate of magnesia	561.0
Carbonate of magnesia	187.3
Sulphate of soda	89.3
Chloride of Sodium	8.8
Protocarbonate of iron	10.5
Potassium	Traces
Organic matter	Traces
Total solids	2290 2

This analysis was made by Prof. L. W. Andrews of the State university.

The water from these wells is about as heavily charged with mineral matter as any artesian water in Iowa. The water leaves a sediment from the lime salts, which incrusts the pipes, and has a red stain from the iron. At the same time, it consumes ordinary galvanized pipe to a shell, in three or four years. The large amount of mineral water in solution does not seem to lessen. No analysis has been made since 1886, so that the present and past amount of mineral cannot be compared. The indications, however, are that there has been little, if any, change. The water consumes pipes just as rapidly, and deposits sediment and stain just as thickly and as quickly as at first. Considering the vast quantity of water which has flowed from the wells, the persistence of the mineral in solution may be explained by the slow flow of the water through the aquifer.

It is not necessary to suppose any extraordinary or unusual source for the mineral matter in the water. The glacial till is made up of rock grindings which can easily supply the minerals found. These are the same as in other Iowa artesian wells, and are directly or indirectly derived from the constituent and accessory minerals of soils and rocks.* The analyses of several artesian wells are compared below. The analyses are from Call's article.

QUANTITATIVE ANALYSES—PARTS TO 1,000,000 PARTS WATER.	Belle Plaine wells.	Hixson No.III	Marengo No. L.	Washington well.	Range 85, 24 W. Sec. 26, Story Co., Ia.; Call's No. 37 *a*.	Range 85, W. Sec. 12, Story Co., Ia.; Call's No. 37.
Sulphate calcium....	1,427.8	284 039	1,295.990	246.95	....	....
Sulphate magnesia...	561.0	149.416	802.910	....	....	....
Chloride sodium.....	8.8	22 662	33.252	91 32	....	1.666
Proto-carbonate iron.	10.5	37.129	9.313	....	....	....
Sulphate sodium.....	89.3	151.997	338.351	547.90	....	....
Carbonate magnesia..	183.3	....	....	153.67	127.681	118.301
Bicarbonate magnesia	....	398.609	....	....	....	....
Silica	1.6	38.122	6.405	*35.14	26.083	Trace
Alumina.............	Trace	Trace	....	17.60	....	....
Potassium...........	Trace	....	....	....	....	....
Carbonate calcium...	....	551.599	} 436.526	} 48.20	207.621	199.064
Bicarbonate calcium.	....	....		......	....	....
Potassium nitrate. ..	....	53.014	....	....	....	....
Phosphates	....	Trace	....	....	....	....
Organic matter	Trace	....	....	....	....	....
Sulphate potassium..	....	244.589	....	....	....	....
Ferrus carbonate.....	....	....	....	Trace	....	....
Sodium phosphate....	....	....	....	Trace	....	....
Potassium chloride...	....	....	....	17.50	....	....
Ferric oxide.........	....	....	....	....	6.243	....
Sodium carbonate....	....	....	....	....	118.949	43.502
Ferric oxide....... } Aluminum oxide... }	....	....	....	....	....	13.956
Total solids....	2,290.2	1,941.179	2,734.348	1,142.24	{ 486.577 (490.459)	376.489 (375 306)

*And insoluble residue.

A comparison of the analyses shows that the Belle Plaine water contains about the same minerals, and in about the proportion, as other artesian wells. The Belle Plaine water

*Norton, op. cit., p. 363.

carries but little more calcium carbonate, and has less total solids than the Marengo well, which is not a well in drift. The pipe-consuming qualities of the water shortens the life of the weaker wells. The temperature of the water remains fixed at about 52° F. the year round.

From examination of the analyses of the Belle Plaine water, its therapeutic or medicinal value, or want of value, is very apparent. The most extravagant claims have been made as to the value of this water in curing almost every human ailment, from rheumatism to dyspepsia. One physician says that the water has mild laxative and diuretic, and slight alterative value. Another physician says that "the water possesses very little, if any, therapeutic value; on the contrary, it is highly injurious in certain conditions of the kidneys. Persons having weakness of the kidneys or bladder trouble cannot use the water at all without suffering bad effects. There are those who claim that the water has performed marvelous cures for them, but the fact must be considered that their ailments have been more mental than physical."

The food taken into the body supplies sufficient mineral matter, so it is unnecessary, and even injurious, to drink water heavily charged with mineral matter, which the Belle Plaine water is. It cannot then be said that the Belle Plaine artesian water has any therapeutic value, or is even a good drinking water. That mineral water is best which contains the least mineral. Pure rain water, or better, distilled water, is the best water for drinking purposes. Several inexpensive and very satisfactory stills are now on the market.

It has been claimed that the water is "magnetic," and that "a knife blade held in this water a few seconds would become charged strong enough to pick up a pin."* The writer has experimented by suspending a knife blade in the running water from a few seconds to half a day, but in no case would the blade, when carefully dried, attract a pin, or even a

*History of Jumbo, p. 24.

Artesian well, at the corner of First and Maple streets, Belle Plaine, Iowa, July, 1886.

needle. The wet blade, however, will "pick up" a pin beautifully, but not by magnetism. This fact may explain the numerous so-called "magnetic" waters.

USES OF THE WATER.

It has been shown that the Belle Plaine artesian water is of little or no value as a medicinal or drinking water. The analysis shows it to be unfit for steaming or manufacturing purposes. Its pipe-consuming quality, and its sediment and unfitness for culinary, household or manufacturing purposes, makes it unavailable for city waterworks.

It is not necessary to use the water for irrigation, and the volume is not sufficient, except for irrigation on a small scale. Neither is the volume sufficient to furnish power for manufacturing purposes. Hon. J. J. Mosnat has attached a small waterwheel to a weak-flowing well (number 62), and uses the power for pumping water to supply his residence. The one use of the water is for stock. Nearly every farm in the area has one or more wells. After cattle become accustomed to the peculiar taste of the water they are said to prefer it to other water. Indeed they appear to thrive on it. This has been the principal use of the water since the vein was first discovered.

WELL RECORDS.

Below are given the records of a large number of the wells in the area. In Table I is the geological section of certain of the wells penetrating the rock.

TABLE I.

SECTIONS OF WELLS.

WELL No. A.

	Description of Strata.	Thickness.	Altitude.	Geological Formation.
7.	Humus and soil	4	793	Recent.
6.	Yellow clay, sand and gravel	33	789	Loess.
5.	Blue clay	148	756	Kansan.
4.	Shale	30	608	Carboniferous.
3.	Limestone, white	6	578	
2.	Limestone, blue	12	572	Devonian.
1.	Limestone, dolomitized	....	.....	
	Flow in rock	.....	.....	
	Total	233		

WELL No. C.

	Description of Strata.	Thickness.	Altitude.	Geological Formation.
8.	Humus and soil	4	820	Recent.
7.	Yellow clay, sand and gravel	30	816	Loess.
6.	Blue clay	171	786	Kansan.
5.	Shale	60	615	Carboniferous.
4.	Limestone, white	8	555	
3.	Limestone, blue	15	547	
2.	Limestone, variable	62	532	Devonian.
1.	Limestone, dolomitic	.....	470	
	Flow in rock	....	.....	
	Total	350		

WELL No. D.

	Description of Strata.	Thickness.	Altitude.	Geological Formation.
8.	Humus and soil	4	.....	Recent.
7.	Yellow clay, sand and gravel	30	.....	Loess.
6.	Blue clay	174	.....	Kansan.
5.	Shale	80	.....	Carboniferous.
4.	Limestone, white	8	.....	
3.	Limestone, blue	12	.....	Devonian.
2.	Limestone, variable	64	.....	
1.	Limestone, dolomitic	.....	.....	
	Flow in rock	....	.....	
	Total	372		

WELL No. F.

	Description of Strata.	Thickness.	Altitude.	Geological Formation.
7.	Humus and soil	5	827	Recent.
6.	Yellow clay, sand and gravel	30	822	Loess.
5.	Blue clay	165	792	Kansan.
4.	Shale	100	627	Carboniferous.
3.	Limestone, white	8	527	
2.	Limestone, blue	12	519	Devonian.
1.	Limestone, dolomitic	.....	507	
	Flow in rock	.....	.....	
	Total	320		

WELL No. L.

	Description of Strata.	Thickness.	Altitude.	Geological Formation.
8.	Soil and humus	5	745	Recent.
7.	Yellow clay, sand and gravel	20	740	Loess.
6.	Blue clay	58	720	Kansan
5.	Shale	50	662	Carboniferous.
4.	Limestone, white	12	612	
3.	Limestone, blue	15	600	Devonian.
2.	Limestone, variable	205	585	
1.	Limestone, dolomitic	.....	380	
	Total	365		

WELL No. M.

	Description of Strata.	Thickness.	Altitude.	Geological Formation.
8.	Soil and humus	5	759	Recent.
7.	Yellow clay, sand and gravel	20	754	Loess.
6.	Blue clay	58	734	Kansan.
5.	Shale	80	676	Carboniferous.
4.	Limestone, white	12	596	
3.	Limestone, blue	15	584	Devonian.
2.	Limestone, variable	226	569	
1.	Limestone, variable	....	343	
	Total	416		

TABLE II.

LIST OF ARTESIAN WELLS OF THE BELLE PLAINE AREA.

No. on map.	COUNTY.	TOWNSHIP.	Section.	OWNER.	Date (about).	DUG BY—	Depth—feet.	Elevation A. T. of curb—feet.	FLOW. Height—feet.	FLOW. Gallons per minute.	REMARKS.
1	Benton	Iowa	10 SE.	William and J. Lester	1882	....	345	....	-100	....	Not used now.
2	Benton	Iowa	8 NE.	S. L Bardwell	1882	....	260	....	- 25	....	Not used now.
3	Benton	Iowa	3 SE.	J. Wortley	1883	....	365	....	-125	....	Not used now.
4	Benton	Fourth St, betw'n Maple and Beech streets, Belle Plaine	....	Company	1886	....	303	918	- 54	..	Not used now; sand over twenty-five ft.
5	Benton	East First St., B. Plaine	....	Hilton Bros	1886	Weir & Sons.	215	836	53	..	First flow.
6	Benton	Cor. First and Beech Sts., Belle Plaine	....	Company	1886	....	225	846	22	....	
7	Benton	Cor. First and Maple Sts., Belle Plaine	....	Company	1886	....	228	848	19	....	Sand vein 5 ft. 3 in.
8	Benton	Foundry, West Washington St., Belle Plaine	....	Palmer Bros	1886	Palmer Bros.	210	830	37	....	
9	Benton	Beech st., Belle Plaine	....	Company	1886	....	193	811	54	....	The famous Jumbo.
10	Benton	East First St., B. Plaine	....	Belle Plaine Canning factory	1886	....	215	838	32	..	
11	Tama	Salt Creek	12 SE.	G. W. Snyder	1885	....	197	....	....	....	Filled up.
12	Tama	Salt Creek	15 SE.	Willey	1886	....	206	....	40	....	
13	Tama	Salt Creek	23 NW	Richard Turnbull	1887	....	143	....	100	....	
14	Tama	Salt Creek	23 NW	Richard Turnbull	1888	....	218	....	32	....	
15	Tama	Salt Creek	15 SW.	John Strubble	1887	....	206	....	44	....	
16	Benton	West First St., B. Plaine	....	Fremont hotel	1886	Weir & Sons.	225	....	....	....	Not used now.
17	Tama	West First St., B. Plaine	22 NW	Mike Zeman	1887	....	166	....	80	...	
18	Tama	West First St., B. Plaine	9 NW	N. Zeman	1887	....	218	....	40	....	
19	Tama	West First St., B. Plaine	5 NE.	—— Mussel	1887	....	226	....	30	....	
20	Benton	Baseball park, B. Plaine	....	Company	1888	....	210	....	37	....	
21	Tama	Salt Creek	13 NE.	Frank Kerner	1887	....	170	....	75	....	
22	Tama	Salt Creek	23 NE.	J. Mac Ilwain	1887	....	197	....	50	....	
23	Tama	Salt Creek	13 SW.	S. Jameson	1888	....	166	....	80	....	
24	Tama	Salt Creek	11 SE.	H. B. Edwards	1889	....	218	....	30	...	
25	Tama	Salt Creek	2 SW.	Joseph Petrizelka	1889	....	230	....	20	....	
26	Tama	Salt Creek	24 NW	J. F. Ealy	1888	....	172	....	75	....	
27	Tama	Salt Creek	23 SE.	G. W. Ealy	1887	....	166	....	80	....	
29	Tama	Salt Creek	4 NE.	Joseph Skarda	1886	....	360	....	-110	....	Highest point in the "Bluffs."
30	Tama	Salt Creek	25 SE.	Alex White	1888	....	164	....	80	....	
31	Tama	Salt Creek	25 NE	J. B. Cox	1887	....	155	770	90	....	

TABLE II—CONTINUED.

No. on map.	COUNTY.	TOWNSHIP.	Section.	OWNER.	Date (about).	DUG BY—	Depth.	Elevation A. T. of curb—feet.	FLOW. Height—feet.	FLOW. Gallons per minute.	REMARKS.
32	Benton	Kane (Irving)	31 SW.	Mrs. Johnson	1888		220		30		
33	Benton	Iowa	22 NW	A. E. Hardy	1886		243		10		
34	Benton	Iowa	22 NE.	F. Mall	1887		223		18		Not flowing now
35	Benton	Iowa	23 NE	H. Wehrman	1886		230		12		
36	Benton	Iowa	26 NW	William Shriver	1886		230		12		
37	Benton	Iowa	22 SE	Christ Ahrens	1887		200		20		
38	Benton	Iowa	33 NW	J. Guinn	1885		170		80		
39	Benton	Iowa	34 NW	Mrs. M. O. Guinn	1885	Palmer Bros.	218		29		
40	Benton	Iowa	34 SE.	E. Trueblood	1888		110		18		
41	Benton	Iowa	35 SW.	Joseph Young	1888		125		20		
42	Benton	Iowa	28 NE	Theresa Beal	1887		240		6		
43	Benton	Iowa	29 NE	Theresa Beal	1887		252		- 5		
44	Benton	South Oak St., B. Plaine		W. P Hanson	1888		184		63		
45	Benton	Iowa	32 SE.	A. J. Hartman	1888		160		87		
46	Benton	Iowa	17 SW.	E. B. Wright	1884		295				Not used now.
47	Benton	Iowa	19 NW	E. B. Edwards	1888		180		90		
48	Benton	Iowa	18 SW.	Gouldy and Bruner line	1887		210		35		
49	Benton	Iowa	7 SE.	H. Bickford	1886		230		18		
50	Benton	Iowa	18 NW	G. W. Gouldy	1887		197		45		
51	Tama	Salt Creek	16 NE.	Anthrom Mussel			206	824	40		
52	Tama	Salt Creek		—— Stickler			208	826			Not running now.
53	Tama	Salt Creek	16 SE.	—— Wilkes	1891		166	785	60		
54	Tama	Salt Creek	4 SE.	F. Posekany			204	822	45		
56	Tama	Salt Creek	4 NE.	Joseph Skarda	1891		247	865			Not running now.
57	Tama	Salt Creek	4 NE	Joseph Skarda	1894		245	863	2		
58	Tama	Salt Creek	27 SW.	D. Wilcox	1890		200	818	4		Very weak flow.
59	Tama	Salt Creek	35 SW.	O. Vickery	1894		201	819	46		
60	Benton	North side schoolhouse, Belle Plaine		School district	1895		312	894	- 18		Water-bearing vein, 46 feet sand, then gravel—water at 276
61	Benton	North Maple St., B. Plaine		J. J. Mosnat	1891		243	861			Not running now.
62	Benton	North Maple St., B. Plaine		J. J Mosnat	1896		243	861	3½		
63	Benton	Fair grounds, B. Plaine		Big Four Fair association	1893		218	836	29		
64	Tama	Salt Creek	12 SE.	G. W Snyder	1894		197	843	50		
65	Tama	Salt Creek	24 NW	J. Donnivan	1888		166	785	81		
66	Tama	Salt Creek	11 SE.	O. MacIntire	1894		218	836	29		
67	Tama	Salt Creek	13 SW.	L. Prill	1891		200	816	47		
68	Tama	Salt Creek	2 SE.	Charles Dvorak			200		50		
69	Tama	Salt Creek	2 SW.	M. Blaha, Jr.	1885		218		35		
70	Tama	Salt Creek	3 NE	M. Dvorak			234		20		

45 G Rep

71	Tama	Salt Creek	2 NW	Charles Dvorak			215		35		
72	Tama	Salt Creek	2 NW	Charles Dvorak	1895		235		15		
73	Tama	Salt Creek	14 NW	Mike Long	1894		170		75		
74	Tama	Salt Creek	22 NE.	Joseph Willey	1893		164		80		
75	Tama	Salt Creek	26 NW	Joseph Mac Ilwain	1893		140		30		Said to be 4 feet hard hard limestone just ab've water-bearing vein.
76	Tama	Salt Creek	9 NE	A. Dvorak	1894		204		50		
77	Tama	Salt Creek	15 Nw	Horace Walton	1892		235		12		
78	Tama	Salt Creek	15 NW	J. J Walton	1894		197		50		
79	Tama	Salt Creek	11 SE.	Anton Robinac	1890		228		20		
80	Tama	Irving	1 NE.	Levi Marsh	1888		225		25		
81	Tama	Irving	1 NE	Levi Marsh	1890		225		25		
82	Tama	Irving	1 NE.	Levi Marsh	1892		230		20		
83	Tama	York	25 SE.	J. Beck	1890		218				Not running now, not properly dug.
84	Tama	York	25 NW	J. Beck	1890		220		2		
85	Benton	Iowa	23 NW	J. Bauchmam	1892		225		15		
86	Benton	Iowa	20 SE.	Ed Boody	1895		222		18		
87	Benton	Iowa	29 SE.	John Beal	1890		180		65		
88	Benton	Iowa	33 SE.	Mary O. Guinn	1889		166		75		The second Jumbo.
89	Benton	Iowa	3 NE.	I Hixson	1894		143		30		
90	Benton	Iowa	18 NW	B. F. Roberts	1895		228		20		
91	Benton	Iowa	18 NE.	H. H. Byers	1894		233		15		
92	Benton	Iowa	7 NW	G. W. Brewer	1891		200		50		
93	Benton	Irving	6 NW	Levi Marsh	1890		218		30		
94	Benton	Iowa	9 SW.	W. A. Parris	1892		158		100		
95	Tama	York	35 SE.	V. Ulch	1894		220		30		
96	Iowa	Marengo			1893		180	743	4		No rock.
98	Benton		29 NE.	—— Tracy	1898		224	846	20		Water-bearing vein 2 feet; 18 feet blue clay below.
100	Tama	Vining			1898		238		10		
101	Tama	Salt Creek	3 SE.	J. Kosnar	1897		240		10		
102	Tama	Salt Creek	15 SE.	—— Willey	1893		168		70		
103	Tama	Salt Creek	16 SE.	Joseph Walton	1894		198		50		
104	Tama	Salt Creek	15 NW	—— Stickler	1893		200		50		
105	Tama	Salt Creek	9 NE.	Charles Upah	1895		234		20		
107	Tama	York	36 SE.	Eliz. Weymer	1892		223		30		
109	Tama	York	35 NE.	V. Ulch	1897		174		75		
110	Iowa	Ladora	7 NW	—— Inghram	1898		223	791	5		
111	Iowa	Ladora	7 NW	City	1898		216	782	3		Not properly dug, should rise 12 feet.
112	Iowa	Ladora	12 NE.	Chicago, R. I. & P. R. R. Co.	1898		229	795	- 1		Water in 30-40 feet sand, above gravel.
113	Iowa	Honey Creek	24 NW	—— Wilkinson			145		35		
114	Iowa	Honey Creek	24 SE.	—— Long			150		30		
115	Iowa	Honey Creek	35 NE.	A. J. Richardson	1890		150		30		
116	Iowa	Honey Creek	14 NW	S. Huston	1890		150		30		
117	Iowa	Honey Creek	14 SE.	J. H. Richards	1890		180		16		
118	Iowa	Honey Creek	22 NE	D. Cronbaugh	1890		190		6		
119	Poweshiek.	Jefferson	1 SE.	J. Hixson	1894		166	776	50		
120	Poweshiek.	Jefferson	1 SE.	J. Scott	1892		167	776	50		

TABLE No. II—CONTINUED.

No. on map.	COUNTY.	TOWNSHIP.	Section.	OWNER.	Date (about).	DUG BY—	Depth—feet.	Elevation A. T. of curb—feet.	FLOW.		REMARKS.
									Height—feet.	Gallons per minute.	
121	Poweshiek	Jefferson	1 SW.	F. Fonnenek	1892	....	236	946	5	...	Very weak because not properly dug.
122	Iowa	Honey Creek	6 NW	L. W Ruhl	1891	....	160	770	60	....	
123	Iowa	Honey Creek	6 SW	H. L. Detwiler	1891	....	200	810	20	....	
124	Iowa	Honey Creek	7 NE.	J Detwiler	1891	....	200	810	20	....	
126	Iowa	Honey Creek	6 SE.	H H. Wheeler	1891	....	164	774	45	....	
127	Iowa	Honey Creek	5 SE	L. B. Anderson	1892	....	220	830	27	....	
128	Iowa	Honey Creek	9 NW	B. Bradford	1890	....	130	760	60	....	
129	Iowa	Honey Creek	10 SW.	H Washburn	1890	....	160	790	30	....	
130	Iowa	Honey Creek	33 SE	W. Border	1888	....	340	910	- 98	....	
131	Iowa	Honey Creek	13 SW	—— Herman	1890	....	140	740	50	....	
132	Tama	York, Vining	20 NW	Stock yards	....	....	217	858	40	....	
133	Tama	Vining	20 NE	City	1896	....	230	875	3½	....	Ought to flow much stronger if properly dug.
134	Tama	Vining	20 NE.	City	....	....	234	879	....	....	Old wells, not now flowing.
135	Tama	Vining	20 NE	City	....	....	234	879	....	....	Old wells, not now flowing.
136	Poweshiek	Jefferson	1 NW	Harry Cunningham	1893	....	215	....	32	....	
137	Poweshiek	Jefferson	2 NE.	Ed. Noble	1893	....	210	....	37	....	
138	Poweshiek	Jefferson	2 NE.	Charles F. Teeman	1893	....	233	....	14	....	
139	Poweshiek	Jefferson	12 NW	W. Foster	1890	....	240	....	7	....	
140	Tama	York	32 SE.	Albert Mussel	....	....	226	....	28	....	
141	Benton	Iowa	21 SE.	—— Robbie	1898	....	222	....	25	....	
142	Iowa	Honey Creek	22 NE.	J. Combaugh	....	....	190	....	6	....	
143	Iowa	Honey Creek	22 SW	M V. Combaugh	....	....	190	....	6	....	
144	Tama	York, Elberon	13 NW	City	1887	....	222	860	7	....	
147	Tama	York, Elberon	13 NW	Creamery	....	....	260	889	- 2	....	
148	Benton	Iowa	28 NE.	Theresa Beal	1898	....	240	....	6	....	
149	Benton	Iowa	33 SE.	—— Shoehardt	1898	....	166	....	80	....	
151	Iowa	Victor	8 SE.	....	....	....	200	811	- 4	....	
152	Iowa	Honey Creek	23 NW	J. Crombaugh	....	....	200	....	15	....	
153	Benton	Iowa	21 NW	F. Smith	....	Wm. Weir	255	872	- 8	....	
154	Tama	Salt Creek	2 SE.	Mike Blake	1895	Geo. Gouldy	240	870	7	....	
155	Tama	Salt Creek	11 NE.	H B. Edwards	1891	—— Prill	230	860	17	....	

NOTE—In classifying the wells Nos. 28, 55, 97, 99, 106, 108, 125, 145, 146, 150, were put on the other list. These wells are Nos. 60-67 in Call's list and map of artesian wells in Iowa. "Iowa Weather and Crop Service," April, 1891, p. 4, and March, 1892, p. 12.

TABLE No. III.

LIST OF ARTESIAN WELLS IN ROCK ADJACENT TO THE BELLE PLAINE AREA.

No. on map.	COUNTY.	TOWNSHIP.	Section.	OWNER.	Date (about).	DUG BY—	Depth—feet.	Elevation A. T. of curb—feet.	FLOW. Height—feet.	FLOW. Gallons per minute.	REMARKS.
A	Tama	Chelsea	....	J. W. Shaler	1895	Geo. Gouldy	233	793	60	....	Head of water about 350 feet. See well sections.
B	Tama	Chelsea	....	O. McCain	1895	....	220	793	10	....	Head of water about 350 feet. See well sect'ns. Would flow much stronger if well opened up.
C	....	Salt Creek	19 SE.	George Crittenden	1895	Geo. Gouldy	350	820	50	....	Head of water about 350 feet. See well sect'ns. Would flow much stronger if well opened up.
D	Tama	Salt Creek	29 NE.	J. P. Wilkson	1894	Geo. Gouldy	372	......	60	....	Head of water about 350 feet See well sect'ns. Would flow much stronger if well opened up.
E	Tama	Salt Creek	29 NE.	J. P. Wilkson	1894	Geo. Gouldy	270				
F	Tama	Richland	36 SE.	N. Blazek	1894	....	320	827	50		
G	Tama	Richland	2 NW	A. J. Tyler	1890	....	298	......	50		
H	Tama	Otter Creek	35 NE.	A. J. Tyler	1890	....	316	......	40		
I	Tama	Otter Creek	33 NE.	E. M. Hall	1888	....	308	......	40		
	Tama	Otter Creek	33 NE.	E. M. Hall	1889	....	280	......	50		
K	Tama	Otter Creek	33 NE.	E M. Hall	1890	....	300	......	30		
L	Iowa	Marengo	....	City	1885	....	365	745	......	65	See well sections.
M	Iowa	Cono	9 SW.	J. A. Brown	1886	....	416	759	18	....	See well sect'ns. Difference in elevati'n of surface.
N	Iowa	Honey Creek	19 NE.	S. Crain	1898	....	257	......	- 42	....	See well sections.
O	Tama	Salt Creek	29 NE	—— Wilkison	1884	....	280	......	......	....	See well sections.

NOTE—No. L is No. 9 on Call's list and map.

TABLE IV.

VARIOUS SHALLOW WELLS IN DRIFT IN OR ADJACENT TO BELLE PLAINE AREA.

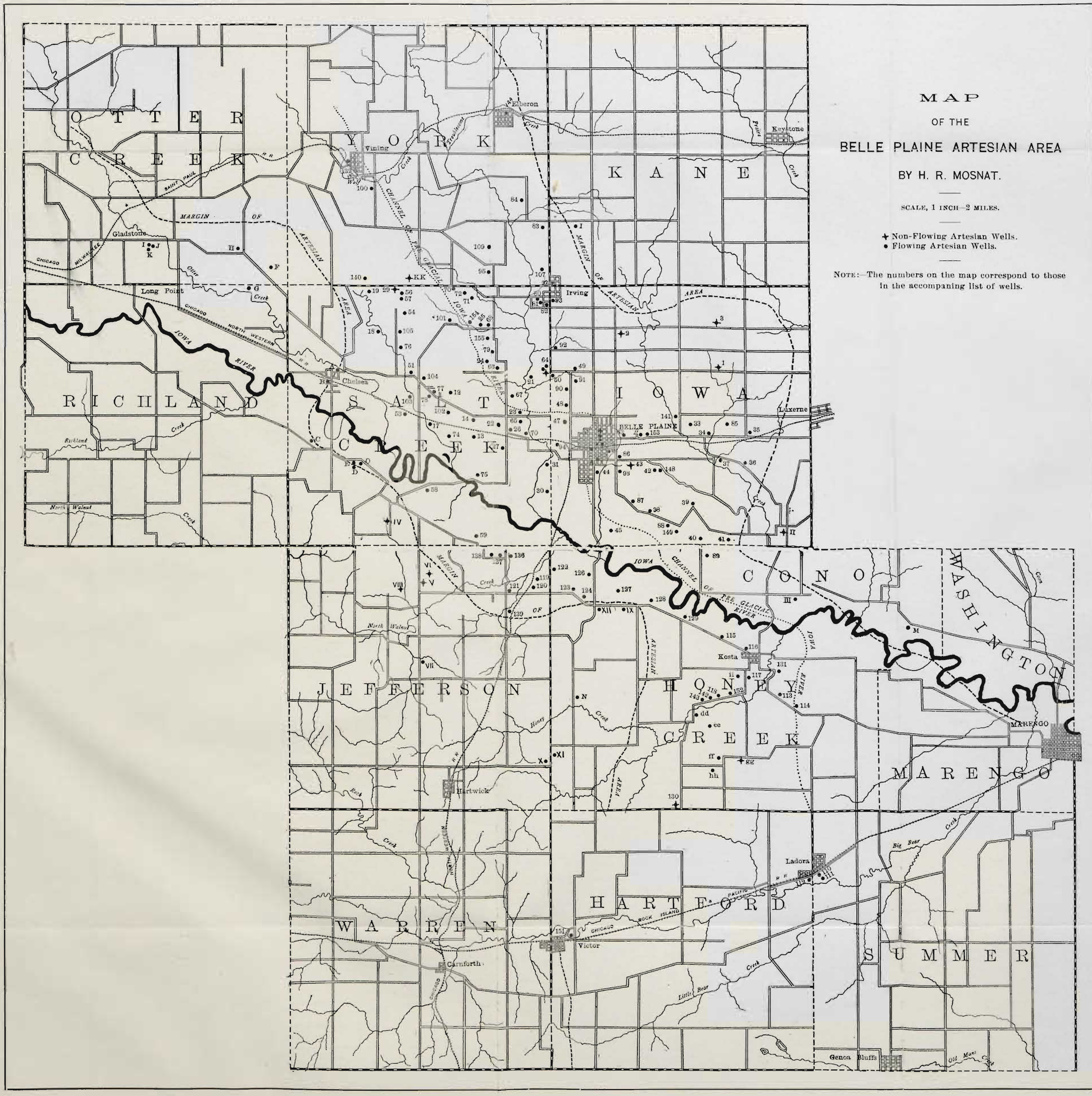
Number.	COUNTY.	TOWNSHIP.	Section.	OWNER.	Date.	Depth.	Elevation A. T.	Flow—feet.	REMARKS.
aa	Tama	Elberon	....	....	......	......	889		
bb	Tama	Elberon	....	....	......	......	889		
cc	Tama	Salt Creek	12 SW	G. W. Snyder	......	68	......	- 34	Within sixteen feet of No. 11.
dd	Iowa	Honey Creek	22 SW.	C. C. Crombaugh	1891	50	......	5	
ee	Iowa	Honey Creek	27 NE.	M. Ingrahm	1893	57	......	5	
ff	Iowa	Honey Creek	27 SE.	M. Ingrahm	1894	204	......	-104	Elevation above No. ee about 50 feet.
gg	Iowa	Honey Creek	26 SW.	F. A. Ingrahm	......	200	......	-100	
hh	Iowa	Honey Creek	34 NE	S. & J. Heller	......	150	......	- 50	
ii	Iowa	Honey Creek	23 NW						
jj	Benton	Iowa	21 NW	Belle Plaine Cemetery Assn.					
kk	Tama	York	23 SE	Albert Skarda	......	140			

TABLE V.

VARIOUS DEEP WELLS IN ROCK ADJACENT TO BELLE PLAINE AREA.—WEAK-FLOWING AND NON-FLOWING.

Number.	COUNTY.	TOWNSHIP.	Section.	OWNER.	Date.	Depth.	Elevation A. T.	Flow—feet.	REMARKS.
I	Benton	Kane	30 SE.	William B. Benson	......	185	......	......	Shale, weak flow.
II	Benton	Iowa	36 SW	C. B. Greenlee	1895	100	......	......	Shale
III	Iowa	Cono	12 NE	Isaiah Hixson	1886	305	......	......	Last 50 feet in soft rock (shale).
IV	Tama	Salt Creek	33 SW	John Loff	......	180	......	- 40	Water in thin stratum of sand and gravel.
V	Poweshiek	Jefferson	3 SW.	G. C. Parks	......	150	......	- 18	Shale.
VI	Poweshiek	Jefferson	3 SW.	G. C. Parks	......	190	......	......	Elevation 10 feet less than V. shale 30 inches, then white limestone.
VII	Poweshiek	Jefferson	15 NW	M Leimberer	......	275	......	......	Rock a few feet.
VIII	Poweshiek	Jefferson	4 SE.	J W. Leimberer	1894	155	......	......	Rock a few feet.
IX	Iowa	Honey Creek	8 NE.	G. Cook	1892	215	......	- 2	No shale; 5 feet white limestone. Sand veins bearing water above this vein.
X	Poweshiek	Jefferson	25 SE	H. Hughes	......	240	......	- 60	Rock.
XI	Iowa	Honey Creek	30 SW.	—— Hickman	......	190	......	- 50	Rock.
XII	Iowa	Honey Creek	8 NW	H. H. Wheeler	1888	200	......	......	Three to 4 feet of rock above water. Weak flow.

NOTE—No. III is No. 18 on Call's list and map.


MAP
OF THE
BELLE PLAINE ARTESIAN AREA
BY H. R. MOSNAT.
SCALE, 1 INCH=2 MILES.
✛ Non-Flowing Artesian Wells.
● Flowing Artesian Wells.
NOTE:—The numbers on the map correspond to those in the accompaning list of wells.
OTTER CREEK
YORK
KANE
RICHLAND
SALT CREEK
IOWA
CONO
WASHINGTON
JEFFERSON
HONEY CREEK
MARENGO
WARREN
HARTFORD
SUMMER
BELLE PLAINE
Elberon
Keystone
Vining
Gladstone
Long Point
Irving
Chelsea
Luzerne
Kosta
Marengo
Hartwick
Ladora
Victor
Carnforth
Genoa Bluffs
IOWA RIVER
CHICAGO NORTH WESTERN R.R.
CHICAGO MILWAUKEE SAINT PAUL R.R.
CHICAGO ROCK ISLAND PACIFIC R.R.
MARGIN OF ARTESIAN AREA
CHANNEL OF PRE-GLACIAL IOWA RIVER
Otter Creek
Richland Creek
North Walnut Creek
Honey Creek
Big Bear Creek
Little Bear Creek
Old Mans Creek

INDEX.